ASSC27

The 27th annual meeting of the Association for the Scientific Study of Consciousness

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List of Abstracts

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Keynote Talks

Assessing consciousness in infants

Ghislaine Dehaene-Lambertz (CNRS ERL 9003, INSERM U992, CEA, Université Paris-Saclay, NeuroSpin center, Gif/Yvette, France)

Presidential Address, July 2nd, Yasuda Auditorium, 4:35PM-5:35PM

Perceptual awareness in infants during the first year of life is understudied, despite the philosophical, scientific and clinical importance of understanding how and when consciousness emerges during human brain development. The lack of adequate experimental paradigms to address this question in preverbal infants has been a hindrance to research on this topic. However, recent brain imaging and behavioral studies have shown that the infant brain is more structured and its cognitive performances more complex than traditionally thought. I will present a concise synthesis of these recent findings, which offer an indirect glimpse of early perceptual awareness, followed by the few studies that have sought to find in infants, the specific signatures of conscious perception described in adults. Despite the scarcity of studies directly testing perceptual awareness in infants, the available data suggest that it is indisputably present in the second half of the first year, and probably earlier, but studies are limited. The question of conscious perception before term remains open, with the possibility of short periods of conscious perception, which would facilitate early learning. Advances in brain imaging and growing interest in this subject should enable us to gain a better understanding of this important issue in the years to come.

Toward Understanding Structural Basis for Autonomy of Consciousness: A Synthetic Neurorobotics Study

Jun Tani (Okinawa Institute of Science and Technology, Onna, Japan)

Keynote Lecture, July 2nd, Yasuda Auditorium, 5:35PM-6:35PM

This presentation offers a compelling perspective on autonomy of consciousness, suggesting that spontaneous shifts between conscious and unconscious states are driven by intricate and often conflicting interactions between top-down intentional processes aimed at proactive engagement with the external world, and bottom-up perception of resulting sensations. This view is supported by neurorobotic experiments that have been conducted in my lab over 25 years, employing hierarchical recurrent neural network (RNN) models extended within the framework of predictive coding and active inference. Insights gained from this extensive research indicate that the indeterminism that inevitably arises due to circular causality within the enactment loop can account for the structural basis of autonomy of consciousness. Furthermore, I propose that a higher-order theory of consciousness can be derived through investigation of the free energy principle, extended toward higher-order inference.

Dimensions of Interoception and Conscious Experience

Sarah Garfinkel (University College London, London, United Kingdom)

Keynote Lecture, July 3rd, Yasuda Auditorium, 9:00AM-10:00AM

Conscious experiences are shaped by the dynamic integration of the brain and internal signals in the body through interoception. Interoception is defined as the process by which the nervous system senses, interprets and integrates internal bodily signals, providing a moment-by-moment mapping of the body's internal landscape across conscious and unconscious levels. Interoception can be delineated into different hierarchical dimensions, including the nature of afferent signals, the precision with which they are sensed and their neural signatures. Informed by empirical research, this talk will detail how these interoceptive dimensions selectively influence a variety of perceptual, cognitive and affective processes, including memory, emotion and pain. In clinical groups, including those with depersonalisation derealization disorder, functional neurological disorder, and schizophrenia, alterations in interoceptive mechanisms have implications for symptom expression. Understanding the nature of these interoceptive differences, and their impact on conscious experience, provides promise for future therapeutic targets.

Subjective Perspectives in Humans and AI

Susanna Schellenberg (Rutgers University, New Brunswick, USA)

Keynote Lecture, July 4th , Yasuda Auditorium , 9:00AM-10:00AM

Ego4D is a new program of Meta that is supposed to teach AI how to have a subjective perspective. As Grauman, the lead researcher of Ego4D, describes the project: “For AI systems to interact with the world the way we do, the AI field needs to evolve in an entirely new paradigm of first-person perspective.” Can AI have a subjective perspective? I argue that yes, it can. Any artificial or biological organism has a perspective on its environment as a consequence of its cognitive, emotional, perceptual, and behavioral schemas (or lack thereof) with which it processes, organizes, interprets, and responds to information it receives. According to this *lens view of perspectives*, a perspective is a spatiotemporally located information processing mechanism. I develop this view of perspectives and show that there are many elements of subjective perspectives, each of which can be more or less complex and many of which come in degrees. AI already has many of the elements that constitute our subjective perspectives. Questions permeating the project include: How does your and my perspectives differ; and how are they the same? How does the perspective of us humans differ from that of AI or a less rational animal? And again, how are our perspectives the same as that of a robot or a rat?

Understanding Neurodiverse Consciousness through Predictive Processing

Yukie Nagai (Project Professor, The University of Tokyo)

Keynote Lecture, July 5th, Yasuda Auditorium, 9:00AM-10:00AM

Neurodiversity encompasses a wide spectrum of cognitive variations among individuals. In this talk, I aim to explore how the neuroscience theory of predictive processing provides a unified framework for understanding the diverse manifestations of consciousness in neurodiverse populations. Predictive processing theory suggests that the brain constructs consciousness by continuously generating and updating predictions about sensory input. By applying this theory, our research investigates how variations in predictive processing contribute to unique conscious experiences across individuals.

Our computational studies utilizing neural networks have demonstrated that alterations in predictive processing underlie heightened perceptual sensitivity and individual differences in cognitive functions. Furthermore, collaborative efforts with Tojisha-kenkyu (the first-person study on neurodiversity) have revealed that aberrant predictive processing of multimodal signals, particularly the integration of interoceptive signals, plays a crucial role in understanding diverse challenges in cognitive behaviors among neurodiverse individuals. This talk aims to foster a deeper understanding of neurodiversity and advocate for a more inclusive approach to consciousness research.

Symposia

SYMPOSIUM:
Functionalism or Not: Discussion and Debate

Biyu He (New York University), Anil Seth (Centre for Consciousness Science, University of Sussex, UK), Stephen Fleming (University College London), Ned Block (New York University), Liad Mudrik (Tel Aviv University)

Thursday July 4th, Yasuda Auditorium, 11:00AM-1:00PM

Computational functionalism (CF) is the implicit assumption made in many theories of consciousness and has been especially influential in recent discussions of assessing consciousness in Artificial Intelligence (AI). Computational functionalism states that performing computations of the right kind is necessary and sufficient for consciousness. Proponents of CF often claim that it is the mainstream approach in both philosophy of mind and cognitive neuroscience.

Whether to believe in CF is currently a major dividing line in the consciousness field. One's position on this fundamental question holds enormous implications for how to approach the investigation of the mechanisms of consciousness as well as how to extrapolate current work on consciousness in humans to other biological organisms and artificial agents. If CF is true, then any two systems that implement the same input-output and intermediate computations will have the same level and kind of consciousness. However, if CF is untrue, then either the physical medium in which the computations are implemented matters, or computation is not the most important building block for consciousness.

This symposium brings together experts who have thought deeply about this question from philosophical, biological, psychological and computational perspectives. Two of the speakers, Flemming and Mudrik, will present views in support of CF. The other two speakers, Seth and Block, will offer skepticism of CF. A brief debate will follow the four presentations.

Talk 1: Consciousness as a biological, not a computational, function

Anil Seth (Centre for Consciousness Science, University of Sussex, UK)

Symposium: Functionalism or Not: Discussion and Debate, Thursday July 4th, Yasuda Auditorium, 11:00AM-1:00PM

Computational functionalism is the idea that performing computations of the right kind is both necessary and sufficient for consciousness. It is both intuitively appealing and widely, though not universally, accepted. I will explore the alternative idea that consciousness is fundamentally a biological property, both questioning assumptions that underlie computational functionalism, and motivating a positive association between properties of consciousness and material properties of its biological substrates. I'll survey how various theories of consciousness fare from this perspective, and explore its implications for consciousness beyond the human.

Talk 2: The promise of psychological models of subjective experience

Stephen M. Fleming (University College London)

Symposium: Functionalism or Not: Discussion and Debate, Thursday July 4th, Yasuda Auditorium, 11:00AM-1:00PM

Cognitive computational models have enjoyed widespread success in capturing many aspects of human psychology – from perception to decision-making to memory. Such models are autonomous with respect to neural implementation (although they may be empirically constrained by neural data): just as, in biology, physically disparate entities can all be lungs as long as they function to respirate blood in a living organism, mental states and processes are defined by their role in a cognitive model, rather than by their neurobiological underpinnings. A challenge is how to integrate subjective experience into these mechanistic models of mind. In my talk I will explore this question, offering an optimistic picture in which satisfying models of subjective experience are within reach. This approach has its origins in 19th century psychophysics that sought to describe lawful mappings between stimuli and subjective sensation. I will briefly describe three research programmes that continue this tradition – on perceptual reality monitoring, introspection of qualitative relations, and the goal-directed control of action. These programmes promise a “rich psychophysics” that captures not only the mappings between stimuli and responses, but also the internal processes that account for the different facets and functional roles of subjective experience. I will argue that this approach avoids the pitfalls of “depsychologizing” consciousness (Frankish, 2021) in which the phenomenal concept of consciousness becomes prematurely divorced from other realms of psychological science.

Talk 3: Functionalism and the biological basis of consciousness

Ned Block (New York University)

Symposium: Functionalism or Not: Discussion and Debate, Thursday July 4th, Yasuda Auditorium, 11:00AM-1:00PM

We are all familiar with the point that a simulation of a rainstorm is not wet. We need a distinction between simulation and implementation of a computational system. But what is an implementation of a computational system? Is it…just more computation? Or is some kind of wet-ware required? This talk will argue that wet-ware may be important and how we could find out whether it is. One approach is to consider the evolution of the electrochemical processing involved in neural systems in which an electrical pulse propagates down an axon triggering the release of chemicals that in turn trigger further electrical pulses in other neurons. At the dawn of multicellular animals, pure chemical signaling was used in placozoans whereas ctenophores (comb jellies) seem to have used pure electrical neuronal systems (and sponges have no nervous systems at all). Only electrochemical control systems led to thinking and feeling organisms, suggesting the possibility that electrochemical processing may be essential to our conscious lives.

Talk 4: Computational functionalism as a provisional working assumption for studying consciousness in AI

Liad Mudrik (Tel Aviv University)

Symposium: Functionalism or Not: Discussion and Debate, Thursday July 4th, Yasuda Auditorium, 11:00AM-1:00PM

One of the most pressing questions of our time, it seems, focuses on consciousness in artificial intelligence (AI): will AI systems acquire any form of consciousness (or have they already?), and if so, how will we know it? In that respect, developing adequate tests for consciousness might be a crucial contribution of the field of consciousness studies to society at large. In this talk, I will argue that adopting computational functionalism (CF) as a provisional working hypothesis is a promising approach for tackling this problem. According to CF, a system that is computationally equivalent to a conscious system, with respect to some critical functions, will also be conscious. While I remain agnostic about the truth value of CF, I argue that it can nevertheless be fruitful in making more informed judgements about the prospects of consciousness in AI systems: while computationally similar systems are not necessarily consciousness, it seems reasonable to hold that they are more likely to be conscious, or to have the potential for developing consciousness. In the absence of a consensus around a theory of consciousness that could provide better justification for deeming an AI system conscious or not, CF accordingly provides the means for knowledge-based estimations about consciousness in AI.

SYMPOSIUM:
Brain dynamics, states and contents of consciousness

Jacobo Sitt (Inserm, Paris Brain Institute, France), Anat Arzi (Hebrew University, Jerusalem, Israel), Rina Zelmann (Massachusetts General Hospital & Harvard Medical School, Boston, MA, USA), Andrea Luppi (Montreal Neurological Institute &, University of Oxford and University of Cambridge)

Wednesday July 3rd, Yasuda Auditorium, 11:00AM-1:00PM

Our symposium explores the link between global brain activity dynamics, states of consciousness, and contents of consciousness. We combine presentations including different neuroimaging modalities (scalp EEG, intracranial recordings, functional MRI, diffusion MRI and PET) and computational modeling to tackle this question. Overall, we will show that brain dynamics is a strong fingerprint of the state of consciousness and characterizes subjective experience at different temporal scales.

The first presentation explores the relationship between the dynamics of global brain patterns and consciousness. Conscious states are marked by a large exploration of global brain patterns, whereas unconscious states, ie. anesthesia or disorders of consciousness, display limited exploration. The study also connects global brain patterns dynamics to subjective experiences, tying brain activity to consciousness content.

The second presentation will examine brain functions during sleep using EEG. Despite lower consciousness, the brain maintains some predictive and sensory processing, which is particularly weakened during deep slow-wave sleep.

The third presentation will contrast brain activity in conscious versus unconscious states. During sleep or anesthesia, unconsciousness is characterized by less information integration and more variability. Anesthesia specifically disrupts prefrontal cortex connectivity, hinting at specific neural changes influencing consciousness and arousal.

The final talk discusses how drugs alter brain activity and consciousness by interacting with the brain’s molecular structure, shedding light into the neuronal mechanisms behind the described brain dynamics. This complex relationship is mapped, showing similar unconsciousness patterns in drug-induced and pathological states.

Overall, our symposium highlights the intertwined nature of brain dynamics, states, and contents of consciousness. They underscore the importance of whole-brain analyses in the study of consciousness, combining insights from neurophysiological, computational, and pharmacological research.

Talk 1: Exploring global brain patterns dynamics and their role in states and contents of consciousness

Jacobo Sitt (Inserm, Paris Brain Institute, France)

Symposium: Brain dynamics, states and contents of consciousness, Wednesday July 3rd, Yasuda Auditorium, 11:00AM-1:00PM

In this presentation, I will explore the probabilistic associations between distinct recurrent global dynamic brain patterns (GDBP) obtained from fMRI data and clinically defined states of consciousness. Through a comprehensive analysis of functional neuroimaging data from both humans and non-human primates, I will demonstrate that conscious states are intricately linked to the dynamic exploration of a diverse repertoire of GDBP, characterized by a characteristic temporal scale of approximately 10 seconds.

Specifically, I will discuss how conscious individuals, whether human or non-human primates, exhibit two distinctive groups of GDBP: (1) ‘High’ GDBP: These patterns involve robust long-range functional cortico-cortical communication, encompassing both positive correlations and anti-correlations between different brain areas, (2) ‘Low’ GDBP: These patterns, in contrast, are characterized by sparse and limited inter-areal communication. Interestingly, unconscious individuals, such as those under anesthesia or in a disorder of consciousness state, primarily express the latter, ‘low’ GDBP category.

Furthermore, I will present recent findings demonstrating that the temporal sequence of GDBP also reflects the fine-grain dynamics of subjective experience. I will show results demonstrating the inter-subject synchronization of GDBPs across subjects that occurs only when subjects are attentive to audiovisual narratives. I will also show that the occurrence of specific modulates the subjects’ perceptual threshold, suggesting a direct relationship between ongoing whole brain dynamics and subjective experience.

In summary, this presentation underscores the critical role of GDBPs in understanding the neural basis of consciousness, highlighting their potential as a novel avenue for investigating subjective experiences across different states of consciousness.

References:

Demertzi, A., Tagliazucchi, E., Dehaene, S., Deco, G., Barttfeld, P., Raimondo, F., ... & Sitt, J. D. (2019). Human consciousness is supported by dynamic complex patterns of brain signal coordination. Science advances, 5(2), eaat7603.

Turker, B., Owen, A. M., Naci, L., & Sitt, J.D. (2022). Processing of the same narrative stimuli elicits common functional connectivity dynamics between individuals. bioRxiv, 2022-11.

Turker, B., Manasova, D., Beranger, B., Naccache, L., Sergeant, C. & Sitt, J.D. High Connectivity Brain States Enhance Consciousnes Perception of Threshold Stimuli. In preparation.

Talk 2: Expectation and surprise in the sleeping brain: Auditory omission prediction error response in sleep across the sleep wake cycle

Anat Arzi (Hebrew University, Jerusalem, Israel)

Symposium: Brain dynamics, states and contents of consciousness, Wednesday July 3rd, Yasuda Auditorium, 11:00AM-1:00PM

How does the sleeping brain make sense of the dynamic and evolving environment? The ability to detect changes in the surroundings while sleeping is crucial for our and of our loved ones' survival (e.g. detecting the smell of a fire or the sound of a crying baby). Indeed, despite the partial disconnection from the environment and the reduced responsiveness to stimuli, some level of sensory processing as well as cognitive operations persist during sleep. Sleeping human regularly sample the environment, create simple predictions, and detects their violation. However, it remains unclear how sleep modulates the formation of predictions and surprise responses. To answer this question, we recorded high-density EEG from healthy participants during wakefulness, and full-night sleep while they were presented with an auditory oddball-omission paradigm. The paradigm included expected and unexpected omitted sounds with intermediate complexity rules, which enabled to disentangle between the neural response to the "pure" prediction error and the neural response to the stimulus's physical properties. I will present recent findings demonstrating a clear omission response across expected and unexpected omitted sounds in wakefulness, NREM and REM sleep as well as neural signatures of expected versus unexpected omitted sounds suggesting sleep stage specific surprise response. This result implies that the sleeping brain is able to create predictions more complex than a mere sensory deviation and that this ability might be compromised in slow-wave sleep.

References:

Canales-Johnson, A., Merlo, E., Bekinschtein, T. A. & Arzi, A. Neural Dynamics of Associative Learning during Human Sleep. Cerebral Cortex 30, 1708–1715 (2020).

Yakim, S., Canales-Johnson, A., Bekinschtein, T., Arzi, A. Expectation and surprise in the sleeping brain: Auditory omission prediction error response in sleep. In prep.

Talk 3: Differential Cortical Network Engagement During States of Un/Consciousness in Humans

Rina Zelmann (Massachusetts General Hospital & Harvard Medical School, Boston, MA, USA)

Symposium: Brain dynamics, states and contents of consciousness, Wednesday July 3rd, Yasuda Auditorium, 11:00AM-1:00PM

What happens in the human brain when we are unconscious? and what when we cannot be awakened? Despite substantial work, we are still unsure which brain regions are involved and how they are impacted when consciousness is disrupted.

Using direct electrical stimulation with simultaneous clinical intracranial EEG recordings, in patients with depth electrodes implanted to localize the origin of their epileptic seizures, we probed the human brain to provide insight into physiological mechanisms and differentiate global, network, and local responses during unconscious states.

Specifically, I will compare the response to stimulation from inside the human brain when participants were awake, asleep, and under general anesthesia. I will present results from global, network and local relative measures that showed that the unconscious brain has less complex, more variable, and less connected responses.

These changes were uniformly distributed across the brain during natural sleep, but there was substantial disruption of prefrontal regions during propofol-induced general anesthesia. Therefore, lack of arousability, during general anesthesia, is linked to a profound disruption of function and connectivity in prefrontal regions.

This presentation will thus highlight that anesthesia is not simply a "deep sleep" state, but rather that different brain regions are responsible for unconsciousness and arousability.

References:

Zelmanni, Rina, et al. "Differential cortical network engagement during states of un/consciousness in humans" Neuron (2023)

Zelmann, Rina, et al., "CLoSES: A platform for closed-loop intracranial stimulation in humans" NeuroImage (2020)

Talk 4: Paths to Oblivion: Bridging neuroanatomy and dynamics across scales to map the landscape of human consciousness

Andrea Luppi (Montreal Neurological Institute &, University of Oxford and University of Cambridge)

Symposium: Brain dynamics, states and contents of consciousness, Wednesday July 3rd, Yasuda Auditorium, 11:00AM-1:00PM

The human brain entertains rich spatiotemporal dynamics, which are drastically reconfigured when consciousness is lost due to brain injury, or perturbed by anaesthesia or psychedelic drugs.

To understand how pharmacological interventions can exert their powerful effects on brain function, we need to understand how they engage the brain's rich neurotransmitter landscape. In this talk, I will outline work bridging microscale molecular chemoarchitecture and pharmacologically-induced macroscale functional reorganisation, by relating the regional distribution of 19 neurotransmitter receptors and transporters obtained from Positron Emission Tomography, and the regional changes in functional MRI connectivity induced by 10 different mind-altering drugs: propofol, sevoflurane, ketamine, LSD, psilocybin, DMT, ayahuasca, MDMA, modafinil, and methylphenidate. These results reveal a many-to-many mapping between molecular chemoarchitecture and drug-induced reorganisation of the brain's functional architecture.

To explain how transient pharmacological intervention with anaesthesia can exert similar reconfigurations of neural activity as chronic disorders of consciousness (DOC), we developed and systematically perturbed a neurobiologically realistic model of whole-brain haemodynamic signals. By incorporating PET data about the cortical distribution of GABA receptors, this computational model revealed a key role of spatially-specific local inhibition for reproducing the haemodynamic activity observed during anaesthesia with the GABA-ergic agent propofol. Incorporating diffusion MRI data from DOC patients revealed that the dynamics that characterise loss of consciousness can also emerge from randomised neuroanatomical connectivity. These results generalise between anaesthesia and DOC datasets, bridging neuroanatomy and dynamics to demonstrate how increased inhibition and connectome perturbation represent distinct neurobiological paths towards the characteristic activity of the unconscious brain.

References:

Luppi, Andrea I., et al. "In vivo mapping of pharmacologically induced functional reorganization onto the human brain's neurotransmitter landscape." Science Advances 9.24 (2023): eadf8332.

Luppi, Andrea I., et al. "Distributed harmonic patterns of structure-function dependence orchestrate human consciousness." Communications biology 6.1 (2023): 117.

Luppi, Andrea I., et al. "Whole-brain modelling identifies distinct but convergent paths to unconsciousness in anaesthesia and disorders of consciousness." Communications biology 5.1 (2022): 384.

SYMPOSIUM: Unconscious Affect and Motivation

Axel Cleeremans (Université libre de Bruxelles), Piotr Winkielman (University of California, San Diego), Colin Klein (Australian National University), Andrew Barron (Macquarie University), Lina Skora (Heinrich-Heine-Universität Düsseldorf & University of Sussex), Léa Moncoucy (Université libre de Bruxelles), Krzysztof Dołęga (Université libre de Bruxelles)

Thursday July 4th, Ito International Center, 11:00AM-1:00PM

Scientific research on consciousness and affect is split between two seemingly incompatible perspectives. On the one hand, bodily pain and pleasure are often considered to be paradigmatic examples of affective states, ones that are uniquely individuated and defined by their subjectively felt qualities or 'what it is like' to experience them. After all, what would it mean to be in a pleasant state without being phenomenally aware that one is in such a state? On the other hand, a number of psychological and neuroscientific findings show that affective states can exert profound influence on decision-making and behavior in the absence of awareness. In particular, research on the difference between the incentive salience of a stimulus (also known as 'wanting') and its hedonic value (or 'liking'), has shown that the two kinds of states are not only dissociable, but can occur in the absence of consciousness (Winkielman & Berridge, 2004). In other words, empirical research seems to vindicate the possibility of being in a positively valenced affective state without being aware of its pleasantness.

The aim of this symposium is to advance our understanding of the relationship between conscious and unconscious affective states and the extent to which they can shape motivational drives and influence behavior. The symposium brings together an interdisciplinary group of experts with backgrounds in neuroscience, psychology, and philosophy to discuss recent findings, methodologies, and theories concerning topics such as the neural substrates, cognitive processes, and evolutionary origins of conscious and unconscious affective states.

Talk 1: New insights into how affect can drive behavior, judgments, and physiology without being subjectively felt

Piotr Winkielman (University of California, San Diego)

Symposium: Unconscious Affect and Motivation, Thursday July 4th, Ito International Center, 11:00AM-1:00PM

There is a growing acceptance of the idea that affective states may not always be represented phenomenologically (subjectively felt). This is partly the result of theoretical work on the mechanisms of consciousness but also reflects empirical evidence from affective neuroscience, animal affect, and the psychology of human emotion. My talk will specifically focus on the human evidence. I will briefly mention earlier work on unconscious influences on simple actions (approach-avoidance, consumption) and physiological responses (peripheral and central). However, my primary focus will be on new data suggesting that "unfelt" emotions influence more complex judgments and decisions, derived from several preregistered experiments. Specifically, I will demonstrate that intuitive trust decisions—quick judgments of whether an unknown politician is trustworthy—draw on affective responses that are "unfelt" yet manifest in affective facial behavior. Additionally, I will describe work on risky financial and moral choices. In several studies, we found that affective stimuli (facial expressions, valenced pictures) lead to riskier decisions: a greater acceptance of a gamble versus a safe option after a positive vs. negative stimulus . Finally, I will present recent evidence on whether the phenomenon of "unconscious affect" represents genuine unawareness or the failure of metacognition, as tested by giving participants the option to report affect nonverbally. I will conclude with a discussion of psychological mechanisms that allow affect to enter and bias judgments without manifesting itself as a conscious feeling.

Talk 2: Homeostatic sensations and the Phenomenal Interface Theory

Colin Klein & Andrew Barron (Australian National University & Macquarie University)

Symposium: Unconscious Affect and Motivation, Thursday July 4th, Ito International Center, 11:00AM-1:00PM

Some of the body's homeostatic demands never reach consciousness. Others—like hunger, thirst, dyspnea, or pain—are accompanied by specific homeostatic sensations. Homeostatic sensations are crucial to life. They are likely to be evolutionarily old (Denton 2006), and may be the precursors to more complex motivational states like moods and emotions (Craig 2008). Yet for all that, it remains unclear why some homeostatic demands are conscious and others aren't, or why the conscious homeostatic sensations seem to many to be obligatorily conscious.

Klein (2015) suggested that the link between homeostatic sensations and consciousness depends on the need for behavioural prioritisation. We expand upon that story by placing the homeostatic sensations within what we term the phenomenal interface theory (PIT). PIT, a generalisation of a story about the origins of consciousness from Bjorn Merker (2005, 2007), is applicable even to relatively simple organisms (Barron and Klein 2016). PIT argues that consciousness arises from a particular kind of interface between perception, interoception, and action. Here we focus on the role of homeostatic sensations as partially constitutive of the phenomenal interface, linking sensorimotor contingencies to a coherent model of a single agent in the world. This situates some homeostatic sensations as constitutively conscious, while opening up the possibility that varieties of unconscious affect might be possible in more complex organisms.

Talk 3: Adaptively conscious: Learning and engaging motivated behaviour relies on conscious access

Lina Skora (Heinrich-Heine-Universität Düsseldorf & University of Sussex)

Symposium: Unconscious Affect and Motivation, Thursday July 4th, Ito International Center, 11:00AM-1:00PM

Learning is a core component of adaptive behaviour, shaping responses, motivations, preferences, and biases. At the simplest level, learning allows agents to form associations between stimuli and events, determining appropriate responses, e.g. through reflexes or simple behavioural tendencies. The more complex forms of learning permit agents to infer the values of their actions, thus shaping motivation and engaging behaviour instrumentally to pursue rewards and avoid punishment. Hence, the extent to which consciousness is required for different forms of learning can shed light on its function and role. Can our behaviour be motivated by environmental signals we cannot consciously perceive? This talk will present evidence that rendering stimuli subliminal abolishes instrumental learning, suggesting that unconsciously perceived stimuli fail to be assigned values to drive adaptive choices. It will then present preliminary results comparing the learning processes in response to subliminal stimuli versus subliminal feedback. Finally, it will assess the ability of subliminally presented stimuli to generate adaptive physiological responses prior to any instrumental behaviour. This series of studies suggests that learning motivated behaviour and its substrates require conscious access. Crucially, maintaining the methodological consistency across the studies allows to determine the boundary conditions for learning without consciousness. We discuss the implications for the concept of unconscious affect and motivation, and the implications for the function of consciousness.

Talk 4: Unknown pleasures? On the nature of unconscious liking

Léa Moncoucy & Krzysztof Dołęga (Université libre de Bruxelles)

Symposium: Unconscious Affect and Motivation, Thursday July 4th, Ito International Center, 11:00AM-1:00PM

The distinction between incentive salience (“wanting”) and hedonic reward (“liking”) is a cornerstone of affective neuroscience and psychology. However, while there are numerous demonstrations of the dissociation between these phenomena, the issue of their relationship to conscious experience remains unclear.

We focus on two issues related to the question of the existence of unconscious hedonic states. Firstly, we are interested in the conceptual relationship between unconscious “liking” and conscious liking. Although this naming convention has been introduced to highlight the dependence of conscious pleasure on the neural processing of chemical rewards, its authors suggest that the two can exist independently of one another (Winkielman & Berridge, 2003). We propose a set of criteria that need to be fulfilled to validate this claim through an analogy with unconscious perception as well as the results of a philosophical survey on common intuitions about the possibility of unconscious pleasure. The second problem targeted in the talk is whether “liking” can occur unconsciously. Here, we point to several problems with the available evidence for the existence of unconscious positively valenced hedonic states. The majority of empirical research has been conducted on animal models (mostly rats and mice) and is too methodologically limited to disambiguate between conscious and unconscious processing. Research on humans is likewise limited by the possible conflation of “wanting” and “liking” responses, as well as an absence of independent measures of subjective hedonic awareness. Analyzed against our criteria, these limitations show that we presently do not possess conclusive evidence for unconscious “liking”.

SYMPOSIUM: Voluntary and Involuntary conscious visualizations: from visual mental imagery to dreams

Alfredo Spagna (Columbia University, Psychology Department), Paolo Bartolomeo (Paris Brain Institute, Paris, France), Lionel Naccache (Paris Brain Institute, PICNIC), Athena Demertzi (Univesité de Liège, GIGA CRC Human Neuroscience)

Friday July 5th, Yasuda Auditorium, 11:00AM-1:00PM

Is there a link between the vivid landscapes of visual mental imagery that we construct at will and the enigmatic and often surreal landscapes of our dreams that seem to unfold beyond our control? The realm of human consciousness is vast and the interplay between voluntary and involuntary conscious visualizations feels intricate and boundless. This symposium intersects data from behavioral and neural findings of visual mental imagery (Spagna), deficits of this ability (congenital and acquired aphantasia) (Bartolomeo), sleeping individuals who can send messages from within their dreams (Oudiette), and EEG correlates of dream contents (Siclari). We will seek an explanatory unification of these axes, namely voluntary, involuntary, conscious and unconscious visualization of images. At the core of the symposium, the debate will relate to current theories of visual conscious perception, and discuss the role of long-range connections between frontoparietal and visual regions for voluntary and involuntary conscious visual perception.

Spagna, A., et al (2023). Visual mental imagery: evidence for a heterarchical neural architecture. PsyRxiv.

Liu, J., et al (2023). Ultra-high field fMRI of visual mental imagery in typical imagers and aphantasic individuals. bioRxiv.

Konkoly KR, et al (2021). Real-time dialogue between experimenters and dreamers during REM sleep. 10.1016/j.cub.2021.01.026. Curr Bio.

Türker B, et al (2023). Behavioral and brain responses to verbal stimuli reveal transient periods of cognitive integration of the external world during sleep. Nat Neurosci.

Siclari, F., et al. The neural correlates of dreaming. Nat Neurosci https://doi.org/10.1038/nn.4545

Talk 1: The role of frontoparietal networks in attention and voluntary imagination

Alfredo Spagna (Columbia University, Psychology Department)

Symposium: Voluntary and Involuntary conscious visualizations: from visual mental imagery to dreams,
Friday July 5th, Yasuda Auditorium, 11:00AM-1:00PM

How do attentional networks influence conscious perception? I will present data from two studies: one featuring magnetoencephalographic recordings, and the other featuring intracerebral recordings assessing the effects of supra-threshold peripheral spatial cues on the conscious perception of near-threshold Gabors. Behavioral and neuroimaging results converge on the importance of lateralized front-parietal networks in shaping our visual conscious perceptions. I'll then discuss the relevance of our findings with respect to current theories of consciousness and conclude by relating them to a less-studied form of visual perception: visual mental imagery. I will briefly review the literature regarding human imagination, and then show recent neuroimaging evidence obtained using 3T and 7T fMRI, pointing at the role of the frontoparietal networks in supporting imagination. I will conclude by bridging between the fields of visual perception and visual imagination, pointing at the frontoparietal networks in these two processes.

Talk 2: Visual mental imagery: causal evidence from neurological patients

Paolo Bartolomeo (Paris Brain Institute, Paris, France)

Symposium: Voluntary and Involuntary conscious visualizations: from visual mental imagery to dreams,
Friday July 5th, Yasuda Auditorium, 11:00AM-1:00PM

How do we generate and manipulate mental images of visual scenes or objects when there is no actual visual input? The dominant model of visual mental imagery states that this ability is a sort of "perception in reverse", with prefrontal regions initiating imagery-related activity in early visual areas. However, individuals with acquired brain damage restricted to the occipital cortex typically have perfectly vivid visual mental imagery. By contrast, patients with damage extending anteriorly in the temporal lobe, especially in the left hemisphere, often find themselves unable to build visual mental images. Inspired by these results, neuroimaging experiments in neurotypical individuals revealed the activity of a visual mental imagery network centered on a specific region in the left fusiform gyrus, the Fusiform Imagery Node (FIN). When individuals with congenital aphantasia, who report a lack of visual mental imagery, attempt to build visual mental images, the same network is active, but FIN activity is functionally disconnected from frontoparietal activity. As a working model of visual mental imagery, consistent with both the neuropsychological and the neuroimaging results, we propose that frontoparietal networks initiate and maintain activity in the FIN and in nearby domain-preferring regions of the ventral temporal cortex. More generally, subjective visual experience - whether perceived or imagined - depends on the integrated activity of high-level visual cortex and frontoparietal networks. Detailed studies of individual neurological patients are still critical to inspire and constrain neurocognitive research and its theoretical models.

Talk 3: Lucid dreamers as undercover agents of the dream world

Lionel Naccache (Paris Brain Institute, PICNIC)

Symposium: Voluntary and Involuntary conscious visualizations: from visual mental imagery to dreams, Friday July 5th, Yasuda Auditorium, 11:00AM-1:00PM

What happens in our mind when we sleep? The impossibility to directly peer on participants' dreams raises an important challenge for scientists, who typically rely on reports of dream memories collected when the sleeper is back to the 'real world'. Here, I will discuss the lucid dreaming model as a way to 'see through the invisible' and get direct access to the sleeping mind. Lucid dreamers are conscious of dreaming while in REM sleep, and some of them can even do imposed missions in dreams and signal it by sending a muscular code, visible to the experimenter via EMG sensors. I will present recent brain and behavioral data collected during lucid dreams and discuss their implications for our understanding of conscious experiences in sleep.

Talk 4: The neural correlates of conscious experiences in sleep

Athena Demertzi (Univesité de Liège, GIGA CRC Human Neuroscience)

Symposium: Voluntary and Involuntary conscious visualizations: from visual mental imagery to dreams, Friday July 5th, Yasuda Auditorium, 11:00AM-1:00PM

Why and how do we dream? Although this question has fascinated humankind since the earliest ages, it remains largely unanswered. Each night, when we fall asleep, we progressively disengage from the external world until we cease to perceive it and to act upon it. Despite this sensorimotor disconnection, in our dreams we perceive and act, and although we do so in a purely imaginary world, our experiences bear so much resemblance with the real world that we almost invariably take them for real. How does the brain create such a real-world analogue, and why? In this talk I will discuss a series of studies investigating the neural correlates of dreaming using high-density EEG recordings coupled with serial awakening paradigms. I will show how brain activity patterns change between dreamless sleep and dreaming and depending on specific dream characteristics and contents.

SYMPOSIUM: Blueprints for Machine Consciousness

Lenore Blum (Carnegie Mellon University), Johannes Kleiner (Ludwig Maximilian University of Munich, University of Bamberg), Ryota Kanai (Araya, Inc.), Joscha Bach (Intel Labs)

Wednesday July 3rd, Ito International Center, 11:00AM-1:00PM

Recent theoretical advances in understanding AI consciousness have shown that conscious machines could potentially be built rather soon. As a result, in addition to the important theoretical work that is currently being carried out, there is a need to study blueprints for machine consciousness – concrete technical schematics of how conscious AI could, given contemporary theories, actually be built in the lab.

The goal of this symposium is to initiate a discussion of the current state of the art of blueprints for AI consciousness. To this end, it features talks from researchers that are actively trying to build conscious machines, as well as talks that take a critical perspective. In doing so, the symposium hopes to help provide a thorough understanding and prediction of where on the road to conscious machines we currently stand, and to inform the managing of ethical and societal implications of AI and AI safety.

The four talks that will be hosted during this symposium will report on:

- Forms of computation that are suitable to support artificial consciousness
- Blueprints for AI consciousness that are based on theories of how consciousness evolved
- Mechanistic implementations of higher order theories of consciousness
- Self-organizing systems as a blueprint for AI consciousness

In addition to these talks, the symposium will reserve ample time for discussions with participants.

Talk 1: Does Artificial Consciousness Require Mortal Computation?

Johannes Kleiner (Ludwig Maximilian University of Munich, University of Bamberg)

Symposium: Blueprints for Machine Consciousness, Wednesday July 3rd, Ito International Center, 11:00AM-1:00PM

More than 50% of IC development and design expenses go into a process called "verification". Verification is at the heart of any modern CPU, GPU and TPU, and is intimately connected to the major paradigm of computation that has been applied over the last 50 years. In this talk, I will show that under very broad conditions, verification—and with it, the current paradigm of computation—has strong implications for AI consciousness. I will explore what this means for computing substrate of conscious agents and show how this points at what Geoffrey Hinton has recently called "mortal computation". The upshot of my talk is that much like we may have yet to "comprehend the long-term implications of deep learning for the way computers are built" (Hinton), we may have yet to understand the implications of the way computers are built for artificial consciousness.

Talk 2: An Evolutionary Road Map for A No-Blooded Conscious AI

Lenore Blum (Carnegie Mellon University)

Symposium: Blueprints for Machine Consciousness, Wednesday July 3rd, Ito International Center, 11:00AM-1:00PM

In a recent article [1], Zacks and Jablonka provide evolutionary evidence for the development of a modified global neuronal workspace (GNW) in vertebrates, suggesting that an AI with a global workspace architecture (GW) could possess at least minimal consciousness. In a recent book [2], Humphrey outlines the evolutionary road taken for the development of phenomenal consciousness in warm-blooded animals. We claim this road map provides a recipe for an AI to construct models of its internal and external worlds (and its sense of self), properties we believe important for phenomenal consciousness.

The Conscious Turing Machine (CTM), a simple formal machine model for consciousness, incorporates both a global workspace and special processors including sensory and motor processors and a Model of the World processor (that constructs world models in a fashion analogous to Humphrey's evolutionary road map). We suggest that together with its predictive dynamics (cycles of prediction, testing, feedback, and learning), and its multi-modal internal language Brainish, the CTM can realize conscious attention and experience "feelings" of consciousness [3, 4], aligning with the evolutionary theories of consciousness above [1,2].

References.

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[2] Humphrey, Sentience: The Invention of Consciousness, MIT Press, 2023.

[3] Blum and Blum, A theory of consciousness from a theoretical computer science perspective: Insights from the Conscious Turing Machine, PNAS, 2022. https://www.pnas.org/doi/epdf/10.1073/pnas.2115934119

[4] Blum and Blum, A Theoretical Computer Science Perspective on Consciousness and Artificial General Intelligence, Engineering, 2023. https://doi.org/10.1016/j.eng.2023.03.010

Talk 3: Meta-Representations and Mechanistic Interpretability of AI

Ryota Kanai (Araya, Inc.)

Symposium: Blueprints for Machine Consciousness, Wednesday July 3rd, Ito International Center, 11:00AM-1:00PM

In this talk, we propose a novel theoretical framework that explores the intersection of mechanistic interpretability of AI and higher-order theories of consciousness. Here, we introduce the notion of "meta-networks" that can be applicable to both the biological brain and artificial neural networks. Meta-networks are neural networks that encode neural networks to map them to representations in a common embedding space. Such representations are considered meta-representations in the sense that they are not representations about the primary sensory data, but about the processes that act on them.

A functional utility of such meta-representation space is that it serves as a foundation to address the qualitative differences of networks trained on disparate datasets in a quantifiable manner. Building upon this idea, we proof-of-concept experiments to test whether the function of an unknown artificial neural network could be predicted by the meta-representations of those networks. Our results confirmed that neural networks trained on data from different modalities (visual vs auditory) as well as for specific training dataset could be predicted based on the meta-representations computed by meta-networks. We hypothesize that similar mechanisms exist within the human brain and underlie our ability to subjectively compare and describe subtle differences and similarities of our conscious experiences, i.e., qualia. Our interdisciplinary approach offers a new insight into potential biological functions of qualia, and their unexpected relevance to mechanistic interpretability of deep neural networks.

Talk 4: Self-Organizing Modelling Systems as a Blueprint for AI Consciousness

Joscha Bach (Intel Labs)

Symposium: Blueprints for Machine Consciousness, Wednesday July 3rd, Ito International Center, 11:00AM-1:00PM

Starting from the observation that biological information processing in multicellular substrates is based on self-organization, I explore the conjecture that the functionality of consciousness represents the simplest algorithm that is discoverable by such substrates, and can impose function approximation via increasing representational coherence. I describe some properties of this operator, both with the goal of recovering the phenomenology of consciousness, and to get closer to a specification that would allow recreating it in computational simulations.

SYMPOSIUM: Structural Approaches to Consciousness

Sascha Benjamin Fink (FAU Erlangen), Fiona Macpherson (University of Glasgow), Chen Song (Cardiff University), Nao Tsuchiya (Monash University), Masafumi Oizumi (The University of Tokyo)

Friday July 5th, Ito International Center, 11:00AM-1:00PM

Recent years have seen structural approaches gain prominence in consciousness sciences, e.g., representational similarity analysis and category theoretical approaches to quality spaces and more. However, these approaches raise the question how exhaustive they are. "Do they simply capture the relations between experiences or do they capture the phenomenal experiences themselves?"

One radical view, ontic phenomenal structuralism, posits experiences as purely structural, challenging traditional notions of consciousness as collections of intrinsic, non-structural qualitative feels (qualia). This perspective offers fresh solutions to long-standing philosophical dilemmas, like Locke's inverted spectrum, by redefining consciousness's basic ontology. It encourages a reevaluation of established philosophical beliefs, promoting more robust interpretations of empirical findings and innovative methodologies.

However, structuralism is divisive because, to many, it still seems to leave something out: It misses the point that it is just a phenomenal fact that experiences are intrinsic, or it fails on methodological grounds as it entails an inconvenient holism, or they see it limited to explaining phenomenology without addressing the difference between consciousness and unconsciousness (i.e., the hard problem), or they are pessimistic because we fail to converge on single structures even for highly researched phenomena like color vision.

This symposium aims to bring together cutting-edge researchers from psychology, neuroscience, and computational neuroscience using structural approaches to do empirical work aimed at structurally characterizing qualia and identifying structural neural correlates of qualia. Philosophers will confront them with both supportive and critical voices from philosophy and together discuss future perspectives of structural approaches to consciousness.

Talk 1: A Problem For Determining the Structural Features of Experience: A Pessimistic Meta-Induction

Fiona Macpherson (University of Glasgow)

Symposium: Structural Approaches to Consciousness, Friday July 5th, Ito International Center, 11:00AM-1:00PM

I argue that we ought to be pessimistic about our ability to determine the structural features of experience – if indeed there are any. The argument takes the form of a pessimistic meta-induction: many claims as to what are structural features of experience have turned out to be false. My diagnosis of their failure is that we are consistently fooled by the limitations of our own sensory imagination. When we understand this, we should not be confident that we can determine the structural features of experience – if indeed there are any.

Talk 2: Global and local structures of consciousness: impacts of environment, sleep, and learning

Chen Song (Cardiff University)

Symposium: Structural Approaches to Consciousness, Friday July 5th, Ito International Center, 11:00AM-1:00PM

Consciousness is holistic and structured. At any given moment, our conscious experience typically comprises multiple contents (multiple phenomenal distinctions), structured in a specific way. Just as the brain cannot be simplified to isolated neurons, consciousness cannot be reduced to dissected contents. Even if the constituent contents remain unchanged, alterations in their structuring, including changes in the integration between different contents, as well as changes in the richness, clarity, intensity of individual contents, can lead to significant shifts in conscious experience. The holistic nature of consciousness highlights the need for a holistic approach, which complements the conventional reductionist approach. In this talk, we will share the results from a five-year project, dedicated to such a holistic approach. We found that individuals who have similar profiles of consciousness contents, such as similar visual illusion experience, similar metacognition experience, tend to have substantially different profiles of consciousness structuring, in terms of what contents occupy their consciousness most frequently, what contents co-occur regularly, how rich / clear / intense individual contents are, how integrated different contents are. Compared to the contents, the structuring of conscious experience exhibits higher plasticity. For example, during learning or sleep deprivation, significant changes were observed in the structuring of conscious experience before changes were detected in the specific contents of conscious experience. These findings suggest that the conventional reductionist approach may have greatly underestimated the extent of inter-individual variation and intra-individual plasticity in consciousness. We will discuss the implications of our findings and outline potential directions for future research.

Talk 3: A Qualia Structure approach

Nao Tsuchiya (Monash University)

Symposium: Structural Approaches to Consciousness, Friday July 5th, Ito International Center, 11:00AM-1:00PM

Do I experience the world in the "same" way as you do? How similar is my consciousness to other humans, animals, insects, octopuses, and artificial intelligence? In this talk, I will discuss this issue focusing on the content of consciousness, what-it-feels-like, or in short "qualia". Can we scientifically investigate if my red qualia is similar to your red qualia? Traditionally, the answer has been No. Because "qualia" are so intrinsic and purely subjective, qualia have often been considered as outside of the realm of scientific inquiry. Recently, our group has proposed a method of characterising a quale in terms of its relation to all other qualia, inspired by a mathematical theorem called "Yoneda lemma" in the field of category theory. Based on this idea, we conducted experiments in which we asked a large number (>500) of neurotypical and colorblind subjects to report the similarity of a subset of ~5000 colour combinations in an online setting. The following talk by Prof Oizumi will discuss how to quantify such data. Our qualia structure approach is generalizable to qualia in other domains (such as similarity of evoked emotional experience of short movies), or even to structures between qualia structures. The relationship between qualia structures may eventually provide an opportunity to address questions such as, "Why are colour qualia perceived as colour qualia?"

Talk 4: Unsupervised alignment of qualia structures

Masafumi Oizumi (The University of Tokyo)

Symposium: Structural Approaches to Consciousness, Friday July 5th, Ito International Center, 11:00AM-1:00PM

Whether one person's experience of "red'' is equivalent to another's has long been considered unanswerable. One promising approach to resolving this fundamental question about consciousness is the intersubjective comparison of the similarity relations of sensory experiences, called "qualia structures''. Conventional methods for comparing similarity relations largely sidestep the issue, assuming that experiences elicited by the same stimuli are matched across individuals, and thus ruling out the possibility that my "red'' could be your "blue''. Here, we present an unsupervised optimal transport method for assessing the similarity of qualia structures without assuming correspondences between individuals. To validate and demonstrate the utility of the proposed approach, we analyzed a massive dataset of subjective color dissimilarity judgments from color-neurotypical and color-blind participants. We show that optimal correspondences between qualia structures within color-neurotypical participants can be "correctly'' aligned based solely on similarity relations. In contrast, qualia structures from color-blind individuals could not be aligned with those of color-neurotypicals. Our results offer quantitative evidence for the interindividual structural equivalence or difference of color qualia, implying that a color-neurotypical person's "red'' is indeed another color-neurotypical's "red'', but not a color-blind person's "red'' from a structural perspective. This method is applicable across modalities, enabling general structural exploration of subjective experiences.

Concurrent Session Talks

The micro-phenomenology of lucid insight: A study of signal-verified lucid dream experiences

Ema Demšar (Monash Centre for Consciousness and Contemplative Studies, Department of Philosophy, Monash University, Melbourne, VIC, Australia), Mahdad Jafarzadeh Esfahani (Donders Institute for Brain, Behaviour, and Cognition, Radboudumc, Nijmegen, The Netherlands), Martin Dresler (Donders Institute for Brain, Behaviour, and Cognition, Radboudumc, Nijmegen, The Netherlands), Thomas Andrillon (Paris Brain Institute, Sorbonne Université, Inserm-CNRS, Paris 75013, France), Jennifer Windt (Monash Centre for Consciousness and Contemplative Studies, Department of Philosophy, Monash University, Melbourne, VIC, Australia)

Concurrent Session: State of Consciousness, Wednesday July 3rd, Fukutake Learning Theater, 2:00PM-4:00PM

Lucid dreaming (LD) - dreaming in which one is aware that one is currently dreaming - offers a unique platform for exploring meta-awareness in dreams with implications for consciousness research more broadly. Methodological advances now make it possible to study the neural basis of lucidity in laboratory and home settings, but existing EEG studies have so far offered mixed or even conflicting findings. This could in part be explained by the diversity of LD experiences. Indeed, anecdotal dream reports and recent questionnaire-based studies indicate that there might be different degrees and types of lucid insight (i.e., the experience of being aware that one is dreaming). However, there has so far been no systematic investigation of LD phenomenology that would allow detailing the structural features and temporal dynamics of LD experience as well as distinguishing between potentially different target phenomena. This is an important step in identifying the neural basis of LD, refining LD induction techniques, and leveraging LD in clinical populations (e.g. in treating recurring nightmares). One of the techniques that enables such investigation is the micro-phenomenological (MP) interview technique, which we implemented in the present study. We present phenomenological findings from a neurophenomenological EEG study in which participants (N=20) took part in two nap sessions in the sleep lab. The study combined two LD induction techniques: Senses Initiated Lucid Dreaming (SSILD) during sleep onset and Targeted Lucidity Reactivation (TLR) during REM sleep, both of which incorporated administration of visual, auditory, and tactile sensory cues. Participants signalled the onset of dream lucidity with intentional eye movements and provided free dream reports and questionnaire responses after the end of each REM phase. Additionally, post-session MP interviews were used for an in-depth exploration of lucidity-related experiences. We conducted 38 interviews in total. The interviews (60-90 minutes in length) focused on temporal dynamics and experiential features associated with lucid insight and the onset and progression of lucidity. Here, we present the results of the phenomenological qualitative analysis of a subset of 24 interviews that focused on signal-verified REM-sleep LD episodes. We identify commonalities and differences between these episodes, focusing on 1) distinct diachronic patterns associated with lucid insight, including phases of pre-lucidity, semi-lucidity, and full dream lucidity; and 2) common phenomenological structures. Our findings suggest a distinction between different trajectories preceding lucid insight, as well as between different degrees and types of lucid insight and meta-awareness in LD more broadly. They also elucidate links between lucid insight and various attentional, (meta)cognitive, self-related and embodiment-related phenomenological structures. We relate our findings to the ongoing discussion about the definition and operationalization of dream lucidity and consider implications for future research into LD and meta-awareness more broadly. By enabling a more precise and phenomenologically grounded understanding and classification of LD, our approach can contribute to ongoing attempts at temporal and structural mapping of LD experience to physiological and behavioural data, including the search for neural correlates of LD.

Measuring the dynamic balance of integration and segregation underlying conscious states

Hyunwoo Jang (University of Michigan), George A. Mashour (University of Michigan), Anthony G. Hudetz (University of Michigan), Zirui Huang (University of Michigan)

Concurrent Session: State of Consciousness 1, Wednesday July 3rd, Fukutake Learning Theater, 2:00PM-4:00PM

Introduction
Integration and segregation (or differentiation) are considered two key features of neural systems thought to mediate consciousness. However, a consensus on how, precisely, to measure this balance has proven elusive. In this study, we aimed to formulate a metric that captures two major surrogates of integration-segregation balance, i.e., functional connectivity strength and network topology. Through application to dynamic functional connectivity in humans, we investigate the potential of this metric to reflect shifts in conscious states during the loss and recovery of responsiveness (LOR and ROR, respectively). Furthermore, at a more granular level, we examine whether a sequential pattern of subnetwork changes in integration-segregation balance exists during the transitions to LOR and ROR.

Methods
Our approach involved analyzing two fMRI datasets consisting of 19 and 26 healthy volunteers. These datasets encompassed fMRI scans taken before, during, and after the administration of propofol. Our analysis centered on dynamic functional connectivity, employing a sliding-window technique. This analysis included 450 regions of interest, spanning cortical and subcortical networks. We incorporated both functional connectivity strength and network topology in a single metric, to advance beyond the status quo of assessing these properties independently. Functional connectivity strength was computed through the average of the functional connectivity matrix, while topology was measured using the linearly rescaled small-worldness. The product of these two was termed the "Topo-Connectivity Index".

Results
Compared to conscious baseline, LOR was linked to functional segregation in the brain. This was evidenced by a significant decrease in connectivity strength ($p=0.0022$) and a shift towards a lattice-like modular topology ($p=0.0022$). The topo-connectivity index proved to be a potent discriminator between the conscious and LOR states ($p=0.0022$). Evaluated by the area under the curve (AUC) of receiver operating characteristic (ROC) curves, the discriminatory capability of TCI (AUC = 0.76) surpassed that of connectivity strength (AUC = 0.75) and topology (AUC = 0.69) in isolation, and other commonly used balance metrics. The whole-brain topo-connectivity exhibited a decline around the onset of LOR, continuing to decrease progressively over 8 minutes. In contrast, as the transition to ROR approached, the topo-connectivity initiated a rebound 5 minutes before the ROR and continued to rise for 10 minutes. The analysis of brain subnetworks revealed a unique sequence of changes: the route to LOR was marked by an initial drop in topo-connectivity within unimodal networks (such as visual and somatomotor), followed by a decrease in transmodal (including fronto-parietal and default-mode) and subcortical networks. The course towards ROR was characterized by the restoration of transmodal networks, followed by the recovery of the unimodal and subcortical networks.

Conclusion
Quantification of functional connectivity strength and network topology as a surrogate for integration-segregation balance is a novel and principled approach for assessing conscious states. We also revealed a distinct temporal sequence of network changes that occur during the transition into and out of anesthetic-induced loss of consciousness. The application of the topo-connectivity demonstrates potential for objectively identifying conscious states or disorders of consciousness independently of behavior.

Changes in functional connectivity in the propofol-induced unconscious state using human intracranial electroencephalography

Mikyung Choe (Neuroscience Research Institute, Medical Research Center, Seoul National University College of Medicine), Seung-Hyun Jin (Neuroscience Research Institute, Medical Research Center, Seoul National University College of Medicine), Medical Research Center, Seoul National University College of Medicine), Chun Kee Chung (Neuroscience Research Institute, Medical Research Center, Seoul National University College of Medicine)

Concurrent Session: State of Consciousness 1, Wednesday July 3rd, Fukutake Learning Theater, 2:00PM-4:00PM

Unconsciousness in general anesthesia results from altered connectivity, decreased network efficiency, and decreased complexity, indicating decreased information transmission of the brain network. In previous studies, changes in connectivity have been incongruent, whereas changes in efficiency and complexity are consistently observed. The incongruity in connectivity changes could arise from factors such as the frequency dependence of connectivity, limitation in spatial resolution, and methodological variations in measuring connectivity. In the present study, we investigated global and inter-regional changes in the amplitude-based and phase-based functional connectivity in the unconscious state across all frequency bands using human intracranial electroencephalography (iEEG), offering high temporal, spatial, and spectral resolutions. We analyzed the iEEG data of 73 patients (38 males and 35 females; age: mean = 33.8, SD = 10.8 years). Anesthesia was induced using the target-controlled infusion of propofol and remifentanil. The average target effect-site concentrations of propofol and remifentanil were 3.93 Œºg/ml and 3.35 ng/ml (SD = 0.35 Œºg/ml and 0.92 ng/ml), respectively. The data were collected during both conscious and unconscious states, with an average analysis duration of 97.57 seconds (SD = 56.48 seconds). We calculated amplitude-based and phase-based functional connectivity using amplitude envelope correlation (AEC), magnitude squared coherence (MSC), and weighted phase lag index (wPLI). Additionally, we calculated power spectral density (PSD), network efficiency, and Lempel-Ziv complexity. In the propofol-induced unconscious state, we observed a significant increase in global functional connectivity across all frequency bands, as indicated by measures including AEC, MSC, and wPLI. This increase in global connectivity was accompanied by the decrease in both global complexity and efficiency. Specifically, efficiency decreased in the low and high gamma frequency bands. Additionally, global Lempel-Ziv complexity decreased in the unconscious state. Slow-delta activity increased, and high gamma PSD decreased with alpha anteriorization. In inter-regional connectivity, the AEC and MSC predominantly increased in the posterior regions in the delta frequency band, while the AEC predominantly increased in the posterior regions in the theta frequency band. Notably, wPLI increased across all cortical regions in both the beta and low gamma frequency bands. The increased functional connectivity with decreased complexity suggests that the brain would be unified in the unconscious state. Decreased efficiency indicates that the capacity of information transmission is limited. It suggests that, in unconsciousness, a repertoire of diverse neural programs shrinks ultimately.

This is your sleeping brain on Espresso: Rich, complex and critical

Philipp Thölke (Computational and Cognitive Neuroscience Lab, Université de Montréal, Montréal, QC, Canada), Maxine Arcand-Lavigne (Computational and Cognitive Neuroscience Lab, Université de Montréal, Montréal, QC, Canada), Tarek Lajnef (Computational and Cognitive Neuroscience Lab, Université de Montréal, Montréal, QC, Canada), Sonia Frenette (Centre for Advanced Research in Sleep Medicine, Université de Montréal, Montréal, QC, Canada), Julie Carrier (Centre for Advanced Research in Sleep Medicine, Université de Montréal, Montréal, QC, Canada), Karim Jerbi (Computational and Cognitive Neuroscience Lab, Université de Montréal, Montréal, QC, Canada), Karim Jerbi (Université de Montréal)

Concurrent Session: State of Consciousness 1, Wednesday July 3rd, Fukutake Learning Theater, 2:00PM-4:00PM

For many, enjoying the delicate flavors of an espresso coffee ranks high up on the list of life's little pleasures. Caffeine is the world's most prevalent psychoactive stimulant, and is consumed by people across all age groups on a daily basis through a wide variety of products such as coffee, tea, soft drinks, energy drinks, chocolate and several pharmaceutical drugs. Caffeine has been extensively studied for its wakefulness-promoting effects, however, it also has disruptive effects on the quality of sleep. Despite important progress, our understanding of how the brain is affected by caffeine, in particular during sleep, is still incomplete. Previous research has reported caffeine-induced effects on spectral power of electroencephalography (EEG) signals recorded during sleep. Yet, while spectral power analysis provides important insights into the oscillatory properties of brain signals, it does not capture the diversity and full complexity of EEG signals. Studies of brain entropy support the view that higher order cognitive processes, as well as states of high vigilance, are mediated by brain dynamics that exhibit heightened complexity. Interestingly, accumulating evidence from a parallel yet closely related stream of research, known as the critical brain hypothesis, suggests that optimal information processing and behavioral capabilities are supported by brain dynamics that are close to a critical phase transition. Like complexity, brain criticality also drops with reductions in the levels of vigilance or consciousness. Whether caffeine alters the brain by shifting it towards a critical regime is not known. Here, we analyzed sleep EEG in 40 subjects, contrasting 200mg of caffeine against a placebo condition in a double-blind cross-over design. Using inferential statistics and machine learning, we found that caffeine ingestion led to an increase in brain complexity, a widespread flattening of the power spectrum's 1/f-like slope, and a reduction in long-range temporal correlations. These results, which were most prominent during non-REM sleep, suggest that caffeine shifts the brain closer to a critical regime and more diverse neural dynamics. Interestingly, these effects were more pronounced in younger adults (20-27 years) compared to middle-aged participants (41-58 years) whose sleep brain dynamics were less affected by caffeine. These data are interpreted in the light of modeling and empirical work on EEG-derived measures of excitation-inhibition balance and provides novel insights into the effect of caffeine on the sleeping brain. In conclusion, our study extends the current understanding of caffeine's impact on sleep by highlighting its role in enhancing brain complexity and shifting dynamics towards a critical regime, with pronounced effects during NREM sleep. The age-dependent response to caffeine, with reduced impact observed in middle-aged individuals, underscores the intricate interplay between caffeine, sleep, and the aging brain. These insights pave the way for future research to further elucidate the mechanisms underlying caffeine's effects and their implications for sleep health across the lifespan.

Anesthesia-induced dreaming; Frequency, content, and outcomes

Pilleriin Sikka (Stanford University), Harrison Chow (Stanford University), May Ching Ngo (Stanford University), Boris Heifets (Stanford University)

Concurrent Session: State of Consciousness, Wednesday July 3rd, Fukutake Learning Theater, 2:00PM-4:00PM

Introduction: While intraoperative dreaming is common, the therapeutic potential of anesthesia-induced dream states remains unexplored. Our recent case series involving three patients (Chow et al. 2022; Hack, Sikka, et al., in press) demonstrated notable reductions in acute stress disorder, PTSD, anxiety, and depression symptoms following anesthesia-based EEG-guided intraoperative dreaming. However, dreaming during anesthesia has also been linked to anesthesia awareness and post-anesthesia anxiety disorders. Therefore, before exploring the therapeutic effects of anesthesia-induced dream states within a broader clinical context, it is important to establish the efficacy and safety of the procedure. Here, we investigated the frequency, content, post-operative outcomes and incidence of anesthesia awareness in surgical patients for whom pre-emergence dreaming was deliberately induced. Methods: We examined 440 patients (age: 20-85 years) undergoing surgery with EEG-guided propofol/opioid-based anesthetic titration. Awakening from anesthesia was based on specific frontal EEG changes: a sudden reduction in alpha power followed by a sudden increase in high-frequency (beta/gamma) power sustained for several minutes. A structured dream interview was administered immediately upon emergence from anesthesia. Additionally, within a subset of 108 female breast cancer patients (age: $M = 58.68$, $SD = 14.87$), we explored outcomes in the Post-Anesthesia Care Unit (PACU). Results: Of the 440 patients, 288 (65.4%) reported experiencing dreams during anesthesia, with 240 (54.5%) able to recall dream content. Within a subset of patients ($N = 57$), we followed a protocol wherein the observed pattern of brain activity prior to emergence (reduced alpha but increased high-frequency power) was sustained for 15 minutes. The majority of dreams were either positively valenced (86.0%) or neutral (12.3%), with only one patient reporting a "somewhat negative" dream. Most commonly reported dream themes included family, but dreams about friends, vacationing/ outdoor activities, home life, work, and aspects related to surgery itself were also common. Generalized linear regression models showed that dreaming during anesthesia was not significantly associated with post-surgical recovery time or the quantity of opioids or antiemetics administered ($p > .05$). There were no instances of anesthesia awareness or vomiting in the PACU. Conclusions: These findings suggest that it is feasible to induce and sustain a neurophysiological state conductive to dreaming and that it is a safe procedure. These results warrant an open-label study to deliberately induce dreaming with anesthesia outside the surgical setting. Such research would enable us to uncover the neural markers of anesthesia dreaming and explore its potential therapeutic effects on mental health outcomes.

Superior Colliculus and Consciousness: a Co-Activation Pattern Study

Sara Cavuoti-Cabanillas (University of Parma, University of Camerino), Davide Orsenigo (University of Turin, CENTAI), Alessio Borriero (University of Turin, University of Camerino), Marco Tamietto (University of Turin), Matteo Diano (University of Turin)

Concurrent Session: State of Consciousness 1, Wednesday July 3rd, Fukutake Learning Theater, 2:00PM-4:00PM

Introduction: The Superior Colliculus (SC) is a small structure in the midbrain responsible for goal-directed behaviours in mammals. By selecting relevant stimuli, the SC creates a saliency map of the visual field and redirects the organism towards salient visual information. This mechanism is crucial for visual attention and contributes to conscious representation of the external world. In this study, we delved deeper into the SC's functionality, exploiting a network dynamics framework, and we examined its activity across various altered states of consciousness. Material and Methods: To explore the dynamics in the Superior Colliculus (SC), we implemented a Co-Activation Pattern (CAP) analysis. This technique allowed us to investigate the connected areas (CAPs) of the SC during resting state acquisitions by recreating the instantaneous brain configurations at specific time points. With such maps, we were able to estimate the intrinsic connections both during wakefulness and sleep. Initially, we computed the CAPs in 98 subjects (392 resting state sessions) from the Human Connectome Project. Subsequently, we assessed the occurrences of different stages of consciousness---wakefulness, sleep NREM1, sleep NREM2, and sleep NREM3---within each CAP. The sleep database consists of 32 subjects that underwent EEG-MRI sleep sessions. Results: Among the six CAPs associated with the SC's activity in the HCP, CAP1 and CAP3 emerged as particularly interesting in regard to consciousness processes. CAP1 was found to correspond to sensory cortices, which reflect redundant networks, while CAP3 was linked with transmodal networks, which represent more synergistic traits of information processing in the brain. More specifically, by observing the distribution of subjects across sleep stages within each CAP, we were able to identify a significant decrease in the relative frequency for CAP3. Conclusion: In conclusion, the SC demonstrates associations with well-documented brain networks in the literature; notably, the transmodal networks (CAP3), which are closely linked to states of consciousness. In fact, CAP3 shows a decrease in occurrences compared to other CAPs as subjects enter a sleep stage (mainly NREM1), indicating a more substantial functional de-integration in comparison to other CAPs. This aligns with the understanding that NREM stages induce a reduction in subcortical-cortical connectivity, emphasising the significance of the latter observation in the modulation of consciousness-related processes.

Cortical correlates of global consciousness

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Concurrent Session: State of Consciousness 1, Wednesday July 3rd, Fukutake Learning Theater, 2:00PM-4:00PM

Consciousness encompasses subjective experiences and awareness of the mind and external world. Many philosophers and neuroscientists posit consciousness as a biological problem intricately linked to brain processes. Investigating the neurobiological correlates of conscious states (NCC) presents a fundamental challenge in understanding consciousness, requiring an exploration of brain structures, neural network connectivity, and local dynamics. Notably, many theories of consciousness underscore the distributed nature of consciousness across interconnected brain regions, while other theories also emphasize the importance of local neuronal dynamics in conscious awareness. Global consciousness potentially emerges from the interactions among various NCCs attributable to different brain functions in concert with arousal systems. Leveraging computational brain models integrating cerebrocortical networks offers a promising avenue to elucidate the dynamics of consciousness. In addition, stability in brain dynamics and their association with different global consciousness levels presents opportunities to unravel the mechanisms of consciousness. Here we employed a whole-cortex model incorporating inter-connected neural mass models (NMMs) with regional neurophysiological variables and effective connectivity variables (i.e., defining connectivity strength between two NMMs). We estimated these model variables in a space-time resolved manner from experimental magnetoencephalography data obtained during xenon-induced consciousness reduction in 15 human subjects. Analyzing the correlation between each type of model parameter and recorded responsiveness levels elucidates the specific association of different potential NCCs (e.g. local neurophysiological variables, effective connections or brain sub-networks) with global consciousness reduction. Furthermore, dynamic stability of the model was assessed based on the estimated parameters, offering insights into the nature of consciousness by considering potential NCCs collectively. Subsequent sensitivity analyses were conducted to pinpoint critical potential NCCs influencing model stability. Our group-level findings indicate: (1) Correlation analyses with responsiveness levels and effective connectivity (centrality) highlight the significance of specific brain regions, such as the right middle occipital ($p=0.006$) and right inferior occipital ($p=0.025$) lobes, as well as the left superior parietal ($p=0.039$) and left angular ($p=0.043$) gyri; (2) Correlation analyses with responsiveness levels and connectivity strength within and between functional networks indicates that changes in responsiveness levels primarily relate to alterations within the default mode network ($p=0.015$), ventral default mode network ($p=0.001$), and visual network ($p<0.001$), as well as external connections between these networks and others ($p<0.01$); (3) Correlation analyses with responsiveness levels and regional neurophysiological variables suggests higher responsiveness levels are linked to reduced regional excitatory synaptic connection strength and diminished afferent input from neighbouring and distant regions in posterior cortical areas ($p<0.01$); (4) Examination of the model's dynamic stability in relation to responsiveness levels demonstrates stabilization of cerebrocortical dynamics during xenon induction, followed by restoration thereafter; (5) Sensitivity analyses indicate that the excitatory synaptic connection strength in the posterior parietal and prefrontal regions serves as the primary neurobiological correlate of global consciousness. Taken together these results provide a novel understanding of the cortical correlates of global consciousness within the context of Xenon anaesthesia. They support existing knowledge of the role of frontoparietal cortex but also add deeper neurophysiological and dynamical systems insights, setting the stage for further multi-scale inference methods to unravel the NCC.

Unveiling the Role of Thalamic Core-Matrix Functional Architecture in Loss of Consciousness

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Concurrent Session: State of Consciousness 1, Wednesday July 3rd, Fukutake Learning Theater, 2:00PM-4:00PM

Introduction. Human neuroimaging data and biophysical modeling simulations suggest that loss of consciousness during general anesthesia is attributed to a targeted suppression of nonspecific, higher order thalamocortical connectivity. However, previous research predominantly examined the thalamus as a whole or concentrated on specific subregions, neglecting the identity of distinct neuronal subpopulations. The thalamus, characterized by a heterogeneous cytoarchitecture, comprises at least two discernible cell classes known as core and matrix cells, each sending distinct projections to the cortex. Given the widespread distribution of core and matrix cells throughout the thalamus from lower-order and higher-order nuclei, a comprehensive exploration of the spatial distribution of thalamocortical connectivity with a specific emphasis on the core-matrix architecture is justified. We hypothesized that loss of consciousness due to anesthesia would be associated with a disruption of core–matrix functional architecture of thalamocortical connectivity.

Methods. We performed functional magnetic resonance imaging (fMRI) investigation in twenty-seven healthy volunteers under conscious baseline, deep sedation, and the subsequent recovery phase. Deep sedation was achieved through a gradual increase of the effect site concentration of the anesthetic propofol until behavioral responsiveness was lost. We advanced the functional gradient mapping method to map the functional geometry of thalamocortical circuits by aligning it with the unimodal-transmodal functional axis of the cortex. First, we utilized cortical gradient mapping to transform the functional brain connectome into a non-linear diffusion space. Second, we examined the thalamic correlates of the unimodal-transmodal cortical gradient. We computed pair-wise correlations between the thalamocortical connectivity values of each thalamic voxel and the cortical gradient values, ultimately generating a topographical map of thalamocortical correlation coefficients. This map highlighted the correlations with the principal cortical gradient and was referred to as the gradient correlation coefficient (GCC). To determine the relative contributions of core and matrix cells in explaining the variations in GCC between conscious and unconscious states, we conducted a multiple regression analysis within a general linear model framework. In this analysis, we integrated the spatial densities of two calcium-binding proteins, Calbindin (abundant in matrix cells) and Parvalbumin (prevalent in core cells), provided by the Allen Human Brain Atlas, as covariates while considering the GCC difference between conscious and unconscious states as the dependent variable.

Results. We found that unconsciousness was associated with specific alterations in a functional hierarchy within thalamocortical circuits. Namely, there was a shift from a balanced unimodal-transmodal geometry during consciousness to a dominantly unimodal geometry during unconsciousness. This shift in functional geometry was depended on the spatial distribution of matrix cells within the thalamus. Specifically, thalamic regions with a high density of matrix cells exhibited a pronounced reduction in transmodal thalamocortical functional connectivity during unconsciousness.

Conclusions. Propofol-induced loss of consciousness is accompanied by a shift from balanced core–matrix functional geometry to unimodal core dominance. By synthesizing cellular-level data with systems-level findings, our research illuminates the pivotal role of thalamic matrix cells in understanding the neural mechanisms of states of consciousness.

Tracing the Footprints of Prior Events on Simultaneity Perception

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Concurrent Session: Time and Temporal Perception, Wednesday July 3rd, Ito Hall, Ito International Research Center, 2:00PM-4:00PM

The temporal resolution for distinguishing two events in time is observed to fall within the range of 30 to 50 msec. Asynchronous events within this short temporal window are often perceived as simultaneous, prompting inquiry into this phenomenon and the mechanism for integrating events into a single perception of simultaneity. Simultaneity Judgment (SJ) and Temporal Order Judgment (TOJ) paradigms are typical avenues to explore our perception of simultaneity. The prior studies concentrated on modifying stimulus attributes and attention (cueing) to influence the SJ threshold. Previous work suggests that temporal perception is quantized, and perhaps, these perceptual quanta or moments occur sequentially without overlap. Events do not occur in vacuum and how temporal resolution is influenced by prior events is not well understood. The current study aims to bridge this gap by investigating the temporal resolution of simultaneity perception and its potential dependence on a preceding event. We designed a three-event paradigm where the SJ task is preceded by an unrelated "Anchor" event. We aimed to look at temporal resolution (threshold) as a function of the anchor's temporal relation with the SJ task. Experiment 1 (N=25) comprised two phases: in Phase One, participants completed an SJ task involving squares (T1, T2) presented for 80 msec each, at an asynchronous SOA of 10 to 80 msec in steps of 10 msec. In Phase Two, a third square (Anchor also presented for 80ms) on top of fixation was introduced and followed by T1, T2 (SJ task similar to Phase 1). In addition to SOA between T1 and T2, we also manipulated SOA (from 10ms to 80ms) between Anchor and T1. The threshold for SJ task was detected from psychometric fits for individual SOAs (Anchor-T1). Initial analysis suggested a decrease in threshold with a maximum decrease at 60-80ms SOA (Anchor-T1). To quantify the finding we fit a quadratic function to the difference between Threshold with and without the anchor as a function of Anchor-T1 SOA (lower value indicating a decrease in threshold) and calculated threshold difference and SOA for minima. In experiment 1, participants could have performed the task based on information about offset temporal alignment. Hence, we conducted a second experiment with T1-T2 offset matched. The remaining procedure analysis was the same as experiment 1. Results suggest that threshold decrease is similar in magnitude for both experiments with the largest effect at 50-80ms SOA (Anchor and T1). Results demonstrate that the SJ threshold can be significantly altered through the influence of a preceding event just ahead of the experienced moment of simultaneity. The results suggest that the temporal width of this brief timescale can be flexible. While models such as attention-switching, the General Threshold, and the Perceptual Moment Theory focus on explaining perceived simultaneity based on sensory signal timing and decision criteria, they neglect to consider the impact of prior events on subsequent perceptions of simultaneity. Models of SJ need to consider how events can interact with each other in influencing temporal resolution.

Temporal resolution of vision varies across the visual field

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Concurrent Session: Time and Temporal Perception, Wednesday July 3rd, Ito Hall, Ito International Research Center, 2:00PM-4:00PM

Visual perception is not uniform across the visual field. Psychophysical tasks revealed that the spatial acuity of vision decreases with stimulus eccentricity. Additionally, the spatial acuity is superior along the horizontal meridian than the vertical meridian, but also superior in the lower hemifield compared with the upper hemifield. Whether such asymmetric patterns, coined performance fields, extend to the temporal acuity of vision remains unknown. In other terms, does our perception of time vary across the visual field? While traditional psychophysical experiments have evaluated temporal awareness in minimalist environment, this study aims to assess how natural scenery affects the temporal resolution of vision. Forty participants engaged in a simultaneity judgment task within immersive virtual reality to estimate the temporal acuity of vision. In this task, participants judged on the presence or absence of a 22 ms delay between the onset of two stimuli located at different eccentricities (2.5, 11.5, 24, and 40 degrees of visual angle from the central fixation point), across all visual hemifields (i.e., top, bottom, left, and right visual fields) and both within a minimalist and a natural visual scenery. Applying signal detection theory to the temporal judgements enabled to differentiate the perceptual sensitivity to time from the response bias. Spatiotopic maps of temporal acuity were derived from these location-specific temporal judgements. The results indicate that perceptual sensitivity, but not response bias, was reduced in the natural scenery compared with the minimal scenery. This suggests that traditional approaches assessing temporal awareness may overestimate time perception skills in ecological settings. Furthermore, the perceptual sensitivity to time reduced as the eccentricity of the stimuli increased, but remained unaffected by polar angle. Therefore, while spatial and temporal acuity of vision may share neurobiological mechanisms, they do not fully overlap. These findings contribute to refining discrete models of perception by highlighting that the segmentation of the inflow of visual information may occur at different frequency across regions of the visual field.

Event-Based Warping: An Illusory Distortion of Time Within Events

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Concurrent Session: Time and Temporal Perception, Wednesday July 3rd, Ito Hall, Ito International Research Center, 2:00PM-4:00PM

Sensory input is a continuous wash of light, sound, and other stimulation. Yet, our conscious experience of the world is not a blooming, buzzing confusion (James, 1890). Instead, it is structured into discrete 'units': objects segmented in space, and events segmented in time. An intriguing finding about object representation is that objecthood warps perceived distance, such that two dots within an object appear farther apart than two dots in empty space—an illusion known as "Object-based Warping" (Vickery & Chun, 2010). This illusion suggests a reciprocal relationship between object segmentation and perception—the visual system segments continuous space into discrete objects, which in turn distort perceived space. How general is this relationship? To investigate this question, we ask whether this object-based effect has an event-based counterpart. Just as two dots in an object are perceived as farther apart in space, are two probes (e.g., tones or flashes) within an event perceived as further apart in time? Here, four pre-registered experiments demonstrate Event-based Warping. In Experiment 1, subjects judged the duration between two tones. In Event trials, tones were presented during an auditory event (a brief period of ambient noise in an otherwise-silent soundscape). In Non-Event trials, tones were played in silence (i.e., not during any auditory event). Subjects judged tones within an event to be further apart in time than tones not within an event, suggesting that event representations warp perceived duration just as object representations warp perceived space. Experiment 2 ruled out effects of noise (which may have interfered with hearing the tones and monitoring their duration), by 'inverting' the design of Experiment 1. Subjects were immersed in ambient noise throughout the experiment. In Event trials, the ambient noise briefly cut out, creating events constituted by silence; in Non-Event trials, subjects experienced tone pairs while the ambient noise continued playing. Subjects judged tone pairs in silent Event trials to be further apart than tone pairs in sound-filled Non-Event trials, thus ruling out the confounding effects of noise. Experiment 3 ruled out another confound: that the temporal distortion arises from cueing or distraction caused by the sudden changes in sound at event onsets. Event trials were identical to Experiment 1; but in Non-Event trials, a short burst of sound played before the tones. Again, subjects judged tones in Event trials to be further apart than tones in Non-Event trials, even when both trial-types began with a change—showing that event-based warping is not simply due to cueing or distraction. Experiment 4 asked whether these warping effects extend beyond audition. Instead of tone pairs, subjects judged the duration between visual flashes occurring either within or not within an auditory event. Flashes in Event trials were judged as further apart in time than flashes in Non-Event trials, showing that event-based warping occurs cross-modally. Object-based warping and event-based warping are thus instances of a more general reciprocal relationship between segmentation and perception: We segment continuous space and time into discrete, structured elements, which in turn change how space and time are consciously perceived.

Cortical representations of number and time are distinct yet overlapping

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Concurrent Session: Time and Temporal Perception, Wednesday July 3rd, Ito Hall, Ito International Research Center, 2:00PM-4:00PM

Our conscious visual experience of a number of objects (numerosity) and the duration of an event (timing) are sufficiently distinct: for instance, the number of apples in a tree can be appreciated separately from how long each apple takes to fall to the ground when the tree is shaken. And yet judgements of number and time show remarkably similar patterns of discriminability, and the duration of high-numerosity displays are perceived as longer than that of low-numerosity displays. Such behavioural interactions are claimed to result from a generalised magnitude system with shared neural responses across different quantities. To interrogate this claim, we used ultra-high resolution (7 Tesla) fMRI and forward encoding model-based analyses to map neural populations selectively tuned to number and time. We find multiple, bilateral brain areas are organized as topographic maps where response preferences to numerosity and event timing change gradually across the cortical surface. While the earliest quantity maps in the visual processing hierarchy do not overlap, more superior maps overlap increasingly. In these overlapping areas, some intraparietal maps have consistently correlated numerosity and timing preferences, and some maps have consistent angles between the topographic progressions of numerosity and timing preferences. However, neither of these relationships increases hierarchically like the amount of overlap does. Overall, our results show numerosity and timing are initially derived separately, then progressively brought together through hierarchical transformations, without generally becoming a common representation. Bringing together distinct responses to different quantities accounts for behavioural interactions between numerosity and timing without the need to invoke a generalised magnitude system. Linking changes in the experience of number and time to changes in their neural organisation (overlap, response preference, and topography) across the visual processing hierarchy can inform models of conscious perception.

Anticipatory context alters perceptual windows of integration

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Concurrent Session: Time and Temporal Perception, Wednesday July 3rd, Ito Hall, Ito International Research Center, 2:00PM-4:00PM

Perceptual organization in real-time can be understood using the notion of temporal windows of processing. Integration of information within temporal windows allows us to understand time-extended phenomena like motion, succession, melody, etc. Is integration isolated to content falling within a fixed temporal window, or is the size of the temporal window dynamically altered by the ongoing temporal context? We think that the temporal window size dynamically depends on prior context. To study this, we developed a novel paradigm of temporal integration where two halves of a Kanizsa square figure are integrated (seen as a full square) or segregated (not seen as a full square) as a function of the temporal gap between them. The inter-stimulus interval (ISI) between the two halves (T1 & T2 frames) was varied across 30, 100, 300, and 800ms. The two halves were preceded and succeeded by rotating discs of the same Kanizsa square either in a temporally a) correlated (predictable) or b) random fashion. That is, in any trial, the discs kept rotating in either fashion as they culminated into and out of the orientation in T1 and T2, before and after their presentation, respectively. We controlled for mean rotation-angle increments in both conditions by randomly sampling them from a truncated normal distribution with an absolute mean of 20° and a standard deviation of 5°. Additionally, there were two different trial types: 1) T-T, where both T1 & T2 were present, or 2) T-X, where either T1 or T2 was present, and the other frame was replaced with discs rotated by 180° (corners flipped outwards). This was done to ensure that half the trials had no explicit geometry for a square to form. We asked participants (N=14) to report whether they perceived a full square or not within the sequence. Across 192 trials, we calculated the proportion of trials participants saw a square across the four ISI, two temporal context (correlated, random) conditions, and the two trial types (T-T & T-X). We also performed SDT analysis to calculate each participant's d-prime and criterion scores across ISI & Condition. We performed linear mixed effects analyses on the proportion of trials square was seen (in the T-T trials) with ISI & Condition as fixed effects and Participant as a random effect. We found a significant main effect of both ISI and Condition, along with an ISI by Condition interaction. Results showed that the proportion decreased as ISI increased in both conditions, as expected. More importantly, the proportions were higher for the correlated condition at short ISIs and took longer ISIs to reduce and become closer to the random condition. These effects were also present when the analysis was performed on d-prime scores. The results indicate that the width of the temporal integration window increases when the context allows prediction of upcoming stimuli. Our study shows that the nature of temporal context flexibly alters the extent of temporal integration windows.

Stepwise evolution of subjectivity

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Concurrent Session: Evolutionary Perspectives, Wednesday July 3rd, Ito Hall, Ito International Research Center, 2:00PM-4:00PM

In recent studies on the evolutionary origin of consciousness, both Feinberg & Mallatt (2016) and Ginsburg & Jablonka (2019) suggest that minimal consciousness is defined as having subjective experience in any form and it is limited to animals with the central nervous system developed to a substantial extent, specifically, vertebrates, arthropods, and cephalopods. Godfrey-Smith (2016, 2020) also admits such experience in these animals, although he does not use the term "consciousness" but prefers "sentience". Nevertheless, some authors are now actively promoting biopsychism, where all living organisms are regarded to have subjective experience (Edwards 2006, Fitch 2008, Reber 2019). Certainly, living things show unique characteristics that are not found in non-living things, for example, goal-oriented behavior and stimulus responsiveness. In regards to this point, Godfrey-Smith (2020) distinguishes between cognition and sentience, admitting only the former to bacteria. In this presentation, I attempt to reinforce this argument through the analysis of subjectivity by combining perspectives of animal consciousness research and biosemiotics. First, two types of subjectivity are defined: subjectivity as the agency and as the conscious experience. These two correspond to protosemiosis and eusemiosis proposed by Sharov (2018). In protosemiosis, a sign/signal triggers an action of a biological agent and no mental object is involved. That is, there is no subject-object relationship in consciousness here. In eusemiosis, on the other hand, signs are associated with objects through interpretation by a conscious subject. According to this scheme, the key to demystifying the origin of consciousness is the transition from the protosemiosis (or the subject as the agency) to the eusemiosis (or the subject as the conscious experience). Sharov & Vehkavaara (2015) argue that the chief differences between protosemiosis and eusemiosis are the categorization of signs and the redundancy of signaling networks. Consistent with this, Ginsburg & Jablonka (2019) suggest that what they call categorizing sensory states underlies the subjective experience and that functional architecture for unlimited associate learning (UAL, the evolutionary-transition marker for consciousness in their theory) is much more redundant than non-conscious limited associate learning (LAL). Integrating these theories, the origin of goal-directed mental representations can be explained as follows. At first, animals with solely reflective nervous systems show protosemiosis. As the next step, animals with LAL appear. In these animals, information about signs/signals is transmitted to the central nervous system to form a neural representation, which triggers a target/goal-directed behavior (note that the target and goal are not differentiated yet). Finally, animals with UAL acquire the conscious subject and mental objects (the targets of their behavior): the latter are now segregated from the mental goals, that is, value-laden predicted states as results of their behavior. This evolutionary scenario should substantially contribute to overcoming the "emargentist's dilemma" (Reber 2019) involved in the saltatory appearance of consciousness in gradual evolution.

Understanding the Ecological Relevance of Human Tetrachromacy

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Concurrent Session: Evolutionary Perspectives, Wednesday July 3rd, Ito Hall, Ito International Research Center, 2:00PM-4:00PM

What can be said about the perceptual experiences of a human tetrachromat? Recent genetic analyses have estimated that over 50% of females have the genetics for expressing four functionally distinct opsins required for tetrachromacy [1]. Psychophysical tests have identified a human capable of passing a screening for tetrachromacy [2], though finding more tetrachromats has proven considerably challenging. These findings raise a puzzle: given that human tetrachromacy at a genetic level is common, why have so few human tetrachromats been identified? To address this question, we develop a comparative account of human tetrachromatic color experience with avian tetrachromatic color vision. It is known that hummingbirds exhibit tetrachromatic color vision, demonstrated by their ability to discriminate non-spectral colors; these are non-contiguous combinations of the spectrum such as UV light and green light [3]. We analyze the ecological relevance for avian and human tetrachromatic color vision through the lens of efficient coding theory, which predicts that neural coding is adapted to the statistics of the ecological environment [4]. Prior work along this direction in the human case reported [5] three principal axes: achromatic, red-green opponency, and blue-yellow opponency, each decreasing by an order of magnitude. This finding is striking, because these axes match the receptive field structure of midget retinal ganglion cells. We extend their analysis by computing PCA on the normalized human and avian cone responses from natural image spectra [6] and hummingbird plumage spectra [7], respectively. We find that the principal component (PC) scores of the human fourth axis are over 10^2 times less important than the 3rd, suggesting that the fourth dimension for color is not ecologically significant. This implies that not many surfaces are distinguished solely along a third color opponency axis. In contrast, analysis of the hummingbird variance shows only a ~2.4 times factor between the third and fourth PC scores. This makes sense ecologically, since ancestral cones such as the UV cone have existed for at least 500 million years, and changes in UV reflectance enable plants and animals to attract or camouflage [8]. Finally, we discuss how our analysis contributes to debates between ecological and inferential theories of perception, which are inseparable from metaphysical debates about perceptual experience [9]. Ecological theories (e.g., sensorimotor approaches) treat perception as an active exploration directly relating perceivers to environments; inferential theories treat perception as computation over internal mental representations. Our analysis is consistent with a sensorimotor study of color [10] relating spectral reflectance statistics to color categories. At the same time, the rarity of human tetrachromacy (even with the requisite opsin diversity) emphasizes the dependence of perceptual experience on internal neural processing. [1] Jordan & Mollon (2019), Curr. Opin. Behav. Sci.; [2] Jordan et al. (2010), JOV; [3] Stoddard et al (2020), PNAS; [4] Simoncelli & Olshausen (2001), Annu. Rev. Neurosci.; [5] Ruderman et al. (1998), J. Opt. Soc. Am.; [7] Arad et al (2022), CVPR; [6] Venable et al. (2022), Commun. Biol.; [8] Baden (2021), Current Biology; [9] Drayson (2021), OUP; [10] Philipona & O'Regan (2006), Vis. Neurosci.

Putting subjective reports in context: a large-scale Bayesian re-analysis of the relationship between PAS and task performance

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Concurrent Session: Unconscious Processing, Wednesday July 3rd, Gallery 1, Ito International Research Center, 2:00PM-4:00PM

The Perceptual Awareness Scale (PAS) is an extensively used subjective measure in consciousness research, and is argued to measure the clarity of perceptual experience (from 'No Experience' to 'A clear experience'). Recent debates focused on whether PAS validly measures awareness, invoking two questions in relation to objective task performance (e.g., discriminating a feature of a briefly presented stimulus): the degree to which task accuracy increased with PAS ratings, and whether accuracy was at chance in trials where participants indicated 'No Experience'. While linking such analyses to facets of validity is itself debatable, a more fundamental question remains: to what extent are these patterns generalizable? Here, we present the first large-scale analysis of the relationship between PAS and task performance, drawing upon datasets where both measures were collected trial-by-trial. We collated over 320.000 trials spanning different experimental designs and stimuli, including 2 novel datasets in addition to 13 published studies. We targeted with Bayesian analyses the same two questions described above. In all studies, we found Bayesian evidence that accuracy increased with PAS ratings, although there was substantial heterogeneity across samples and between participants in the strength of this pattern. However, most experiments (80%) failed to meet the chance accuracy criterion, the evidence being either inconclusive (33%) or favouring the hypothesis that accuracy was higher than chance (47%). Additional analyses found that stimulus and mask duration explained <5% variance in accuracy in 'No Experience' trials, and that participants gave frequent ratings indicating some stimulus awareness even when no stimuli were presented. The findings highlight that there is very high variability across studies in the relationship between PAS and task performance. Consequently, it is difficult to interpret the two statistical patterns mentioned above through the lens of 'PAS validity', since conclusions about their presence and strength do not generalize well. More broadly, these results imply that it is challenging to use previous PAS findings from different tasks to predict PAS behaviour in new contexts.

Kelley's Paradox and strength skewness in research on unconscious mental processes

Daryl Y. H. Lee (University College London), Christopher J. Berry (University of Plymouth), David R. Shanks (University College London)

Concurrent Session: Unconscious Processing, Wednesday July 3rd, Gallery 1, Ito International Research Center, 2:00PM-4:00PM

In a widely-used analytical approach in unconscious process research, contrasts are made between behavioral or neural responses to stimuli that participants have been exposed to with those to stimuli they have not encountered, for which participants report equivalent lack of awareness. We argue that this method does not permit valid inferences about unconscious processing due to two primary factors. Firstly, we introduce Kelley's Paradox, a statistical artifact resulting from regression to the mean in the context of measurement error, which compromises the assumed equivalence of true memory strengths between contrasted stimuli. Secondly, we analyze the role of unequal skewness in the strength distributions of target and non-target items within the framework of Signal Detection Theory, which further undermines the validity of conclusions drawn from such contrasts. Through computational simulations, formal analysis, and a narrative literature review, we illustrate the fallacious reasoning underpinning this approach and document its prevalence in the literature. Additionally, we report findings from a recognition memory experiment designed to test a specific prediction derived from our critique and which confirm the susceptibility of this analytical method to artefacts attributable to Kelley's Paradox and strength skewness. Our work challenges the methodological soundness of a popular analytic approach in unconscious process research, urging a critical re-evaluation and advocating for methodological advancements. The implications of our findings are broad, offering critical insights for future research on unconscious processes and contributing to the refinement of analytical practices in the field.
Keywords: unconscious processing, Kelley's Paradox, Signal Detection Theory, measurement error, cognitive psychology.

Searching for the Best Calibration Method: Estimating Subliminal Thresholds in Unconscious Processing

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Concurrent Session: Unconscious Processing, Wednesday July 3rd, Gallery 1, Ito International Research Center, 2:00PM-4:00PM

A major challenge in the study of unconscious processing is to effectively suppress the critical stimulus while ensuring it evokes a strong enough signal to be unconsciously processed. To meet this challenge, many studies use a calibration procedure to find the unique perceptual threshold per participant. This allows researchers to present the stimuli at the maximal intensity for which participants are still unable to consciously perceive the stimulus (commonly operationally defined as showing chance level performance in a direct task about the stimulus). Despite the widespread use of such calibration procedures, their efficiency for targeting the perceptual threshold (where true performance is at chance level), has been questioned due to responses being noisier around chance. The adaptive staircase method, for example, uses previous responses within an adaptive track to select the intensity of the next stimulus. If these responses are less informative (being more based on guesses, for example), the intensity might not be accurately set. Furthermore, chance level performance characterizes not only the perceptual threshold but also all the intensities that fall below it, making it difficult to differentiate between them and target the optimal intensity. Notably, this method, like many other threshold estimation procedures, was developed for finding the midpoint of the psychometric function, which parallels ~75% performance (in a 2 alternative forced choice task), while in unconscious processing studies, the aim is to obtain 50% performance. Thus, these methods might not be optimal in finding the desired threshold. Here, we used simulations to evaluate the effectiveness and accuracy of existing threshold estimation methods at finding subliminal thresholds. We further propose a new calibration method tailored for this purpose. To simulate the data, we used a sample of 40 healthy volunteers who took a metacontrast masking paradigm, where the prime was either a left or right arrow, followed by a larger bidirectional arrow. At the end of each trial, participants were asked to rate prime's visibility and discriminate its orientation. To capture the entire spectrum of prime awareness levels, the interstimulus interval (ISI) was varied across nine different durations. Finally, we fitted psychometric functions to each participant's results. These functions were then used to create stimulated datasets on which the different threshold estimation methods were run. Our findings suggest that these methods show surprisingly low efficiency in finding the desired threshold. In contrast, our proposed approach – which involves new criteria for setting the threshold - showed higher accuracy and reliability in estimating subliminal thresholds across varied psychometric functions. This promises to improve calibration procedures in studies of unconscious processing, hopefully maximizing the chances of finding an effect while minimizing contamination by conscious processes. This can also minimize the threat of regression to the mean in studies that use post-hoc selection of trials and/or participants.

Is feedforward processing truly unconscious?

Nicolás Sánchez-Fuenzalida (Free University Amsterdam), Simon van Gaal (University of Amsterdam), Timo Stein (University of Amsterdam), Johannes Fahrenfort (Free University Amsterdam)

Concurrent Session: Unconscious Processing, Wednesday July 3rd, Gallery 1, Ito International Research Center, 2:00PM-4:00PM

One of the least contested findings in consciousness research is the idea that the first sweep of cortical processing occurs unconsciously. In one of the classic studies backing up this claim (Fahrenfort et al. 2007), observers were objectively at chance when detecting strongly masked stimuli. Yet, these stimuli still evoked a robust feedforward response in the brain as measured through EEG. However, several statistical and methodological pitfalls have been identified in past studies of unconscious processing, and this study is no exception. For example, one common pitfall is to evaluate the lack of awareness by inappropriately accepting the null hypothesis based on the p-value on a test being higher than a certain cutoff. Another problem is excluding participants who are not at chance based on the same data that is used to test hypotheses, potentially resulting in double dipping and regression to the mean.

Here we introduce a novel methodological-statistical framework that overcomes these and other problems. This framework combines preregistration, Bayesian statistics and model selection, and optional-stopping. Rather than accepting the null hypothesis at a population level, we run this study using a Bayesian framework at the single-subject level. For each subject, we obtained two sensitivity measures: (i) a behavioural measure that establishes the extent to which there is evidence for a behavioural detection effect and (ii) a neural measure that establishes the extent to which EEG decoding uncovers the presence of a feedforward sweep. To ensure each subject is objectively at chance, we devised a sequential testing procedure where the task difficulty increases across many sessions until there is strong evidence that participants perform at chance before starting EEG data collection. Preliminary data shows this procedure is highly effective at driving subjects' performance to chance while accounting for practice and learning effects.

When chance performance is achieved, both behavioural and neural sensitivity are jointly tested in a sequential testing procedure on a series of ordinal models where either behavioural sensitivity is at chance but neural sensitivity is above chance (unconscious processing), both measures are at chance (no-processing), or both measures are above chance (conscious processing). The procedure adjusts visibility and sessions are added until either the unconscious processing model obtains substantial evidence, or until it is established that the winning model consistently alternates between the no-processing and the conscious processing model without ever converging on the unconscious processing model.

With this novel framework we aim to answer the question "is feedforward processing truly unconscious?", and validate our framework for use in future studies of unconscious cognition.

Unconscious perception exists: Objective measures of conscious perception are contaminated by unconscious perception

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Concurrent Session: Unconscious Processing, Wednesday July 3rd, Gallery 1, Ito International Research Center, 2:00PM-4:00PM

To what extent can we process visual stimuli that we are unaware of? Researchers have long debated whether a subjective or an objective measure of conscious perception should be used to answer this question. On the one hand, the finding that observers can correctly discriminate above chance level stimuli that they report not seeing is taken to demonstrate unconscious perception. On the other hand, skeptics argue that the observers may have some conscious percept that they fail to report and advocate using forced-choice discrimination performance to measure conscious perception. What is debated, then, is whether subjective reports of unawareness are contaminated by conscious perception or whether objective (discrimination) measures of awareness are contaminated by unconscious perception. To address this question, we took advantage of a well-replicated finding from our lab whereby when participants make a speeded response to a target, subjectively seen and subjectively unseen primes affect behavior differently depending how fast participants respond to the target: seen stimuli affect responses regardless of response speed, whereas unseen stimuli affect only fast responses. This qualitative difference between conscious and unconscious priming undermines the possibility that in these experiments, stimuli reported as unseen were in fact consciously perceived but misreported. We reasoned that replicating this dissociation while also finding above-chance categorization of unseen primes would support the existence of unconscious perception. On target-categorization trials, participants categorized animal names (targets) as small or large; masked primes (also animal names) appeared before the targets and were either congruent or incongruent with the target category. On prime-discrimination trials, the target was replaced with a prompt instructing participants to categorize the prime instead of the target. Prime discrimination accuracy served as our objective measure of conscious perception. At the end of both trial types, participants rated the subjective visibility of the prime using a variant of the Perceptual Awareness Scale (PAS) from subjectively unseen (0-rating) to clearly seen (3-rating) trials. The main findings were that (1) unconscious and conscious response priming were again dissociated across the RT distribution and (2) prime-categorization accuracy was above chance on subjectively unaware trials. Together, these results provide evidence that unconscious perception exists and suggest that objective measures of conscious perception are contaminated by unconscious perception.

Using 2AFC tasks to measure awareness free of criterion bias.

Pietro Amerio (Université libre de Bruxelles), Axel Cleeremans (Université libre de Bruxelles)

Concurrent Session: Unconscious Processing, Wednesday July 3rd, Gallery 1, Ito International Research Center, 2:00PM-4:00PM

Experiments studying unconscious perception face the "criterion problem", that is, the challenge of ensuring that subjective visibility judgments are bias-free. When participants merely express visibility judgements (e.g., using the Perceptual Awareness Scale), their reports are always biased by how liberal or conservative their decisions are. Recently, 2-Interval Forced-Choice (2IFC) tasks were introduced as a way of obtaining bias-free subjective judgments. In 2IFC tasks, a stimulus (e.g., a Gabor patch) is presented in each of two successive intervals. Participants typically carry out a discrimination task (e.g., about the Gabor's orientation) on each stimulus and are then asked to judge in which interval the stimulus was most visible. Unbeknownst to them, only one interval actually contains a stimulus. Unconscious perception is demonstrated when participants can correctly perform the discrimination task while remaining unable to indicate which interval contained the stimulus.

2IFC tasks assume equal sensitivity in the two intervals. However, this assumption is often violated. The worry is that participants might perceive the stimuli in the two intervals equally well but might not be equally able to report them. Indeed, one interval might be easier to hold in working memory or it might be strategic to focus more on one interval than the other. If this was the case, we would underestimate awareness.

Here, we propose a solution to this problem. It consists of using a 1-interval 2-Alternative Forced-Choice (2AFC) task instead of the 2IFC task. In this design, the two stimuli are presented simultaneously, but at different locations in the visual field (to the left or to the right of a central fixation spot). The underlying logic remains intact – when observers cannot tell on which side the stimulus was presented, we conclude they were unconscious of it.

We applied this rationale to a gaze-contingent task to test whether healthy human participants can correctly discriminate the direction of Vernier offsets while remaining unconscious of said offsets. On every trial, two Vernier stimuli were shown - one on either side of a fixation spot. Participants were instructed that their offsets would be congruently oriented, but in fact only one stimulus had an offset. The other was a neutral non-discriminable Vernier. This allowed us to assess participants' awareness of the offset, that is the precise feature they are asked to discriminate.

Using this improved design, we report evidence in favor of perception in the absence of awareness. We support our conclusions with Bayesian data analyses calibrated to detect small effects, as well as Bayesian ideal observer models.

Additionally, we ran a control study to check the assumption of equal sensitivity in the left and right visual hemifields. Strikingly, we found a clear detection advantage for stimuli presented on the left side. We believe this depends on a bias of spatial attention, possibly caused by reading habits. As such, this sensitivity imbalance is less problematic that it was for 2IFC tasks. Since access awareness requires attention, this effect likely reflects a difference in stimulus visibility – exactly what our design aims to measure.

A simple Bayesian formula to correct regression to the mean in research on unconscious mental processes

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Concurrent Session: Unconscious Processing, Wednesday July 3rd, Gallery 1, Ito International Research Center, 2:00PM-4:00PM

To investigate the scope of unconscious mental processes, researchers frequently collect a behavioral measure (e.g., some assessment of learning) and a measure of awareness (e.g., recognition judgments) of the critical cue or contingency. Evidence that behavioral change was indeed unconscious may require that participants were unaware of the critical regularity. A standard research method to constitute unawareness involves selecting participants with awareness scores below a cut-off and analyzing behavioral data from these "unaware" participants. In recent years, however, researchers have become aware that ignored measurement error in post-hoc subject selection can systematically bias any test results performed on the subsample—a statistical bias referred to as regression to the mean. Because measurement error is defined as the amount of uncertainty about an individual's true score, additional information about the individual (e.g., their group membership) and the measure (e.g., its precision) can help to obtain a better true-score estimate. We achieve this by means of a simple correction formula for observed data, which provides a true-score estimate as a weighted combination of the individual's observed score and a selected group mean. Applying our correction formula corresponds to running a Bayesian hierarchical model, but can be done in seconds on a standard data spreadsheet. In a series of simulations, we show that our correction formula provides a method to correct regression to the mean: The corrected data offer a more representative subsample to test research hypotheses and consequently better inferences in research on unconscious mental processes.

Unlocking the mind: comparing virtual reality hypnosis to hypnosis in eliciting dissociation – A non-inferiority investigation in healthy volunteers

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Concurrent Session: Hallucination and Altered States, Wednesday July 3rd, Seminar Room, Ito International Research Center, 2:00PM-4:00PM

Background and aim: From its very beginnings, hypnosis has always been closely linked to dissociation. Dissociation can be defined as the “split off” of mental processes and bodily awareness and perceptions. Recently, an innovative technique has emerged: the combination of hypnosis and virtual reality (VRH). A pioneer study highlighted that VRH decreases pain perception in healthy volunteers. Furthermore, reduced pain perceptions were correlated to increased dissociation (1). The majority of the research on VRH aims at assessing its effectiveness in various clinical conditions while its processes remain understudied. Following these findings, the present study aims at assessing whether VRH induces at least as much dissociation as hypnosis. We hypothesized that VRH induced at least as much dissociation as hypnosis alone.

Methods: Sixty-six healthy participants (41±14yo; 38 women) received two conditions in a randomized order: VRH (Aqua©, Sedakit Oncomfort, www.hypnovr.io, following a whale in an underwater world) and hypnosis (prerecorded hypnosis that is heard in the VRH set, safe place and fixation of a black cross in the VR headset). After each condition, dissociation state, absorption (i.e., in the experience) state, and automaticity (i.e., altered state of agency) were assessed using a numerical rating scale (NRS, 0–10). An open-ended question examined time perception. Anxiety was also noted before and after each session using a NRS (0–10). To compare whether variables were at least as much scored between the conditions (VRH vs. hypnosis) and due to the abnormal distribution of the variables, Wilcoxon univariate tests were performed using a non-inferiority margin set at -1 based on previous effect sizes calculation. This test allowed to examine whether the median difference was greater than the pre-specified non-inferiority margin of -1. Significant results indicate that participants scored at least as much in both conditions.

Results: Compared to hypnosis alone, VRH induced at least as much dissociation (7 [3.25-8]; 6 [3.25-8], respectively) and absorption (8 [5-9]; 6 [4.25-8], respectively). Both before (VRH: 0 [0-1]; hypnosis: 0 [0-1]) and after the session (VRH: 0 [0-0]; hypnosis: 0 [0-0]), anxiety was similarly low in both conditions. Other variables did not reach significant results.

Conclusion: In line with our hypothesis, VRH induces at least as much dissociation as hypnosis in healthy volunteers. The findings of this pioneer study contribute to understand common mechanisms of action of hypnosis and VRH. This lays the foundation for future theoretical, fundamental, and clinical studies.

Reference: 1.Rousseaux F, Panda R, Toussaint C, Bicego A, Niimi M, Faymonville ME, Nyssen AS, Laureys S, Gosseries O, Vanhaudenhuyse A. Virtual reality hypnosis in the management of pain: Self-reported and neurophysiological measures in healthy subjects. Eur J Pain. 2023 Jan;27(1):148-162.

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Classical serotonergic psychedelics induce changes to functional and structural brain hierarchies

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Concurrent Session: Hallucination and Altered States, Wednesday July 3rd, Seminar Room, Ito International Research Center, 2:00PM-4:00PM

Psychedelic intervention has garnered substantial attention in recent years for its ability to induce profound reorganisation within the human brain, both in the acute and long-term phases of its effects (Barsuglia et al. (2018), Progress in Brain Research). Understanding these aspects is important not only for a comprehensive grasp of the underlying neurobiology but also for potential therapeutic applications (Anderson et al. (2020) Lancet Psychiatry). In the brain, psychedelic effects have been hypothesised to reflect a shift in the functional hierarchy of the brain, where unimodal regions, related to sensory cortices, become less constrained from the transmodal higher-level cognitive cortices, leading to novel perceptual experiences (Carhart-Harris and Friston. (2019) Pharma.Rev.). Furthermore, it has been hypothesised that at the acute stage of a psychedelic experience, there is a dynamic interplay between short-term and long-term timescales of brain activity (Ruffini et al. (2023) Entropy). Yet, what remains largely uncharted is how psychedelics exert the changes in hierarchy on these short-term (functional) and long-term (structural) timescales. In this work, using methods from non-equilibrium dynamics (Deco et al. (2020) Nat.Comm.Bio.) and whole-brain modelling (Deco and Kringelbach (2014) Neuron), we quantify the level of hierarchy at the functional (time-shifted functional connectivity) and structural (generative effective connectivity) scale. We focus our analysis on three classical serotonergic psychedelics, namely psilocybin (N=9, Carhart-Harris et al. (2012), PNAS), LSD (N=15, Carhart-Harris et al. (2016), PNAS)) and DMT (N=17, Timmermann et al. (2023), PNAS)), in the acute post-intervention stage in a resting-state fMRI condition. The preprocessed data were parcellated to the Schaefer1000 atlas (Schaefer et al. (2018) Cerebral Cortex). Corroborating previous literature, we show the level of hierarchy consistently decreases for all three psychedelic drugs. This is further reflected in resting-state network analysis where we observe consistent and discriminate changes for each psychedelic drug in terms of the unimodal and transmodal separation. This is further supported by the collapse of the uni to transmodal gradient across all three drugs. Moving on, we build whole-brain models based on non-linear oscillators coupled by structural connectivity, empirically derived from Human Connectome Project Connectomes of 985 participants, and we then infer the structural changes in terms of generative effective connectivity revealing a consistent landscape flattening under the influence of all three psychedelic drugs. In summary, our project bridges the existing knowledge gap in understanding the temporal dynamics of psychedelic effects on the brain. By investigating both short-term and long-term timescale influences, we provide a comprehensive picture of how these substances induce changes on brain structure and function. By extending the presented analysis on long-term effects of psychedelics and psychedelic therapy (in the context of depression for example), we hope to illuminate the mechanism pertaining to the window of plasticity and the related positive clinical outcomes.

Jhana Meditation Alters Bayesian Priors and Perception: An Empirical EEG Neuroimaging Study

Jonas Mago (McGill)

Concurrent Session: Hallucination and Altered States, Wednesday July 3rd, Seminar Room, Ito International Research Center, 2:00PM-4:00PM

Background: The predictive brain hypothesis suggests that perception is an interpretive process, where sensory stimuli are contextualized by a mental model employing Bayesian inference. Jhana meditation, characterized by its deconstructive and constructive phases, is posited to modulate these perceptual priors. Jhana meditation, originating from Buddhist traditions, involves deep states of absorption achieved through intense concentration, often resulting in profound joy, equanimity, and a diminished awareness of sensory input. During the deconstructive phase, Jhana is theorized to lessen the rigidity of high-level cortical priors, potentially altering perceptual processing. This study aimed to empirically investigate the neurophysiological underpinnings of this modulation through advanced meditative states. Methods: Ten expert Jhana practitioners were monitored using a mobile 32-channel semi-dry EEG system during a 10-day silent retreat. Complementary physiological measures, including ECG, skin conductance, and breathing rates, were concurrently recorded. The deconstructive phase was examined through Jhana and mindfulness of breathing meditations, employing an auditory hierarchical oddball paradigm. The study design also included comprehensive phenomenological interviews to capture the subjective experiential narrative of each practitioner. Results: Results indicate a pronounced mismatch negativity response during mindfulness meditation, whereas such a response was notably absent during Jhana meditation. This suggests a significant reduction in the influence of higher cortical priors during Jhana. We propose this effect is due to heightened precision allocated to the meditation object (e.g., breath, nimitta, or Jhana factors), leading to diminished engagement with other sensory data and their eventual fading from conscious experience. Conclusions: The data suggests Jhana meditation uniquely influences the brain's Bayesian inferential process by reducing the rigidity of perceptual priors. This reduction may underlie the profound subjective experiences reported during Jhana, such as the fading of sensory perception and subsequent psychological pliability during the reconstructive phase. Our neurophysiological and phenomenological data begin to illuminate the brain mechanisms and networks implicated in this transformative practice, providing a foundation for understanding how meditative states can be leveraged for psychological and spiritual well-being.

Hallucination Machine in the Wild: Simulating Altered States of Consciousness with the Real-Time Deep-Dream Algorithm in Augmented Reality

Keisuke Suzuki (Hokkaido University), Ayumi Nagai (Konel Inc., IAMAS)

Concurrent Session: Hallucination and Altered States, Wednesday July 3rd, Seminar Room, Ito International Research Center, 2:00PM-4:00PM

Capturing the essence of subjective experience, especially in the realm of altered states of consciousness, has long been challenging, requiring reliance on verbal description or artistic expression. This landscape has been revolutionised by machine learning, in particular, convolutional networks that mirror the brain's visual processing and now simulate our perceptual phenomenology with high fidelity. Leveraging this leap, we introduced the Hallucination Machine, an XR system that uses deep learning to simulate psychedelic experiences. We demonstrated the comparability of these synthetic experiences with real psychedelic experiences (Suzuki et al., 2017) and validated the effectiveness of the system in facilitating phenomenological research on altered states of consciousness (Suzuki et al., 2024). However, in the original setup, computational limits meant that our system only offered quasi-immersive experiences through the playback of pre-processed 360-degree videos. This approach resulted in a simulation that, while visually appealing, lacked the depth of real-time interaction with the environment. Here, we present a real-time iteration of the Hallucination Machine, characterised by its ability to process live video feeds directly from external cameras. This leap forward is facilitated by the use of multi-threaded processing within the openFrameworks environment, complemented by the power of an enhanced, high-performance GPU. Despite the need for a wired connection to a desktop computer to support the head-mounted display (HMD), this innovative system offers participants the freedom to traverse a space of up to 7 square metres. This capability significantly enhances the ecological validity of the experience by immersing users in a dynamically interactive environment that closely mirrors the fluidity and spontaneity of the real world. We evaluated our system with 11 volunteers in 15-minute sessions, using a 66-item questionnaire designed to gauge altered states of consciousness (OAV scale; Bodmer, 1989). The system's evaluation, conceived as both a technological innovation and an experiential art piece, incorporated additional elements aimed at intensifying the experience of altered states. One such innovation involved dynamically adjusting the intensity of the hallucinations based on the length of time a participant's head remained stationary, inspired by anecdotal evidence suggesting that fixed, prolonged gazes may induce more vivid hallucinatory experiences. Auditory stimulation using binaural beats was used in the hope of a synergistic effect to enhance the altered experience. Although the results of this pilot study, as measured by the OAV scale, were modest in comparison to genuine psychedelic experiences, the qualitative feedback from the open-ended responses of the participants revealed some fascinating insights. These narratives underscored the potential of our system to evoke deeply immersive and nuanced hallucinatory experiences that more closely mirror naturalistic conditions than ever before. This advance in simulating hallucinatory experiences with unprecedented realism heralds a new era in the field of computational neurophenomenology. What's more, we're prepared to give live demonstrations of the real-time hallucination machine at an upcoming conference. This opportunity will allow attendees to directly experience the forefront of experiential technology and explore human consciousness first hand.

The Widening Gyre: Challenging Existential and Ontological Psychedelic Experiences and their Neural Correlates

Pascal Michael (University of Greenwich), Eirini Ketzidzidou (University of Exeter), Julian Evans (Independent Researcher), Oliver Robinson (University of Greenwich)

Concurrent Session: Hallucination and Altered States, Wednesday July 3rd, Seminar Room, Ito International Research Center, 2:00PM-4:00PM

Psychedelics have been re-branded as 'psychoplastogens', inducing a more supple brain-state. This is a key source of transdiagnostic therapeutic potential (Kocarova et al, 2021), but also of challenging experiences. This is owing to structures normally supporting stable cognitive constructs being pathogenic if too rigid (Carhart-Harris & Friston, 2019), but also necessary for healthy psychological functioning. By heightening cortical entropy they can give way to a so-called pivotal mental states (Brouwer & Carhart-Harris, 2020), where their valence can turn on a razor's edge depending on intrinsic or extrinsic perturbations. Given that one's models about the world are probabilistically encoded in our belief priors supporting a sense of certainty, any dismantling of these – while engendering potentially salutary flexibility – can manifest as feelings of groundlessness, and eventually existential crises. If the content of the experience itself is especially novel, such as the mystical experience – which has hitherto been emphasised as a central driver of therapeutic change (Kangaslampi, 2023) – or exceptional human experiences, this can also have considerable ontological implications; especially challenging to integrate into newly-formed world-models. Psychedelics, as such, incur profound shifts in consciousness both acutely and persistently, which may entail shifts in metaphysical beliefs (Timmermann et al, 2021; including beliefs about consciousness). This presentation shall refer to findings from the Challenging Psychedelic Experiences Project, in which 26 participants were interviewed, and a thematic analysis was conducted. A host of major themes were identified, but here the acute experiences generated will be highlighted, mainly emphasising the existential themes of Experiences of Death, Experiences of Emptiness, and Experiences of Solipsism, as well as ontological themes aligned with expectational human experiences, such as Entity Encounters, Near-death Experiences and Glimpses into an Afterlife. Qualitative extracts will be employed demonstrating their subjective content, but a phenomeneurological approach (Michael et al, in review) will then tie these to putative neural correlates. This may include, but is not limited to, the unitive state as underpinned by a flattened cortical energy landscape (Singleton et al, 2022), which when felt negatively (as in emptiness) is linked to the loss of one's world model (one's only access to the world). An increased fear of death, neuropsychoanalytically, is accounted for by higher-order networks normally maintaining a repression of death anxiety being undermined (Dor-Ziderman et al, 2019). And obsessive questioning mirrors diagnoses of existential OCD, betraying disruption of inhibitive frontal networks – comparable to the expanded repertoire of conscious states giving way to apeirophobia, the fear of infinity (Azarian, 2016), which is commoner in children and related to their naturally hyper-plastic brains. Generally, persisting challenges likely pertain to neural annealing (Juliani et al, 2023) occurring during the acute experience, which when maladaptive and not successfully navigated, may dysfunctionally feedback into reforming synaptic networks. This paper serves to bring attention to risks inherent to psychedelic therapy, raises the ethics of giving metaphysical experiences, and proposes their neural concomitants. A separately submitted presentation will expound on the possible leveraging of these challenging experiences to, ultimately, bring about personal growth and therapeutic shifts.

Analysing the phenomenology of stroboscopic hallucinations using natural language topic modelling

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Concurrent Session: Hallucination and Altered States, Wednesday July 3rd, Seminar Room, Ito International Research Center, 2:00PM-4:00PM

We introduce a novel approach to the study of strobe-induced hallucinations (SIH) using Natural Language Processing (NLP) to analyse open reports of subjective experiences (n=3663). We applied topic modelling to data collected from participants of the Dreamachine - an immersive multisensory experience that uses strobe lighting and 360 degree spatial sound designed to induce visual hallucinations and altered states of consciousness (ASC) (https://dreamachine.world/) -. We identified three primary dimensions of hallucinatory experiences: simple visual hallucinations (VH), complex VH, and ASC. Through hierarchical clustering, we reveal that complex VHs and ASCs can be grouped under an overarching theme, which we refer to as “High-level” hallucinations and ASCs. This observation led us to hypothesise that high-level hallucinations might be driven by top-down processes (Powers et al.,2016; Sulfaro et al.,2022) such as expectations or mental imagery - more prone to prediction errors and interpretative influences - in contrast to simple VH (“Low-level” hallucinations), which are likely driven by purely visual or sensory excitability bottom-up processes (Rule et al.,2011). Furthermore, by comparing two topic modelling approaches, Latent Dirichlet Allocation (LDA) and Bidirectional Encoder Representation from Transformers (BERT) - a word embedding based approach-, we emphasise the significance of selecting an appropriate model to accurately delineate the underlying dimensions of experience. This comparison reveals the critical role of context in word meaning analysis; hence, the use of advanced algorithms such as transformers - which are sensitive to sequence structure - presents significant benefits for phenomenological research over conventional methods, such as LDA, which rely mainly on word frequency analysis. Our study also makes a methodological contribution by exemplifying the potential of NLP to bridge qualitative and quantitative research. Based on our NLP analysis, we developed a new questionnaire, named the Strobe-ASC questionnaire (Strobe-ASCq), by refining the Altered-State of Consciousness Rating Scale (5D-ASC) to better reflect the distinct characteristics of SIH as uncovered through topic modelling. By aligning closely to the 5D-ASC, the Strobe-ASCq is specifically designed to better capture the nuances of strobe-induced ASCs while enabling comparative analysis with ASCs induced by other techniques. This tailored approach in the Strobe-ASCq, grounded in both quantitative and qualitative analysis, holds the potential to enhance the precision of experiential assessments across various ASCs, while maintaining the ability to compare across states.

Thalamocortical interactions reflecting the intensity of flicker-induced visual hallucinations

Timo Torsten Schmidt (Freie Universität Berlin), Ioanna Alicia Amaya (Freie Universität Berlin), Till Nierhaus (Freie Universität Berlin)

Concurrent Session: Hallucination and Altered States, Wednesday July 3rd, Seminar Room, Ito International Research Center, 2:00PM-4:00PM

Visual hallucinations occur in diverse pathologies and altered states of consciousness; however, they are difficult to investigate due to unpredictable onsets and coexistence with other physiological changes. Flickering light stimulation to the closed eyes induces visual hallucinations in healthy participants, constituting a well-controlled experimental setup to investigate underlying neural mechanisms. Previous work found that 10 Hz flicker light stimulation increases thalamocortical connectivity. Recently, an arrhythmic flicker control condition was introduced that elicits fewer hallucinatory effects while the same amount of visual stimulation is applied. This allows to test for cortico-thalamic connectivity changes that are specific to the subjective experience of the visual hallucinations. Two Resting-state fMRI datasets were collected. In the first dataset we assessed changes in functional connectivity for 3 Hz and 10 Hz flicker light stimulation. In the second dataset we assessed differences between 10 Hz rhythmic and arrhythmic stimulation. Participants reported their hallucinatory experience following each condition. To quantify thalamocortical connectivity, thalamic and visual regions were parcellated using the AAL3 and probability maps of visual topography; thereafter, ROI-to-ROI functional correlations were calculated. We found that 3 Hz and 10 Hz rhythmic flicker increases bottom-up and top-down thalamo-cortical interactions; namely connectivity of the LGN with early visual cortices as well as connectivity between higher-order visual regions to higher-order thalamic nuclei. This finding was replicated in the second fMRI dataset. We next tested for the contrast 10 Hz rhythmic > arhythmic to identify connectivity changes related to the visual hallucinations. We found specific increased connectivity between ventral thalamic nuclei and upstream visual cortices (e.g., hV4, LO1). Furthermore, the rhythmic>arrhythmic contrast revealed activation clusters in upstream visual cortices (FWE corrected $p<0.05$) consistent with regions displaying increased connectivity. Cluster peaks were situated in bilateral LO1. Together, our findings indicate that increased connectivity between ventral thalamic nuclei and upstream visual cortices reflect the intensity of flicker-induced visual hallucinations. That the rhythmic and arrhythmic flicker were matched with regards to the amount of physical stimulation, renders these results specific to the rhythmicity and corresponding differences in subjectively experienced visual phenomena.

Self-induced cognitive trance is associated with changes in neural oscillations and brain complexity patterns

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Concurrent Session: Hallucination and Altered States, Wednesday July 3rd, Seminar Room, Ito International Research Center, 2:00PM-4:00PM

The self-induced cognitive trance state (SICT) is a non-ordinary state of consciousness characterized by its self-induced nature. it allows individuals to enter an altered state of consciousness without the use of substances or reliance on external stimuli. This state can be voluntarily ended without any associated side effects. This state is of particular interest due to its potential applications in enhancing creativity, learning, therapy, and stress reduction, offering a non-pharmacological approach to improving mental health and cognitive performance. Despite its promising applications, the neurophysiological mechanisms underlying SICT remain poorly understood. This study aimed to explore the neural and phenomenological characteristics of SICT state, highlighting alterations in brain oscillations, neural complexity, and self-reported experiences. A total of 55 participants underwent electroencephalographic (EEG) recordings during both rest and SICT conditions. We used several EEG features to investigate neural changes, including Lempel-Ziv complexity, sample entropy, spectral entropy, 1/f exponent, and canonical frequency bands spanning from delta (1-4Hz) to gamma (30-60Hz). Multi-feature machine learning classifications, involving EEG metrics across 300 regions of interest, have been computed to distinguish between the two states. Self-reported measures of absorption, dissociation, and time perception were collected and analyzed in conjunction with EEG data. All participants reported reaching the SICT state with a mean intensity of 6.72/10. A significant increase in self-reported absorption and dissociation was observed during SICT compared to rest. EEG analysis revealed prominent changes in oscillatory patterns during SICT, particularly in the delta, theta, and gamma bands. Furthermore, SICT led to a reduction in the 1/f exponent across multiple brain areas. Intriguingly, complexity metrics indicated a substantial drop in neural complexity throughout the brain under SICT. Through multi-feature regression, specific EEG metrics, like the 1/f exponent and alpha band power, were linked to self-reported measures, establishing neural correlates for the subjective experience during SICT. These data suggest a prominent role for these two EEG metrics in the neural mechanisms that mediate the subjective experience associated with SICT. Our EEG data suggests that the SICT state is accompanied by pronounced alterations in brain oscillations, reduced neural complexity, and a shallower slope in the EEG power spectrum. These modulations were predictive of the intensity of participants' self-reported experiences. Taken together, these findings shed light on the neural underpinnings of SICT and pave the way for a deeper understanding of such trance states and their potential applications.

Double Body Effect and the Proprioceptive-Vestibular Self in Virtual Reality

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Concurrent Session: Body and Self 1, Wednesday July 3rd, Conference Room, Ito International Research Center, 2:00PM-4:00PM

One of our most basic bodily experiences is that each of us, from the first-person perspective (1PP), experiences a particular body as our own at a specific location. Is it possible for us to have the experience of owning two bodies (double body ownership) located at different places (double body locations)? Call this the Double Body Effect. This is an important issue, not only because researchers disagree about it, but also because various types of bodily self-consciousness are involved that require investigations, including body ownership (what it is like to feel a body part or a full body as mine), self-location (the sense of where I am in space), body-location (the sense of where my body is in space) and 1PP-location (the sense of where my 1PP is in space). Most previous studies used visual-tactile manipulations to induce bodily illusions (Lenggenhager et al., 2007; Ehrsson, 2007; Petkova et al., 2011; Guterstam et al., 2020). This approach is fruitful but fails to capture a key feature of bodily self-consciousness, that is, we can feel our own body "from the inside". To remedy this deficiency, we applied VR technologies and developed a new approach by focusing on the proprioceptive sense from within the body and the sense of balance sustained by the vestibular system. In one of our experiments, the participants were immersed in a virtual gym where they saw and controlled a life-sized avatar from the 1PP. A motion tracker was attached to a Bosu ball (semicircular balance ball) correlated perfectly with a virtual Bosu ball in the gym. Following instructions, the participants stepped onto the real Bosu ball while watching the avatar stepping onto the virtual one. This immediately caused the participants to wiggle their body involuntarily to maintain balance. Then they saw the avatar splitting into two identical ones, with their visual 1PP located in the middle between the avatars, and remained on the Bosu ball for 4.5 minutes. The constant bodily wiggling triggered the participants' proprioceptive sense and their sense of balance. The questionnaire results showed that in the synchronous condition the participants felt that both avatars were their own and that their body was simultaneously located at the places of the two avatars. These results were supported by SCR evidence. In another experiment, the 1PP-location was set in the middle but about 45 cm behind the two avatars so that the avatars were viewed from the third-person perspective (3PP). In this 3PP condition, we observed a weaker but similar double body ownership and double body locations. Together, we demonstrated that it is indeed possible for healthy subjects to experience the Double Body Effect. We argue that this effect is compatible with the philosophical idea that each of us is a single conscious self associated with a unique 1PP, and that bodily self-consciousness depends more on proprioceptive-vestibular integration rather than external, especially tactile, sensations.

Alpha oscillations bind visuo-tactile information to generate the sense of body ownership.

Mariano D'Angelo (Karolinska Institutet), Renzo Lanfranco (Karolinska Institutet), H. Henrik Ehrsson (Karolinska Institutet)

Concurrent Session: Body and Self 1, Wednesday July 3rd, Conference Room, Ito International Research Center, 2:00PM-4:00PM

A highly debated proposal in cognitive neuroscience concerns the role of alpha oscillations in sampling external multisensory signals and shaping the width of the temporal binding window (TBW) - the temporal interval in which different stimuli integrate into a unified percept. Faster oscillations in the alpha band result in more frequent perceptual frame and a narrower TBW, while slower oscillations yield fewer perceptual units and a wider TBW. However, it remains unknown if alpha frequency also integrates bodily sensory information to generate the sense of body ownership, i.e., the experience of one's own body as one's own. Here, we demonstrated that the temporal resolution of multisensory perception correlates with the temporal resolution of multisensory integration involved in body ownership (Exp 1). Moreover, we showed that alpha frequency integrates visuo-tactile stimuli to generate the sense of a unified bodily self, using both correlational (Exp 2) and causal (Exp 3) approaches. In Exp 1, participants performed simultaneity judgments, where they judged the perceived synchronicity of a visual (i.e., a light) and tactile (i.e., a vibration) stimulus presented synchronously or at different delays, and body ownership judgments, where we induced illusory body ownership over a rubber hand (i.e., the rubber hand illusion). Two robot arms applied taps to a prosthetic hand and the participant's hidden hand, synchronously or at different delays. Participants judged whether they perceived the rubber hand as their own hand or not. In Exp 2, we recorded EEG activity while participants performed body ownership judgments and a simultaneity judgment task where they judged if the taps on the fake and real hands were synchronous or not. Finally, in Exp 3, we used transcranial alternating current stimulation (tACS) over the parietal cortex to modulate oscillations at low (8Hz) or high alpha (13Hz), in addition to a non-stimulation control condition (Sham). Participants received tACS while they performed body ownership and simultaneity judgments over the rubber hand. Exp 1 showed that participants with larger TBW, and lower sensitivity, in the simultaneity judgments also displayed a larger TBW, and lower sensitivity, in body ownership judgments. Exp 2 revealed that participants' individual alpha frequency in the posterior parietal cortex correlates with TBWs and sensitivity in both the body ownership and simultaneity judgments. Moreover, alpha peak frequency speed up in the simultaneity judgments and slowed down in the body ownership judgments. Finally, Exp 3 showed that tACS modulated the TBW and the sensitivity in both simultaneity and body ownership judgments: low alpha-tACS enlarged the TBW and reduced the sensitivity, while high alpha-tACS reduced the TBW and increased the sensitivity.

In conclusion, temporal resolution of multisensory integration for external events correlates with multisensory integration involved in body ownership. This is because alpha oscillations integrate sensory stimuli to generate the sense of body ownership, just like alpha oscillations support multisensory integration for external events. In addition, the alpha peak speeds up during simultaneity judgments and slows down during body ownership judgments, suggesting that alpha frequency integrates multisensory information based on the specific task demand.

Bodily self-awareness is sustained by continuous conscious access to multisensory signals: Converging evidence from computational models of signal detection, metacognition, and evidence accumulation.

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Concurrent Session: Body and Self 1, Wednesday July 3rd, Conference Room, Ito International Research Center, 2:00PM-4:00PM

The sense of owning one's body arises from the integration of multiple sensory signals into a single perceptual unit. How these multisensory signals integrate over time and gain access to awareness is a central question. To investigate body ownership, researchers use bodily illusions such as the rubber hand illusion (RHI), which involves synchronously stroking a person's hidden hand alongside a visible rubber hand placed in front of them; this induces the feeling that the rubber hand is their own. Conversely, asynchronous stimulation weakens or abolishes the illusion, reflecting low visuotactile integration. Here, we employ a novel psychophysical paradigm to objectively quantify body ownership signal processing in a bias-free manner. Graded stimulation asynchronies are introduced using robot arms to simultaneously induce the RHI with two rubber hands. Participants must then report which rubber hand feels most like their own in a two-alternative forced-choice task and rate their subjective experience. In Experiments 1 and 2, we implement signal-detection theoretic (SDT) analyses to assess the sensitivity of body ownership to multisensory signals (body ownership sensitivity or d') and how these signals are consciously accessed (metacognitive sensitivity or meta-d'). We found that the sense of body ownership is sensitive to visuotactile asynchronies from ~30ms. Similarly, we found that conscious access is sensitive to visuotactile asynchronies from ~30ms, which may suggest that both multisensory processing and awareness of body ownership signals arise together. Maximum likelihood estimation and hierarchical Bayesian computational models of metacognitive efficiency support this conclusion. To ascertain that our conclusions so far cannot be explained by low-level perception (i.e., detection of visuotactile asynchrony alone), we implemented Experiment 3, in which participants performed a similar task with the rubber hands rotated in 90-degrees, i.e., in conditions where the RHI cannot arise. If participants performed the tasks in Experiments 1 and 2 using visuotactile asynchrony alone, we should expect equivalent results in Experiment 3. Neither d' nor meta-d' departed from chance, suggesting Experiments 1 and 2 results are driven by body ownership signal processing. To assess the robustness of our method against cognitive biases (e.g., prior expectation), we ran Experiment 4, which shows that neither SDT metric is affected by expectation. So far, multisensory processing and conscious access of body ownership unfold together. However, body ownership involves accumulating multisensory evidence over time. In Experiment 5, we tested whether the number of touches modulate d' and meta-d' of body ownership. Both SDT indices increased with number of touches, and once again, they arose together. To explore evidence accumulation further, in Experiment 6 participants performed a speeded version of our task and responded as soon as they felt ownership with either rubber hand. We used drift-diffusion modelling to assess evidence accumulation rate across asynchronies and v-ratio for conscious access during accumulation. We found that evidence accumulation rate increases with increasing asynchrony, while v-ratio remains constant. Our findings indicate that the multisensory signals behind the sense of body ownership enjoy continuous access to awareness, which strongly supports the notion that body ownership is a crucial component of self-awareness.

The bodily-self development: how early motor experiences shape multimodal representation of the bodily self in space

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Concurrent Session: Body and Self 1, Wednesday July 3rd, Conference Room, Ito International Research Center, 2:00PM-4:00PM

Spatially organized multisensory integration (MSI) is considered a hallmark of the bodily-self representation in space. While influential studies investigated the role of visual deprivation in shaping this representation, less attention has been paid to motor deprivation. Electrophysiological studies in non-human primates show that multimodal neurons encode multisensory bodily stimuli in body-centred reference frames by anchoring visual, auditory and tactile receptive fields to a given body part by means of proprioceptive inputs. Thereby, the motor context seems to play a crucial role in shaping this mechanism. Here, to challenge the idea that early motor experience is the typical developmental context that allows the emergence of multisensory representation of the bodily-self in space, we exploited the atypical development of hemiplegic children with cerebral palsy (CP). In this population, the deprivation of hand movements since birth should have prevented proprioceptive input to anchor multisensory stimuli in a hand-centered reference frame, thus leading to an altered multisensory representation of the affected hand in space. We formulated our hypotheses on the comparison between acquired and congenital motor deprivation. While individuals with acquired motor deprivation should show a spatially organized multisensory integration due to their previous motor experiences, we anticipated that CP children with congenital motor deprivation should not, since multisensory stimuli have not been anchored to proprioceptive inputs through development.

Preliminary data were acquired in post-stroke patients with acquired upper-limb hemiplegia (N=11; 6 females; 8 right-brain damage; 55.2±13.8 years), in CP children with congenital upper-limb hemiplegia (N=4; 1 female, 3 right-brain damage; 10.7±2.2 years) and in two groups of 20 controls age-matched to acquired (12 females; 63.2±16.1 years) and congenital (10 females; 13.5±5.3 years) populations. Data collection is still ongoing.

Participants were asked to provide speeded responses to tactile stimulation on their left or right hand (in different sessions) which could be delivered alone (T-trials) or concomitantly with a visual stimulus (VT-trials). Faster reaction times (RTs) to bimodal (VT) than unimodal (T) stimuli should show a MSI facilitation. To test a spatially organized MSI (body-proximity effect), we manipulated the proximity of the visual stimulus to the hand by leveraging a postural manipulation where the hand was passively moved either near or far from the visual stimulus. Faster RTs to bimodal Near than Far stimuli should show a body-proximity effect. Patients with acquired motor deprivation showed, in both intact and affected sides, a body-proximity effect (significantly greater MSI facilitation in Near than in Far conditions) comparable to that found in their controls. CP children with congenital motor deprivation showed a body-proximity effect comparable to their controls only in the intact side, while no difference between Near and Far conditions was present in the affected side. These preliminary results, if confirmed in a larger sample, may suggest that early motor experiences play a crucial role in shaping multisensory representation of the bodily-self in space. From a clinical perspective, this can also promote new rehabilitation interventions focusing on body representation deficits in CP children and on their interaction with functional outcomes.

Strategic Norm Emergence in Large Language Model Agents: An Evolutionary Approach to Social Norm Formation

Ilya Horiguchi (The University of Tokyo), Takahide Yoshida (The University of Tokyo), Takashi Ikegami (The University of Tokyo)

Concurrent Session: AI and Consciousness 1, Wednesday July 3rd, Conference Room, Ito International Research Center, 2:00PM-4:00PM

This study investigates the emergence and evolution of strategic norms among Large Language Models (LLMs) acting as agents within a game-theoretical framework. Inspired by Axelrod's exploration of metanorms—norms enforcing the punishment of those who do not punish defection—our research seeks to understand how LLM agents develop complex strategies and social norms purely through natural language interaction. By simulating a Norms Game where agents communicate, negotiate, and make strategic decisions in natural language, we demonstrate the potential of LLM agents to autonomously generate normative behaviors that align with cooperative dynamics observed in human societies. Our experimental setup extends Axelrod's metanorm games by introducing a tag-based system that enables LLM agents to perform game-specific commands, such as punishing defection or choosing to defect, within the context of natural language dialogues. The agents were characterized by traits of Vengefulness and Boldness, influencing their likelihood to punish defection and to defect, respectively. Through a series of simulations, we observed the spontaneous formation of punishment strategies and metanorms, where agents not only punished defection but also those who failed to punish defection, thereby reinforcing cooperative behavior across the agent population. The study's findings highlight several key insights into the behavior of LLM agents in strategic interactions. High levels of Vengefulness and Boldness were associated with increased use of punishment commands, suggesting that these traits significantly influence the emergence of cooperative norms. Furthermore, the dynamic evolution of agent strategies over time revealed a tendency towards moderate levels of Vengefulness and Boldness, indicating a balance between cooperative and competitive behaviors for optimal group outcomes. Notably, our results illustrate the capacity of LLM agents to engage in complex social reasoning and norm formation through language, suggesting a powerful method for studying the evolution of cooperation and normative behaviors in artificial societies. The study underscores the potential of using LLMs for simulating social interactions, providing valuable insights into the mechanisms behind social norm formation and strategic decision-making in human and artificial societies alike. Future research could expand on these findings by exploring a wider range of agent characteristics, interaction scenarios, and environmental factors to uncover more nuanced mechanisms of social norm evolution. Additionally, investigating the implications of these dynamics for AI alignment and the integration of artificial agents into human societies offers a promising avenue for further exploration. This work not only contributes to our understanding of the capabilities and limitations of LLMs in complex social simulations but also opens new pathways for leveraging natural language processing technologies to study the foundational principles of social interaction and cooperation.

Emergence of prosocial behavior in homeostatic reinforcement learning with vulnerable agents

Kingson Man (Feeling Machines), Naoto Yoshida (The University of Tokyo)

Concurrent Session: AI and Consciousness 1, Wednesday July 3rd, Conference Room, Ito International Research Center, 2:00PM-4:00PM

Homeostasis is the regulation of internal body states within a range compatible with life. In organisms capable of forming mental states, conscious feelings are the mental expression of these internal viability states (Damasio 1999; Damasio & Carvalho 2013). The feeling of conscious presence has itself been attributed to the monitoring and prediction of internal body states (Seth et al 2012). It has been proposed that machines that implement a process resembling homeostasis could exhibit a feeling-like device for the motivation and evaluation of their behavior (Man & Damasio 2019). Recent developments in machine learning have implemented homeostatic-like processes in reinforcement learning (RL) agents and observed the emergence of integrated behaviors (Keramati & Gutkin 2014; Yoshida 2017; Yoshida et al 2021, 2023; Laurencon et al 2024). Here we extend these ideas to a model of the function of conscious feeling and social behavior using multi-agent RL, where each interacting agent is formulated as a vulnerable homeostat. Vulnerability is defined as the circular causality of allowing an agent's homeostatic states to affect its ability to regulate those homeostatic states. Simply put, agents find it harder to repair themselves if they begin to fall apart. In the limit, the agent loses constitutional integrity and can take no action to further itself – it dies. We offer a novel treatment of mortality in the RL context. The standard RL optimization objective maximizes the expected value of reward, but in non-ergodic RL scenarios (Baumann et al 2023), the population-average reward differs from the time-average reward achieved by most individuals. These situations arise in RL with absorbing states (i.e. death) that foreclose any future reward. Mortal agents, who play mortal games, end up behaving in ways far different from those who 'rationally' maximize the expected value of reward across a population (cf. Ororbia & Friston 2023). The advantage of a machine learning approach to optimizing the behavior of a physically oriented agent is that the agent's survival problem is described as a special case of RL in the partially observable Markov decision process, so that state estimation and decision making based on Bayesian inference can be theoretically organized in terms of optimality. In this regard, we may also define optimality as it relates to the individual's own 'felt' interests. This treatment extends to social behavior when the capacity for self-feeling is augmented with the capacity for fellow-feeling, or empathy (e.g. Lim & Okuno 2014; Asada 2014). Vulnerable agents can express their homeostatic feeling states as inter-observable emotions. This final element creates a positive feedback loop in which agents act for the good of others in order to feel good for themselves. We aim to witness the emergence of brotherhood and charity among machines, including pro-social behaviors such as helping a damaged agent, or forgoing a resource so that a needier neighbor may benefit. In sum, we offer a computational approach and theoretical account of the emergence of prosocial behaviors from vulnerable agents guided by homeostatic feelings.

From Text to Motion: Grounding GPT-4 in a Humanoid Robot "Alter3"

Takahide Yoshida (The University of Tokyo), Atsushi Masumori (The University of Tokyo), Takashi Ikegami (The University of Tokyo)

Concurrent Session: AI and Consciousness 1, Wednesday July 3rd, Conference Room, Ito International Research Center, 2:00PM-4:00PM

We present Alter3, a humanoid robot driven by a Large Language Model (LLM) for motion generation. In recent years, the fusion of LLMs with robotics has marked a burgeoning frontier in artificial intelligence and robotics research. LLMs enhance robotics by improving human-robot interaction and optimizing task planning. Notably, there's a growing focus on developing empathetic and socially-aware robots. However, low-level robot control is hardware-dependent and falls outside the scope of LLM corpora, presenting challenges for direct LLM-based robot control. In the case of humanoid robots like Alter3, LLM can control it directly by mapping the linguistic expressions of human actions onto the robot's body through programming code.

Remarkably, this approach enables not only instant actions or gestures, e.g., "taking a selfie", "pretending to be a ghost", but also the creation of motions with a temporal sequence of events, accompanied by emotional expression without explicit programming. For instance, Alter3 can perform scenes that involve a mixture of multiple emotional expressions, such as "I was enjoying a movie while eating popcorn in the theater, when I suddenly realized that I was actually eating the popcorn of the person next to me." This complex motion generation is achieved through few-shot learning.Notably, the system can generate these complex motions in approximately 30 seconds, highlighting its efficiency and practicality for real-time interaction. Our approach interestingly captures the importance of emotions in embodying LLM in the real, practical world.

This experiment has shown capability in mirroring emotions, such as displaying sadness or happiness in response to corresponding narratives. By utilizing this capability, we also conducted conversational experiments between humans and Alter3. We created the six personalities powered by GPT-4. They engage in empathetic dialogue by generating reactions of Alter3 based on the verbal conversation. When no humans were present, the internal personalities conversed with each other. This multi-personality framework exemplifies the brain's modular design, demonstrating how the social brain aids in cooperation, empathy, and smooth social interactions. However, we observed that open-ended conversational development occurred only with human intervention. GPT-4 alone tended to fall into a certain attractor. This finding suggests that surpassing the appearance of consciousness requires not just GPT-4 in isolation, but the inclusion of external dynamics or uncertainty and information sources. The crucial open-endedness essential to life has not yet been achieved in LLMs. What might be the missing piece here? The answer may lie beyond this research. This research contributes to grounding LLM in Alter3, unlocking its yet unseen potential.

Utility of large language models in characterizing creative communication dynamics

Takayuki Nozawa (University of Toyama)

Concurrent Session: AI and Consciousness 1, Wednesday July 3rd, Conference Room, Ito International Research Center, 2:00PM-4:00PM

The ability to generate new, imaginative ideas through communication is a unique and distinctive aspect of human consciousness and intelligence. The recent surge in applications of artificial intelligence (AI) has extended to the realm of creativity, which is considered a hallmark of human intelligence. In divergent thinking tasks, such as the Alternative Uses Task (AUT), which requires subjects to generate as many creative uses as possible for a set of everyday items, large language models (LLMs) like ChatGPT have demonstrated performance levels of creativity comparable to or even sometimes surpassing those achieved by humans. Moreover, attempts have been made to employ natural language processing and LLMs in evaluating the creativity of ideas generated by human. However, prior research has mainly focused on individual creativity. In contrast, this study examines the potential of LLMs for analyzing the semantic temporal evolution of ideas generated collaboratively through communication and for characterizing the dynamics of creative communication. This research analyzed sequences of creative ideas (approximately 900 in total) generated through communication by 19 groups of 3 individuals each during the group AUT. The ideas generated through creative communication were represented using embedding vectors (semantic space representations) through the utilization of a large language model. Subsequently, a creativity score was calculated for each idea based on the cosine similarity/distance between its embedding vector and that of its corresponding daily item. This score was then compared with subjective creativity ratings by a third party. Furthermore, for each pair of idea sequences, the cosine similarity of the embedding vectors was calculated to evaluate the connections between ideas. High similarity (proximity) between ideas indicates developmental or derivative idea generation, whereas low similarity (distance) signifies independent idea generation. The analysis revealed three key findings: (1) Quantified creativity scores based on the semantic distance between items and ideas demonstrated a significant positive correlation with subjective evaluations, suggesting that the creativity of ideas generated by groups through communication can be captured by LLMs, similarly to automated evaluation of individually generated ideas. (2) Ideas generated later in the communication process exhibited significantly higher creativity scores than those generated earlier, indicating that the so called “serial order effect” observed in individual creativity tasks also takes place in groups idea generation through communication. (3) Developmental or derivative ideas with closer semantic distances to preceding ideas yielded significantly lower creativity scores compared to independent ideas with greater semantic distances, suggesting that cooperation does not necessarily lead to objective improvements in creativity, contrary to intuition. Overall, these findings underscore the utility of LLMs in elucidating the dynamics of creative communication. Additionally, the results highlight the challenge of reconciling subjective aspects of collaboration, such as satisfaction and motivation enhancement, with the objective assessment of group creativity.

The Blindsight Spectrum: evidence from behavioural and neurophysiological assessment of hemianopic patients

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Concurrent Session: Metacognition 1, Wednesday July 3rd, Fukutake Learning Theater, 5:00PM-7:00PM

Blindsight is defined as the residual visual discriminatory capacities in the blind field of patients having suffered a lesion of the primary visual cortex. Patients with blindsight are indeed capable of discriminating above chance-level between visual stimuli presented in their blind field in 2-alternative forced-choice designs. These pure objective visual capacities in the blind field can be accompanied by some forms of awareness, different from normal visual consciousness. More recently, it has been described that some patients show evidence of only this residual awareness, without the objective capacities, a phenomenon referred to as blindsense. These dissociations between visual perception and consciousness offer the opportunity to shed light on the neural correlates of visual consciousness and isolate the purely non-conscious perceptual processing, thus having significant implications for theories of consciousness. Nonetheless, neither the underlying mechanisms nor the neural correlates of blindsight and its derivatives are yet understood. Currently, blindsight is categorised into 3 subtypes (blindsight type I, blindsight type II and blindsense) and is argued to either be the result of unconscious processing relying on subcortical visual pathways or of degraded conscious vision. However, we believe these three categories and two theories do not encapsulate the diversity of perceptual profiles observed in clinic, hence why we have proposed the residual capacities in the blind field of hemianopic patients are better represented along a blindsight spectrum.

In order to test this theory, it is crucial for the study of blindsight phenomena that the objective and subjective residual capacities are assessed in the most rigorous and sensitive manner. With this in mind, we present here the newly developed protocol for a complete characterisation of the perceptual and neurophysiological profiles of hemianopic patients. Participants undertake a motion detection and a motion direction discrimination task in their blind and intact visual hemifields, with a response modality probing simultaneously objective and subjective responses, whilst neural activity is recorded by electroencephalography. The first-order, objective response allows to calculate classical signal detection theory sensitivity whilst the second-order, subjective component assesses visual metacognition and allows to compute gold-standard meta-d'. Prompting for confidence rather than visual awareness allows to circumvent the fact that the subjective component of residual processing in the blind field of hemianopic patients is rarely reported by patients as visual in nature but rather as an amodal sensation. Moreover, evaluating metacognition in hemianopic patients with and without blindsight allows to explore the hypothesis that blindsight results from a disrupted perceptual metacognitive system. We show our protocol allows to precisely describe the diversity of residual capacities observed in the blind field of hemianopic patients. We discuss these results in their impact of the understanding of blindsight and in turn discuss these results in the contexts of local and global theories of consciousness.

Evidence Accumulation as a support mechanism for the metacognition of perceptual decisions

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Concurrent Session: Metacognition 1, Wednesday July 3rd, Fukutake Learning Theater, 5:00PM-7:00PM

We present the results of two experiments in which we used stereotactic electroencephalography to examine the functional role and implementation of evidence accumulation for two components of human metacognition: confidence judgments and changes of mind. Although evidence accumulation has proven to be a powerful mechanism to understand the underpinnings of decision-making itself, the question of how and where in the brain it could give rise to metacognitive processes remains unclear. In the first experiment, we recorded high-gamma activity in participants with focal epilepsy while they performed a decision-making task followed by a confidence judgment. Participants had to report the motion direction of a random dot kinetogram using a computer mouse, which allowed us to use mouse-tracking to detect sudden changes in trajectory indicative of changes of mind. With this task, we were able to document the functional overlap between evidence accumulation, confidence, and changes of mind in a temporally resolved manner. First, we were able to reproduce the decision accuracy, decision times, and confidence observed at the behavioral level using a computational model allowing evidence accumulation to continue after the initial decision. At the neural level, we found that evidence accumulation is instantiated widely across the cortex, notably in the pre-supplementary motor area (pSMA) and the insula. More importantly, in these regions, we found an overlap between the neural correlates of evidence accumulation, confidence, and changes of mind. Interestingly, our results indicate that the correlation between neural activity and confidence was maintained after the decision in the insula, but stopped at decision time in the pSMA. By modulating the duration for which evidence accumulation took place after the decision in our model, we could qualitatively reproduce these electrophysiological results. To further characterize how post-decisional evidence accumulation drives changes of mind, we designed a second experiment in which the stimulus was manipulated following decision time, either by reducing the amount of information available or by providing confirmatory or disconfirmatory information relative to the initial choice. Preliminary results indicate that disconfirmatory postdecisional information had no effect on confidence judgment. However, changes of mind were more frequent in the disconfirmatory condition than in the information reduction condition. In conclusion, by combining intracranial electrophysiology, mouse-tracking, and computational modeling, we propose that confidence and changes of mind result from post-decisional evidence accumulation instantiated in the pSMA and the insula. Additionally, the fact that disconfirmatory evidence impacts confidence and changes of mind differently suggests that it modulates distinct aspects of evidence accumulation that remain to be elucidated.

Metacognition is mentally demanding: revealing the costs and consequences of metacognitive effort

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Concurrent Session: Metacognition 1, Wednesday July 3rd, Fukutake Learning Theater, 5:00PM-7:00PM

Metacognition, the capacity to evaluate and control our own mental processes, is an important cognitive function. It plays a key role in consciousness science where metacognitive ratings are frequently used as an index for distinguishing conscious from unconscious decisions. It is widely assumed that metacognition automatically and effortlessly accompanies decision making. However, this assumption has never been tested and is challenged by a wealth of evidence that other cognitive functions are mentally demanding and costly. The mental demand of metacognition is a problem for consciousness science because failures of metacognition may stem not from lack of conscious knowledge but rather from participants' rational cost-benefit calculations, leading them to disengage from self-evaluation. Here, we hypothesise that metacognition is an effortful process that demands cognitive resources, influencing the quality of self-evaluation as a function of costs and benefits. To illuminate this thesis, we conducted two studies that examine the costs and consequences of metacognitive effort. To reveal the costs of metacognition, we developed a novel, effort-based decision making paradigm where participants could trade-off monetary rewards for reduced metacognitive effort. We operationalised metacognitive effort as the precision of confidence judgments. Participants can maintain more precise confidence rating criteria at the expense of mental exertion. Our design incentivises metacognition while controlling for fatigue and the effortfulness of the primary task. Across three experiments, we found that individuals were sensitive to the costs of metacognition and reliably sacrificed rewards to minimise metacognitive effort, suggesting that metacognition is mentally demanding. Next, to examine the consequences of such cost-benefit trade-offs in metacognition, we studied a famous observation—confidence leaks. These are correlations in confidence ratings for independent tasks with independent sensory content that are performed in close temporal proximity. Using the same confidence rating twice is cognitively effortless, and so confidence leaks may be a rational by-product of metacognitive effort. In a pre-registered experiment, we used rewards to incentivise the precision of confidence judgments in a confidence leak paradigm. We found that for the same participants, confidence leaks were significantly reduced by rewards, and the correspondence between metacognitive ratings and sensory content improved. This indicates that confidence leaks, previously considered intrinsic to metacognitive systems in the brain, can emerge due to a lack of incentives for investing metacognitive effort. In summary, our research shows that metacognition is sensitive to costs and benefits, challenging the assumption that it automatically accompanies decision making. Critically, this rational process affects metacognitive ratings independently of sensory content and can present as biases such as confidence leaks. If such consequences of metacognitive effort are as widespread as our thesis suggests, they pervade consciousness science. Metacognitive ratings in many studies may reflect the state of the world where participants are disengaged in self-evaluation. This challenges a common approach in consciousness science where impaired metacognition is taken as a marker of diminished conscious access.

Studying metacognitive abilities with functional networks - predictive coding on four sensory modalities.

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Concurrent Session: Metacognition 1, Wednesday July 3rd, Fukutake Learning Theater, 5:00PM-7:00PM

Metacognition is a person's ability to correctly assess and control their cognitive processes. As it concerns a wide range of cognitive domains, one of the leading questions is whether the metacognitive process is domain-general or domain-specific. Observation of brain activation at rest (when subjects are not performing any task) with fMRI has shown the existence of functionally connected networks of brain regions, i.e. regions with synchronous neural activity. Here, we ask whether resting-state networks carry information about the metacognitive processing of 4 sensory modalities: vision, audition, nociception and touch.

Methods: Behavioural data: 4 homologous perceptual tasks were performed, one for each sensory modality. Each task consisted of 2 alternative forced choice tasks followed by confidence judgment. Data was analysed with the Signal Detection Framework.

Resting-state fMRI: 302 participants underwent resting-state fMRI. Denoised data were divided into 19 networks:17 cortical networks (Yeo et al. 2011, J. Neurophysiol.) plus cerebellum and subcortical regions. Average time series were extracted from parcels to estimate functional connectivity as pairwise Pearson's correlation.

Predictive framework: Functional connections were used to predict the meta-d' scores (since we were interested in the metacognitive sensitivity of individual modalities) using Elastic Net linear regression. We included data from 253 subjects in visual, 231 in auditory, 175 in tactile and 208 in nociceptive task. We ran prediction starting with all connections (whole-brain) and then consecutively removed one of the networks, thus creating 'artificial lesions' (Dubois et al. 2018, Philos. Trans. R. Soc. B: Biol. Sci.), until the model reached the set of networks giving the best prediction. The model's accuracy was estimated with mean squared error (MNE).

Results&Discussion: With the top-down lesions approach, we have shown that the prediction accuracy with a subset of networks greatly improved compared to the whole-brain approach. We found that different sets of networks best predict metacognitive scores for different modalities: visual=[somatomotor A&B, limbic B, control A, default B, cerebellum], auditory=[peripheral visual, somatomotor A&B, dorsal attention A, control B, default B, subcortical], touch= [peripheral visual, limbic B, control B&C, default A, temporal parietal, subcortical, cerebellum], pain=[central visual, dorsal attention B, ventral attention A&B, control A&C, default C, temporal parietal]. Although multiple networks overlap between modalities, none is present in all modalities' final set of networks. This suggests some level of functional independence in metacognitive processing, i.e. domain-specificity. However, in all modalities, at least one of the control (sub)networks and one of the default (sub)networks are involved, which suggests the involvement of more general processes as well.

Confidence-informed belief state informs decision policy.

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Concurrent Session: Metacognition 1, Wednesday July 3rd, Fukutake Learning Theater, 5:00PM-7:00PM

Adapting decision-making strategies to the current task context is crucial for efficient behavior. Rational humans should adjust their level of caution based on perceived task difficulty, being less cautious and make rapid decisions in easy tasks and being more cautious and avoid errors in hard tasks. In the absence of external feedback, participants likely base their decision policy on an internal belief about the difficulty of the current task. However, this then raises the question: what determines the belief state regarding the difficulty of the current task? We propose that the accumulation of decision confidence, i.e., the internal estimate of accuracy, shapes one's belief state, which subsequently informs decision policies. To test this, participants performed a random dot motion task where task difficulty (easy vs. hard) unpredictably switched approximately every 20 trials. On each trial, participants rated their decision confidence, and periodically, participants indicated their belief with respect to the task context. To model the dynamics of human context beliefs, we compared various belief updating models, where different measures were used as sources for belief updating (e.g., confidence, accuracy and (confidence) response time). Confidence-based models provided the best fit to the observed belief patterns, outperforming the alternative models. Critically, we observed a contextual modulation of performance by model estimated belief about current task difficulty. Fits from a hierarchical drift diffusion model showed that model estimated beliefs were associated with the drift rate (i.e. higher drift when you belief the current task is easy), but contrary to our expectations not with decision boundaries. Together, these results show that confidence shapes contextual beliefs and subsequent latent decision-making parameters.

Evidence accumulation explains the temporal dynamics of behavior and brain activity associated with perceptual experience

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Concurrent Session: Metacognition 1, Wednesday July 3rd, Fukutake Learning Theater, 5:00PM-7:00PM

Perceptual experience refers to the subjective feeling associated with the processing of sensory information. It is a dynamic process during which perceptual contents fade in and out of consciousness over time, giving rise to a sense of subjective duration. Moreover, metacognitive monitoring of sensory signals gives rise to a sense of confidence that typically accompanies conscious percepts. How perceptual experience occurs and what underlying mechanisms are responsible for subjective duration and confidence remain under investigation. Here, we propose that a single mechanism of leaky evidence accumulation accounts for both subjective duration and confidence. We suggest that a stimulus leads to a perceptual experience when sensory evidence is accumulated above a perceptual threshold. Our model posits that perceptual experience lasts as long as evidence remains above the threshold, and that confidence is proportional to the maximum of evidence accumulated over time. Using stereotactic electroencephalography we could isolate the temporal unfolding of brain activity in the mid-fusiform gyrus during a face detection task. Participants were required to immediately detect faces embedded in frames of visual noise and then assess their confidence in their responses. Remarkably, the evidence accumulation mechanism generated traces of evidence accumulation resembling the high gamma activity response observed in the mid-fusiform cortex. The same evidence accumulation model was fitted to the behavioral data of healthy volunteers. In addition to detection and confidence evaluation, they were asked to reproduce the duration of the perceived stimulus. The model successfully accounted for stimulus detection, response times, subjective duration, as well as confidence judgments. Together, our results elucidate the role of leaky evidence accumulation in qualitative aspects of phenomenal experience such as its duration and associated metacognitive feelings of confidence. Building upon the sEEG results, we suggest that this mechanism might be instantiated in high-level sensory regions like the mid-fusiform cortex.

Decoding confidence from frontal regions to validate tuned inhibition as a model of perceptual metacognition

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Concurrent Session: Metacognition 1, Wednesday July 3rd, Fukutake Learning Theater, 5:00PM-7:00PM

When making a subjective confidence judgment about a perceptual decision, confidence tends to track decisional accuracy. However, experimental manipulations have been successful in forcing confidence and accuracy to dissociate, i.e., reporting high confidence in an incorrect decision, and vice versa (Maniscalco, Peters, & Lau 2016). In previous work, we showed that a competing accumulator computational model implementing "tuned inhibition" – such that the degree to which a neuron is inhibited by neighboring neurons with opposing tuning preferences (which differs from neuron to neuron) dictates the neuron's contributions to choices versus confidence judgments – can help explain this dissociation (Maniscalco et al., 2021). We also have previously observed evidence of tuned inhibition within decision making regions (medial temporal (MT) and parietal) of humans via fMRI (Abachi et al., in preparation). In that work, tuned inhibition levels for voxels were observed to covary with predictive power for confidence judgments in a manner consistent with this tuned inhibition model of perceptual confidence.

In the present work we sought to expand on previous findings to investigate how voxels within MT/parietal regions may differentially transmit information about the decisional process (i.e., information leak; Taschereau-Dumouchel et al., 2018) to regions that have been correlated with confidence judgments as a function of their inhibition tuning levels. We began by decoding high- versus low- confidence judgements on a trial-by-trial basis within the entire prefrontal cortex (PFC). The decoder is a linear support vector machine (SVM), trained with 10-fold cross validation and a cost/penalty parameter of 9 on the less-dominant class to avoid overclassification, falsely predicting the majority class. The decoder was trained for each of the 20 individual subjects collected in the previous study. Preliminary results show that confidence can be decoded from PFC with a mean accuracy of 61.6% (ranging from 45.2% to 80.7%) across subjects, demonstrating signal accessibility on par with previous decoding findings in PFC (Bhandari et al., 2018). Ongoing work uses searchlight algorithms to examine which sub-regions within the entire PFC may specifically "receive" information from MT/parietal regions, and the degree to which such information transmission is dependent on voxel inhibition tuning, by correlating classifier output in each searchlight with BOLD fluctuations in MT/parietal regions and subsequently examining whether such correlations are dependent on each voxel's inhibition tuning level.

Our findings further support the tuned inhibition model describing the neural computations underlying perceptual metacognition, and provide new evidence as to the way in which information is transmitted from specific components of decision-making circuitry to regions responsible for computing and/or representing perceptual confidence in humans.

Perceptual changes of mind require overcoming the impact of the earliest available pre-decisional evidence

Vinay Mepani (The University of Melbourne), Daniel Feuerriegel (The University of Melbourne), Stefan Bode (The University of Melbourne)

Concurrent Session: Metacognition 1, Wednesday July 3rd, Fukutake Learning Theater, 5:00PM-7:00PM

Title: Perceptual changes of mind require overcoming the impact of the earliest available pre-decisional evidence Authors: Vinay Mepani, Daniel Feuerriegel, Stefan Bode Metacognition allows us to be aware of the accuracy of our decisions in the absence of external feedback. One adaptive response to a perceived erroneous decision is to rapidly change our mind and correct our mistake. In perceptual decision-making, these changes of mind are thought to be driven by late-arriving, unprocessed information just before or at the time of the initial decision. However, it is unclear if information processed prior to the initial decision can also influence change of mind decisions. To investigate this, six participants completed an expanded judgement perceptual task over six sessions, where they judged which of two dynamically fluctuating, left- and right-tilted gratings was higher in contrast. After an initial response, the stimulus continued to be presented for a fixed time which participants could use to change their mind. We used psychophysical reverse correlation analysis to quantify what information in the evidence stream correlated with the speed and likelihood of change of mind decisions. We found that change of mind speed and likelihood were dependent on various sources of pre-decisional information, in particular the strength of the first sample of evidence and the consistency and strength of subsequent samples. In general, change of mind behaviour appears to be dependent on whether (and how quickly) post-decisional information can overcome the evidence supporting the initial decision. This suggests that changing one's mind is not a secondary process but relies on an integration of decision evidence from early and late processing stages.

Intracortical correlates of simple conscious perception in humans

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Concurrent Session: Perception 1, Wednesday July 3rd, Ito Hall, Ito International Research Center, 5:00PM-7:00PM

What is the extent of cortical activation needed to simply see a flash of light, hear a beep, or feel a touch on our hand? This question is central to the current debate on the neural correlates of conscious perception, yet it remains unanswered. One primary challenge lies in the conventional contrastive approach where subjects are prompted to report, e.g., whether they have perceived or not stimuli around threshold levels. While effective in eliminating pre-conscious neuronal processes, this experimental design may inflate post-stimulus activations to areas involved in detection and reporting, saliency, and task relevance. A secondary challenge stems from the ambiguous demarcation of cortical responses when observed through the lens of non-invasive techniques such as scalp EEG and functional magnetic resonance imaging (fMRI). In addition to their limited spatial and temporal resolution, respectively, these two methods do not differentiate between the boundaries of neuronal activations (i.e., firing) and those of their postsynaptic effects. Finally, whether simple perception requires the activation of a common multimodal area remains elusive. This uncertainty persists because, so far, no study has directly compared in the same space the cortical activations associated with perception across different sensory modalities. In this work we address, at once, all these challenges. First, we use simple stimuli well above sensory threshold, which pervasively affect experience but require minimal computations, cognitive effort, and no reporting. Second, we employ extensive intracortical recordings and stimulations (>10000 contacts in 109 subjects) to detect neuronal activations (gamma power) and to identify their postsynaptic targets (cortico-cortical evoked potentials, CCEPs) and postsynaptic effects in the broadband Local Field Potential (LFP). Finally, we assess the topographical overlap between these responses across three stimulation modalities encompassing flashes, beeps and median nerve stimulation. Across all sensory modalities, we find well-defined clusters of gamma power in low and high-order cortices within occipital, temporal, and parietal lobes with no areas of overlap. Analyzing the LFP, revealed responses beyond the boundaries of gamma activations, showing overlap across modalities in perisylvian and precentral areas. Yet, these additional LFP responses could be explained by a postsynaptic input from the sites showing gamma activity, as identified by CCEPs. This study, by overcoming the constraints of conventional experimental designs and non-invasive recordings, informs the current debate on the neural correlates of conscious perception. More specifically, our results indicate that the perception of simple stimuli is associated with neuronal activations that are confined within the posterior cortices, while additional and widespread LFP responses reflect their postsynaptic halo.

The Perception Census: A large-scale online study of perceptual diversity

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Concurrent Session: Perception 1, Wednesday July 3rd, Ito Hall, Ito International Research Center, 5:00PM-7:00PM

We all experience the world differently, but the nature and extent of perceptual diversity remain largely unknown. Here we introduce The Perception Census: an online research project which is part of the Dreamachine programme (https://perceptioncensus.dreamachine.world/). The Perception Census aims to capture individual differences across different perceptual domains. By collecting responses from large numbers of participants, each of whom completed a range of perceptual tasks and questionnaires, the Census will shed new light onto questions that have so far been examined in relatively small, highly specific samples. The Perception Census consists of 55 tasks divided into 11 sections investigating diverse topics in perception. Topics and tasks were selected according to theoretical interest as well as by constraints imposed by suitability to relatively uncontrolled home environments and limiting the time needed per-participant (nevertheless, completing all tasks would take several hours). We first collected basic demographic data including age, ethnicity, gender, and education level. All participants were then invited to complete a core 'fundamentals of perception' section, which comprised 7 tasks: colour preference, neon colour spreading, self-reported visual and auditory imagery, the Ebbinghaus and Müller-Lyer illusions, the McGurk effect, the Mooney face test, and a synaesthesia questionnaire. Over 35,000 people completed this section. Participants were then able to complete the remaining 9 sections in whichever order they chose. These sections explored topics including the perception of colour, music, and time, as well as sensory precision, imagery, the influence of perceptual expectations, and susceptibility to illusions of various kinds. Over 3,400 participants completed all 10 sections. Participants who had reported a form of synaesthesia were invited to take part in an additional synaesthesia section which implemented various tasks depending on the nature of the synaesthesia reported. Initial analysis of the Census data, to be presented at ASSC, will report on the demographic makeup of the dataset, as well as the results of a descriptive analysis. This analysis will compare task-wise performance with previously reported data for each task based on a literature survey, and will also examine demographic influences. Additional analyses, focusing on relations among different tasks, are being carried out based on pre-registered plans. Pre-registrations were developed either before accessing any data, or after examining small (participant n=100) data samples from the relevant tasks - samples which will be excluded from the pre-registered analysis. The full dataset is closed until the initial set of pre-registrations has been uploaded. We intend The Perception Census to provide a community resource for studies of perceptual diversity, and in particular to stimulate hypothesis generation for future research. All data will be made easily accessible in a fully anonymised form, accompanied by access to each task implementation. The Perception Census showcases the potential of deep collaboration between scientists, artists, and technologists. The creative interdisciplinary development was critical in many aspects, including the Census design and general approach, in reaching large and diverse participant groups, and in optimising language, usability and accessibility for public engagement via many iterations of user-group testing.

Suppression from visual awareness is uniform regardless of image type in a new 'tracking' version of Continuous Flash Suppression

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Concurrent Session: Perception 1, Wednesday July 3rd, Ito Hall, Ito International Research Center, 5:00PM-7:00PM

When the eyes view separate, incompatible images, the brain suppresses one image and the other is perceived. This interocular suppression can be prolonged by presenting a dynamic stimulus to one eye, resulting in continuous flash suppression (CFS) of the static image. The time required for a suppressed image to break into awareness (bCFS) is often used to investigate unconscious processing and has led to controversial claims about visual processing without awareness. Advocates interpret faster bCFS times to as evidence for unconscious high-level processing of suppressed images, while opponents claim breakthrough times are simply due to differences in low-level stimulus properties. bCFS data cannot resolve this debate as it only provides a breakthrough threshold. A suppression threshold is needed as a baseline to quantify the change from unawareness to awareness. Our new 'CFS tracking' paradigm (tCFS) measures both thresholds: a suppressed image steadily increases in contrast until breaking suppression (indicated by a key press) and then decreases until it again becomes suppressed (indicated by another key press), and so on in a continuing cycle. Using tCFS we confirm that: (i) there is variation in breakthrough thresholds across target types (e.g., grating vs face), as bCFS has shown, (ii) suppression thresholds show the same pattern of variation, and therefore (iii) the depth of suppression is the same for all images. In particular, we find no evidence for the commonly claimed priority access to awareness of fearful faces. Uniform suppression depth indicates a single mechanism of CFS suppression, one likely occurring early in visual cortex prior to stages that process image identity and semantics.

Elucidating the Mechanisms: A Top-Down Cortical Circuit for Somatosensory Perception

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Concurrent Session: Perception 1, Wednesday July 3rd, Ito Hall, Ito International Research Center, 5:00PM-7:00PM

Elucidating the circuit mechanisms underlying perception constitutes one of the principal challenges in neuroscience. Several theories of perception emphasize the important role of long-range projections, including bottom-up and top-down inputs. These theories are being tested by many studies of the neural correlates of perception in monkeys and humans. However, it remains unclear how such hierarchical interactions contribute to perception due to methodological limitations in dissecting and manipulating circuits precisely in time and space in primate research. We have previously reported a recurrent hierarchical circuit consisting of cortical long-range projections between the secondary motor cortex (M2) and the primary somatosensory cortex (S1) in mice (Manita et al., Neuron 2015). Furthermore, somatosensory stimulation sequentially induced activity in S1, M2, and S1 on the recurrent circuit. M2 top-down input can trigger dendritic spikes and burst firing in S1 neurons. Based on these results, we hypothesized that the M2 top-down projection to S1 contributes to somatosensory perception. Here, we tested this hypothesis using optogenetic, chemogenetic, pharmacological, and lesions of the circuit during a somatosensory stimulus detection task. We defined a perceptual detection threshold in each mouse that performed the behavioral task and investigated how the threshold changes with circuit manipulations. First, we found that S1 and M2 lesions, pharmacological and optogenetic inhibition of each area significantly increased the threshold, indicating impaired perception. Pathway-specific optogenetic and chemogenetic inhibition of both the S1->M2 bottom-up and M2->S1 top-down projections also impaired perception. These results suggest that the S1-M2 recurrent circuit contributes to perception via bottom-up and top-down inputs. Next, we tested whether activation of either bottom-up or top-down projections is sufficient for somatosensory perception. Pathway-specific optogenetic activation of both S1 bottom-up and M2 top-down projections was able to induce illusory somatosensory perception. Finally, we investigated which pathway is closely correlated with perception. Pathway-specific activation of M2 top-down inputs with pharmacological M2 inactivation was able to induce illusory perception. In contrast, activation of the S1 bottom-up input with pharmacological S1 inactivation impaired perception. These outcomes lend support to our hypothesis, suggesting that somatosensory perception necessitates the activation of S1 mediated by recurrent top-down inputs from M2.

A neural basis for distinguishing reality from imagination

Nadine Dijkstra (UCL), Peter Kok (UCL), Stephen Fleming (UCL)

Concurrent Session: Perception 1, Wednesday July 3rd, Ito Hall, Ito International Research Center, 5:00PM-7:00PM

Our conscious visual experience can either reflect the current environment ("reality") or internally generated scenarios ("imagination"). Neuroimaging studies have shown that imagination and perception are encoded in highly similar patterns of brain activity throughout the human visual cortex. It remains unclear how, given this overlap, the brain keeps track of whether visual activity reflects reality or imagination. In this study, we used a novel experimental paradigm in combination with fMRI to investigate the neural correlates that distinguish reality and imagination in healthy participants. Participants were instructed to simultaneously detect and imagine either the same (congruent) or different (incongruent) stimuli while looking at dynamic noise.

Behaviorally, congruent imagery was associated with an increase in the likelihood of reporting the presence of a real stimulus (an increase in both false alarms and hits). In turn, judging that a real stimulus was present during congruent imagery was associated with higher imagery vividness. In the brain, we found that the same brain regions, especially the bilateral fusiform gyrus (FG) and intraparietal cortex (IPS), tracked variation in both imagery vividness and judgments of perceptual presence using similar neural codes. Finally, representations of the perceived stimulus in the right FG were increased during congruent compared to incongruent imagery conditions. Importantly, signals in these areas were stronger when stimuli were judged to be real. Taken together, our results are in line with a model in which imagined and perceived signals are intermixed at the level of the ventral visual and parietal cortex, and that the strength of these mixed signals determine whether they are experienced as real.

CFS as TMS: Phenomenologically distinct perturbations of visual content at different timescales

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Concurrent Session: Perception 1, Wednesday July 3rd, Ito Hall, Ito International Research Center, 5:00PM-7:00PM

How do visual contents unfold over time? Over the last three decades, evidence supporting the thesis that awareness evolves over multiple timescales has grown. This has come from clustering timing of perceptual processes over distinct timescales (Pöppel, 2004), temporal phenomenology (Singhal & Srinivasan, 2021), and neural dynamics of awareness (Varela,1999). However, these findings have not made headway in changing the way consciousness theories formulate evolution and devolution of visual content. Almost all theories of consciousness posit single timescales of processing (ranging between 100-500 milliseconds), with disagreement only about how long it takes to become aware of a stimulus (Kent & Wittmann, 2021). In an effort, to allow findings from temporal-phenomenology to inform theories of consciousness, we developed a new variant of the continuous flash suppression (CFS) paradigm. The original CFS paradigm stipulated using a suppressor which flickers at a rate of 10Hz as it matched the transient cycles of visual awareness. Drawing predictions from a hierarchical framework of temporal phenomenology (Singhal & Srinivasan, 2021), we reasoned that different flicker rates of the suppressor should be able to perturb phenomenologically distinct tasks. We modulated the flicker frequency of the suppressor at four different rates (1, 4, 10, and 25 Hz). Thereafter, we designed four tasks which were predicted to have distinct phenomenological and temporal regularities (N = 48). For instance, we tested temporal regularities of content entering visual awareness using a simple breakthrough task (Experiment 1). To see the dynamics of sampling of content we used a spatial attention task (Experiment 2). To show that perceptual integration has its own temporal regularity, we tested the flicker frequencies at which illusory contours show no priority in a CFS task (Experiment 3). Finally, to show that visual contents exit awareness asymmetrically, we reversed the CFS task to see which flicker frequency slows down suppression of a target that is initially visible. We expected and found that performance was maximally inhibited at different flicker frequencies in different tasks. Participants were slowest in reporting breakthrough of targets into awareness when the mask flickered at 4 Hz (Experiment 1). Similarly, in the spatial attention task, performance was slowest when the suppressor flashed at 10 Hz (Experiment 2). In Experiment 3, the priority that illusory contours receive in breaking out of suppression was absent when the suppressor flickered at a rate of 25 Hz. Finally, in experiment 4, we found that visual targets exited awareness slowest when the suppressor flickered at 1 Hz. Overall, the four experiments put together showed that entry of contents into conscious awareness, their attentional sampling, perceptual grouping, and exiting from awareness all happen at distinct temporal regularities. The results from the study allow elucidating multiple timescales of awareness from a single consciousness paradigm. Our demonstration shows that (i) different flicker frequencies maximally hinder different tasks of visual awareness, (ii) wherein these flicker frequencies systematically map onto temporal hierarchies of timing of awareness, and (iii) these tasks have distinct phenomenological modes (temporal extension, retention, and frame-like) consistent with their different temporal regularities.

Harnessing AI to generate pictures of mental images from human brain activity

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Concurrent Session: Perception 1, Wednesday July 3rd, Ito Hall, Ito International Research Center, 5:00PM-7:00PM

The task of reconstructing seen images from brain activity–in which subjects view images under fMRI that are later decoded and reconstructed using generative AI–has received a lot of attention in contemporary research efforts. Fueled by recent leaps in generative models such as Stable Diffusion, and the release of large-scale functional magnetic resonance imaging (fMRI) datasets like the Natural Scenes Dataset (NSD) (Allen et al. 2021), researchers have been able to reconstruct seen images from fMRI with unprecedented accuracy. However, it is untested and unclear whether these methods can decode private conscious states such as mental imagery. Successful high-fidelity reconstructions of mental images have numerous potential applications in consciousness science, from introducing new diagnostic tools for patients with disorders of consciousness in clinical settings, to providing a channel to directly examine the content of internal conscious states in research settings.

While fMRI data recorded during mental imagery often has a much weaker signal-to-noise ratio when compared to data collected during vision, the two modalities of experience do share significant similarities in their representational structure in the visual cortex (Naselaris et al. 2015). This suggests that existing reconstruction methods, trained on data collected during vision, might exhibit some degree of generalizability when extended to instances of mental imagery. Our work examines this hypothesis by analyzing the fMRI brain activity of the NSD subjects during a held-out scanning session where the subjects were instructed to imagine a discrete set of images. We test how several recently released seen image reconstruction methods–including MindEye1 (Scottie et al. 2023), MindEye2 (Scotti et al. 2024), Brain Diffuser (Ozcelik et al. 2023), Brain-Optimized Inference (Kneeland et al. 2023), and the method proposed in (Takagi et al. 2022)–generalize to this dataset and reconstruct the visual content present in the subjects' mental images. Our findings reveal that modern vision reconstruction methodologies can be successfully applied to instances of mental imagery, and provide a massive leap in reconstruction quality and accuracy compared to previous approaches. Across the majority of methods tested, we were able to produce reconstructions that broadly capture similar or identical object classes and significant amounts of structural content.

One of the most exciting applications of these methods is disambiguating what contents are contained in a mental image from the subset of those contents that are consciously accessible to the subject. For example, aphantasics report no conscious experience of any content but can still perform various downstream tasks that would seem to depend upon a mental image. Our results produce reconstructions with sufficiently high fidelity to be useful in cases that require examining mental images independently of the subject's conscious experience, and can potentially facilitate entirely novel research directions within mental imagery research and consciousness science.

The central neural mechanisms of afterimage perception: A whole brain and cortical layer fMRI study

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Concurrent Session: Perception 1, Wednesday July 3rd, Ito Hall, Ito International Research Center, 5:00PM-7:00PM

Afterimage perception is a common kind of sensory perseveration that typically follows adaptation to light stimulation. The neural mechanisms of afterimage perception and its relationship to other categories of conscious perception (e.g., vision and imagery) have been minimally studied. In a recent investigation, we reported a relationship between the perceived vividness of afterimages and imagery. This and other findings (e.g., conditioned afterimages and afterimages induced by illusory images) indirectly support the role of central neural mechanisms in forming and modifying afterimage perception. To directly interrogate the neural basis of afterimage perception, the current experiment recorded whole brain (BOLD; voxel size: 1.2 mm3; TR: 1000 ms; 7T; Siemens, Inc.) and primary visual cortex (V1) fMRI (BOLD/VASO; voxel size 0.8 mm3; TR: 1500 ms, 7T; Siemens, Inc.). fMRI processing was performed primarily using the AFNI toolbox. During recordings, healthy, adult participants (N = 34 whole brain; N = 13 V1) perceived images and afterimages. Afterimages were induced by a face silhouette image. The image stimulus or so-called mock afterimage was a version of the face silhouette image that was manipulated in brightness, sharpness, and duration to perceptually-match each participants' afterimage perception. Perceptual matching was achieved in an afterimage subjective experience, self-reporting task phase completed outside the scanner. Perceptual matching was successful, as the majority of participants believed that they were perceiving real afterimages when viewing their mock afterimage – analogous to the Perky Effect. Preliminary whole brain fMRI results show that the mock and real afterimages involve similar subcortical and cortical networks, including sensory regions (e.g., VI and fusiform gyrus [FG]), arousal and neuromodulatory regions (e.g., thalamus and brainstem), salience regions (e.g., insula and anterior cingulate cortex), and attention/detection regions (e.g., posterior parietal cortex [PPC] and dorsal lateral prefrontal cortex [DLPFC]). Meanwhile, the mock afterimage revealed greater fMRI responses relative to the real afterimage in FG, PPC, and DLPFC, and real afterimage revealed fMRI decreases absent for the mock afterimage, particularly in the prefrontal cortex. Preliminary analyses of the V1 fMRI suggest that the mock afterimage involves larger signals in the middle cortical layer (feedforward dominant). Meanwhile, the afterimage involves larger signals in the deep cortical layer (feedback dominant). Overall, these findings detail the role of central neural mechanisms in afterimage perception and help explain previous results that show afterimages are perceptual-linked to other categories of sensory-independent perception (e.g., imagery and hallucination).

Critical energy landscapes: The spin glass as a model of psychedelic action

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Concurrent Session: Psychedelics, Wednesday July 3rd, Gallery 1, Ito International Research Center, 5:00PM-7:00PM

Background: Statistical physics studies the emergent, large-scale behaviour of systems composed of a great many small-scale parts, and as such, it presents a natural framework for understanding how the brain's billions of neurons come together to shape a single human-scale consciousness. Statistical physical concepts of critical phase transitions (Atasoy et al., 2017; Varley et al., 2020; Toker et al., 2022; O'Byrne & Jerbi, 2022; Gervais et al., 2023) and energy landscapes (Singleton et al., 2022) have been proposed to underlie changes in consciousness under the effects of psychoactive substances such as psychedelics, but to date, these characterizations have lacked a formal connection. We propose that an elegant connection exists within a simple and well-studied model of statistical physics known as a 'spin glass'. Essentially, a spin glass is a network of coupled binary nodes where each pairwise coupling can be either positive or negative. When its temperature, or randomness, dips below a critical point, the frozen enmeshment of interactions yields an energy landscape over its possible states, which becomes the more rugged as the temperature falls. Classic psychedelics, we hypothesize, have the effect of raising the spin-glass temperature of the brain, such that the normally rugged energy landscape over brain states becomes flatter, and hitherto hidden valleys of conscious states become accessible.
Methods: We tested this model in 15 volunteers who underwent magnetoencephalographic (MEG) recording during infusion of psilocybin, a classic psychedelic, in a placebo-controlled, within-subjects design (Muthukumaraswamy et al., 2013). Using maximum entropy modelling (Tkacik et al., 2015; Ezaki et al., 2020), we fitted the individual MEG time courses to a spin-glass model and evaluated the distance of their dynamics to the spin-glass (critical) phase transition. Before fitting, we bandpass-filtered the MEG signal in the alpha (8-12 Hz) band, as this band is associated with perceptual processes (Klimesch et al., 2012) and subjective psychedelic effects (Muthukumaraswamy et al., 2013; Timmerman et al., 2019, Alamia et al., 2020). For comparison, we also applied some "classical" metrics of avalanche criticality (Beggs & Plenz, 2003) and the edge of chaos (Toker et al., 2022).
Results: In accordance with our hypothesis, we found that brain dynamics under placebo were situated in the spin-glass phase, corresponding to a rugged energy landscape, and that psilocybin had the effect of pushing brain dynamics out of this phase and towards the spin-glass transition ($t=2.57$, $p<.05$), thereby flattening the energy landscape. This shift was largely explained by a reduction of the average magnitude of couplings in the inferred spin glass network ($t=3.37$, $p<.01$), as well as a reduction in the intrinsic bias of each node ($t=4.12$, $p<.01$). Meanwhile, no significant effects of psilocybin infusion were found for the tested avalanche and chaos metrics.
Conclusion: We showed that psilocybin has the effect of bringing brain dynamics closer to the spin-glass phase transition, while other "classical" criticality metrics are less affected. Altogether, our results showcase the spin glass model as a promising framework for understanding altered states of consciousness in terms of phase transitions in the emergent action of neurons.

Quantifying emergence in brain activity under psychedelics

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Concurrent Session: Psychedelics, Wednesday July 3rd, Gallery 1, Ito International Research Center, 5:00PM-7:00PM

Many researchers believe that consciousness is an emergent property of brain activity. Emergence is a hotly debated philosophical issue, yet to date there have been relatively few quantitative measures of emergence. Recently, Rosas, Mediano, and colleagues developed an information-theoretic framework for measuring two types of emergence, including downward causation: the irreducible causal power of macroscopic features over the individual parts of a system (Rosas, Mediano et al., 2020). Here, we apply the framework to previously-acquired magnetoencephalography (MEG) data of healthy human participants under the influence of lysergic acid diethylamide (LSD), a psychedelic drug that induces strongly altered states of consciousness (Carhart-Harris et al., 2016). We measured periods of transient synchronisation in the MEG data, which we refer to as metastable oscillatory modes (MOMs) (Cabral et al., 2022). Compared to the timeseries of individual brain regions, MOMs can be considered a higher-order, emergent property of brain activity. Firstly, we find that LSD significantly reduces the number and duration of MOMs in the data, which is consistent with prior findings that LSD decreases brain synchronisation. Secondly, we define downward causation based on the extent to which the MOMs determine the future dynamics of individual brain regions more than the pasts of each region do. We show that downward causation is significantly greater on placebo compared to LSD, across multiple experimental conditions and frequency bands. To our knowledge, this is the first study demonstrating the effect of psychedelics on emergent brain activity.

A perturbational whole brain modelling approach exploring the efficacy of psychedelic treatments in DoC patients.

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Concurrent Session: Psychedelics, Wednesday July 3rd, Gallery 1, Ito International Research Center, 5:00PM-7:00PM

Current theories linking brain complexity to consciousness posit psychedelic drugs as promising treatments for Disorders of Consciousness (DoC). This includes patients in the unresponsive wakefulness syndrome (UWS) and minimally conscious state (MCS). Computational modelling offers an ethical precursor to experimental work which can guide future empirical studies. Here, we introduce a novel approach to simulate the effects of Lysergic Acid Diethylamide (LSD) in DoC patients.

We built whole brain computational models of patients with DoC, for the first time at the single subject level. Each brain region's dynamics (AAL90 parcellation) were modelled by the normal form of a supercritical Hopf bifurcation (Stuart-Landau oscillators). The local dynamics were coupled through the empirical patient structural connectivity (SC) from DWI tractography. We firstly optimised the global coupling parameter via minimising the Kolmogorov-Smirnov distance between the simulated and empirical functional connectivity (FC). Subsequent optimization of local bifurcation parameters employed a genetic algorithm guided by the FC and constrained to a nine-parameter space identified through independent component analysis. To simulate the application of LSD, the changes in parameters between the drug state and the non-drug state in healthy controls were applied to patient models. Using this framework, we simulated the administration of LSD on patients with DoC. We assessed simulated treatment effects by calculating the perturbation integration latency index (PILI) at both the baseline and the LSD state, a measure of instability which quantifies the recovery of a perturbed brain region to its basal dynamical state. The change in PILI between the baseline and drug state then acted as a proxy for theoretical treatment response. We used previously acquired fMRI data from DoC (23 UWS, 29 MCS) and 12 healthy controls (HC) after LSD and placebo.

Group-level analysis showed a significant increase in PILI in healthy controls under LSD compared to placebo ($t=2.4$, $p<0.001$). PILI was higher at the individual level for MCS than UWS patients ($z=2.32$, $p=0.02$), and for HC compared to UWS patients ($z=3.73$, $p<0.01$). No difference was observed between MCS patients and controls ($z=1.94$, $p=0.05$). Simulations of LSD treatment on patient models led to significant PILI increases in MCS ($t=6.6$, $p<0.01$) and UWS ($t=3.43$, $p<0.01$) patients. The mean FC correlated with the treatment-related increases in PILI for MCS patients ($r=0.6$, $p<0.0001$) but not for UWS patients. Furthermore, whilst regional changes in PILI were not associated with regional FC in patients, PILI results were associated with FC in MCS within certain resting state networks, such as the limbic ($r=0.54$, $p<0.001$) and default mode network ($r=0.53$, $p<0.001$). In UWS patients, the treatment associated PILI changes were linked to the mean strength of SC ($r=0.67$, $p<0.01$).
The observed PILI increases during psychedelic simulations suggest that these treatments may shift the brain of DoC patients towards a more critical regime, enhancing sensitivity to perturbations—a foundational concept for this therapeutic approach. We also identify potential biomarkers for treatment efficacy. Specifically, in MCS patients higher mean and network FC is associated with a larger modelled treatment. Conversely, in UWS patients, SC strength was correlated to treatment response.

Mapping the space of altered states of consciousness

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Concurrent Session: Psychedelics, Wednesday July 3rd, Gallery 1, Ito International Research Center, 5:00PM-7:00PM

Altered states of consciousness are defined as a transient change in the overall pattern of subjective experience. States of consciousness are increasingly better understood across a spectrum ranging from unconsciousness (e.g., coma or anesthesia) to the waking state. However, there seems to be no unified approach for capturing qualitative diversity manifesting within conscious wakefulness. We suggest that the specificity of deviations from the ordinary/baseline state can be probed to outline the space of states of consciousness. A fundamental challenge seems to lie in identifying the dimensions that can effectively structure the coarse-grained representation of the phenomenological landscape. The goal of this study was to create the empirically grounded classification of pharmacologically induced altered states using a bottom-up approach. In a large-scale preregistered study (n = 739), participants assessed the dissimilarity between pairs of vividly remembered experiences associated with the use of particular psychoactive substances. The ratings were given on a continuous labeled dissimilarity scale, originally used for capturing unimodal qualia spaces such as for colors or odors. We employed the multidimensional scaling technique (MDS) to create models representing the averaged dissimilarity ratings between states as distances in a geometric space. First, we observed that states induced by pharmacologically similar substances were clustered in close proximity, which served as a control validation for our methodology. Importantly, the resulting 2-D model was organized in a way that allowed phenomenological interpretation. The primary dimension, interpreted as the 'intensity of mind alteration', positioned baseline alongside states evoked by stimulants, and depressants at one end, while situating psychedelic- and dissociative-induced states at the other. The second dimension covered the inhibition-stimulation spectrum, ranging from states evoked by depressants and opioids to classical stimulants. The MDS analysis was complemented by the use of other multidimensional reduction techniques (such as PCA, UMAP, and t-SNE), which enabled us to preserve subject-level information. Consequently, we obtained a set of empirically grounded geometric models that expose the basic dimensions along which diverse experiential phenomena may vary from one another. We propose that such avenue of research might eventually inform our understanding of the dimensionality, topology, and metrics that underlie the landscape of states of consciousness. While the question of "how to regard altered states – for they are so discontinuous with ordinary consciousness" remains pertinent, we agree that "no account of the universe in its totality can be final which leaves these other forms of consciousness quite discarded" (W. James, 1902, p. 388).

Integrative Neuroimaging Approach in Assessing Disorders of Consciousness: A Multimodal Interpretable Machine Learning Study

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Concurrent Session: Disorders of Consciousness 1, Wednesday July 3rd, Gallery 1, Ito International Research Center, 5:00PM-7:00PM

Patients with disorders of consciousness, following brain damage, sometimes present a disconnection between observable behavior and internal conscious processes. To bridge this dissociation, neuroimaging techniques are utilized to assess residual brain functions, where each modality captures different aspects of brain preservation—functional, anatomical, or both. This study aims to use integrative neuroimaging to understand the characteristics of disrupted consciousness. By comparing different metrics of anatomical and functional brain region preservation across modalities, we distinguish between markers of current consciousness disruption and signatures of consciousness recovery.

We adopt a multicentric, comprehensive approach by integrating neuroimaging scans through interpretable machine learning. The included scans are high-density EEG (resting state and a two levels Local-Global auditory regularity task), anatomical and resting-state functional MRI (aMRI and RS-fMRI), Diffusion Weighted Imaging (DWI), and Positron Emission Tomography (PET). The study is multifaceted, focusing on both clinical aspects and fundamental neuroscience of consciousness. From a clinical standpoint, we investigate the patients' present condition (diagnosis) and future progression (prognosis). We employ unimodal models to assess the significance of individual modalities and multimodal models to evaluate combinations of modalities. From a theoretical standpoint, our investigation aims to elucidate how different neuronal processes in subcortical areas and cortical networks, indexed by various neuroimaging modalities, offer insights into the theoretical underpinnings of consciousness.

Unimodal neuroimaging models exhibited diverse accuracies in diagnosing and predicting patients' outcomes, underscoring their complementary nature in capturing distinct facets of patient conditions. Functional scans like PET and EEG proved most informative for diagnosis, while aMRI scans gained predictive utility for prognosis, with DWI emerging as the most informative.

Analysis of feature importance revealed distinct patterns in the relevance of brain regions. For diagnosis, the Somato-Motor, Visual, and Default mode networks ranked high in importance scores, while their relevance diminished for predicting patient evolution. Conversely, subcortical areas gained importance for prognosis, and the Control network emerged as highly informative. In EEG-based classifiers, low-frequency spectral bands were most relevant for diagnosis, whereas high-frequency bands were critical for prognosis.

Incorporating multiple modalities enhanced predictive accuracy, more so with the inclusion of demographic and etiological data. Prediction disagreements were observed between modalities, with notably higher discrepancies in patients in a Minimally Conscious State versus those in an Unresponsive Wakefulness Syndrome. Both findings highlight the modalities' complementarity and the significance of additional patient information.

Our study underscores the potential of integrative neuroimaging coupled with interpretable machine learning in unraveling the intricate mechanisms of disrupted consciousness. Through an in-depth analysis of feature importance across subcortical regions and cortical networks, we glean crucial insights into the neural signatures characterizing patient conditions. Moreover, our examination of cross-modal discrepancies potentially sheds light on complex phenomena such as functional hemispherectomies, covert cognition, or islands of residual cortical activity. These multimodal findings enhance our understanding of diagnostic and prognostic neural signatures and open new avenues for probing the underlying mechanisms of disrupted consciousness.

Exploiting interactions between EEG markers of consciousness for patients with disorders of consciousness

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Concurrent Session: Disorders of Consciousness 1, Wednesday July 3rd, Gallery 1, Ito International Research Center, 5:00PM-7:00PM

Introduction: Patients with disorders of consciousness (DoC) present a diagnostic challenge due to their inability to communicate and variability among etiologies. Clinicians diagnose DoC using the coma recovery scale - revised (CRS-R), categorizing patients into Unresponsive Wakefulness Syndrome (VS/UWS), Minimally Conscious State (subcategorized into MCS+ and MCS-), and Emergent Minimally Conscious State (EMCS). However, reliance on subjective assessments and patient behavior limits its objectivity. EEG protocols compute markers based on consciousness theories, aiding in predictive modeling with machine learning algorithms. Despite their proven diagnostic value, little attention has been given to the effective information they provide. Specifically, the degree of redundancy and synergy in describing conscious states, as well as the true dimensional space of the conscious states information they provide, remains unexplored. Method: We employed two EEG protocols: a Resting State and an Auditory Task. After preprocessing the EEG, we computed the Power Spectral Densities (PSD), Permutation Entropy (PE), Weighted Mutual Symbolic Information (wSMI), Power Spectral Summaries (PSDS), and Kolmogorov Complexity (KC). Computing the mean and standard deviation across channels resulted in a total of 34 markers to characterize the patients DoC state. Next, we computed the mutual information (MI), which quantifies shared information between markers, and O-information (Í≠•), which assesses the balance between synergy and redundancy between 3 or more markers. MI was calculated for all marker pairs, while Í≠• was exhaustively computed for every marker combination, ranging from triplets (order 3) to sets of fourteen (order 14). To understand the influence of each marker within the entire system, we constructed graphs depicting the markers' synergistic relationships for each order, then computed eigenvector centrality to gauge a marker's centrality in interactions of that particular order. Finally, we employed various dimensionality reduction techniques such as PCA, UMAP, and Auto-Encoders. These methods aimed to preserve most of the information contained in the markers while eliminating redundancy and exploiting synergies to obtain a lower-dimensional representation. Results: The markers displayed significant mutual information, spanning various families and aggregations (mean and std). Synergy peaked at orders 8-9 before declining, with no further synergistic interactions beyond order 13. We successfully reduced the markers to eleven dimensions while preserving 90% of the information. Finally, Centrality analysis highlighted a subset of markers with increasing centrality driving most of the effective information dynamics (PSD_summaries_sef/std$_{90,95}$, PSD/std$_{\text{Œ±,Œ¥,Œ∏}}$, PSD/mean$_{\text{Œ¥,Œ∏}}$, wSMI/mean$_{\text{Œ±,Œ≤}}$, wSMI/std$_{\text{Œ∏}}$), while the rest of the markers have decreasing centrality. Conclusions: Our results suggest that markers of consciousness provide both redundant and synergistic information and suggest a lower-dimensional space for conscious states information. Notably, synergy peaked at order 8 and exists until order 13, aligning with optimal linear reduction up to 11 dimensions and with an existing set of 10 different central markers, enabling an effective and more disentangled dimensionality reduction. Synergistic interactions between diverse families of markers could reflect different aspects of brain dynamics. Finally, our results resonate with multi-dimensional approaches to consciousness rather than with uni-dimensional ones, giving support to a more complex and less reductive measurement of consciousness.

In-phase and anti-phase acoustic stimulation alter arousal thresholds during dexmedetomidine sedation via distinct neural mechanisms

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Concurrent Session: Disorders of Consciousness 1, Wednesday July 3rd, Gallery 1, Ito International Research Center, 5:00PM-7:00PM

Background—Characterizing the neurophysiological mechanisms determining the threshold for arousal during sedation is a fundamental question in neuroscience and of marked clinical impact. Here, we utilize results obtained from an interventional trial combining acoustic stimulation during sedation and electroencephalography (EEG) to investigate the impact of different types of acoustic stimulation on arousal thresholds.

Methods—While deeply sedated with dexmedetomidine titrated to achieve loss of responsiveness and induction of EEG delta oscillations (0.5-4Hz), participants (n=13; mean age:27.7±5.6 years; 4 female) were exposed to three acoustic stimulation conditions, using a balanced crossover study design: in-phase (stimulation phase-locked to delta-wave upslopes of channel Fz), anti-phase (stimulation phase-locked to delta-wave downslopes of channel Fz), and sham (silence). Peripheral thermal stimulation was then sequentially applied during each type of acoustic stimulation, until the participant displayed purposeful behavior, as determined by volitional behavioral tasks. High-density (64-channel) EEG recordings were acquired during acoustic and thermal stimulation to assess the effect of acoustic stimulation on the underlying neuronal dynamics and behavioral responsiveness thresholds.

EEG recordings were processed using MATLAB/Python. Three metrics were computed for each 2-minute EEG recording: phase coherence, phase-amplitude coupling (PAC), and band-power, across different frequency bands (delta:0.5–4Hz, theta:4–8Hz, alpha:8–13Hz, beta:13–30Hz, gamma:30–50Hz).

Results—Collectively, we established that in-phase and anti-phase acoustic stimulation during sedation impacts arousal thresholds, by distinctively modulating the coupling between the phase of delta frequencies and amplitude of higher frequencies in the theta, alpha, and gamma bands. Our results were four-fold: (1) In-phase stimulation led to significantly higher arousal thresholds, compared to anti-phase and sham stimulations (repeated-measures [rm] ANOVA:p=0.045). Moreover, in-phase stimulation was associated with increased coupling between delta phases and theta amplitudes across the whole brain (rmANOVA:p=0.042); in fact, delta-theta PAC levels were found to significantly mediate the correlation between lower phase coherence among the frontal delta frequencies and higher overall arousal thresholds (bootstrapped confidence-intervals:[1.07,31.3]). (2)Conversely, anti-phase stimulation was associated with decreased coupling between delta phases and gamma amplitudes across the frontal channel Fz (rmANOVA:p=0.021); notably, lower levels of delta-gamma PAC were significantly associated with higher overall arousal thresholds (Spearman's rho=-0.78;p=0.003). (3)In the absence of acoustic stimulation (i.e., sham condition), there was a significant association between both lower levels of frontal alpha band-power and frontal delta-alpha PAC, with higher arousal thresholds (Spearman's rho=-0.59;p=0.033, and rho=-0.72;p=0.006, respectively). Critically, delta-alpha PAC levels strongly mediated the relationship between alpha power and arousal thresholds (bootstrapped confidence-intervals:[-0.32,-0.08]). (4)Lastly, we trained a deep neural network to predict arousal thresholds using each EEG channel's delta-theta, delta-gamma, and delta-alpha PAC values, delta phase coherence, and theta, gamma, and alpha band-powers. The predicted arousal thresholds were significantly correlated with the empirical values (Spearman's rho=0.58;p=3.1E-45), pointing towards the potential clinical utility of machine learning in predicting behavioral responsiveness from EEG signals.

Conclusions—Overall, we examine how different types of acoustic stimulation during sedation differentially impact the underlying electrophysiological properties of the brain, altering behavioral responsiveness thresholds. Elucidating such mechanisms could pave the way for the non-pharmacological manipulation of sedation duration—a pivotal step towards improving outcomes in patients receiving sedation in clinical settings and patients with sleep disorders.

Sleeping unaware: sleep-intrusions at the core of sleep state misperception

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Concurrent Session: Disorders of Consciousness 1, Wednesday July 3rd, Gallery 1, Ito International Research Center, 5:00PM-7:00PM

Introduction Sleep difficulties are of utmost importance for public health given their far-reaching consequences and high-prevalence. However, the diagnosis and treatment of sleep disturbances can be complex, notably because of a lack of robust markers for sleep quality. This difficulty is partly due to the frequent disconnection between what individuals report regarding their sleep quality and what classical sleep exams reveal. This discrepancy is also known as sleep state misperception (SSM) and is frequent in insomnia. SSM is an example of a mismatch between third and first person reports, as the former informs good sleep quality but the latter the opposite. Here, we hypothesize this mismatch in SSM may be given by intrusions of sleep-like activity during intra-sleep wakefulness. By analyzing a large database of polysomnographic (PSG) recordings we aim i) to provide a continuous characterization of sleep beyond the traditional sleep scoring and ii) to address the SSM mismatch by providing novel neural signatures of sleep quality.

Material and Methods More than a thousand of full-night PSG with their respective hypnograms were obtained from the Hotel Dieu Hospital (Paris) including Good Sleepers (GS), insomnia without SSM (INS) and SSM. We developed a novel analytic framework to harmonize PSG recordings differing in recording device, electrode layouts and sampling rates. By using machine learning techniques, we transformed each 30s epoch of the PSG into a probability distribution supported on the 5 sleep stages (W, N1, N2, N3 and REM), also known as hypnodensity. Then, the hypnodensities were analyzed with information theory to measure the level of intrusion of other sleep stages (entropy) and of instability (Kullback-Leibler divergence). We further interpreted these metrics in terms of the power spectrum and stage transition probabilities. Finally, we used these measures as markers to distinguish SSM from INS and GS.

Results We found that both INS and SSM showed intrusions of sleep stages into wakefulness, specially in intra-sleep wakefulness. SSM showed the largest intrusions. Conversely, INS showed large intrusions of wakefulness in sleep, while SSM did not. In addition, intra-sleep wakefulness was significantly more unstable for SSM than for INS and GS. We found that sleep intrusions into wakefulness positively correlated with power in lower frequencies (<8Hz), while wake intrusions into sleep positively correlated with power in higher frequencies (>10Hz). The stability, in turn, was correlated with the self-transition probabilities of each sleep stage. Finally, we obtained a classification accuracy for SSM of 0.8, overcoming any previous attempts of detecting SSM using PSG data.

Conclusions As recently proposed, SSM could be more related to a mismeasurement of sleep quality rather than to a misperception. In this line, we developed a method tailored to detect intrusions of wake-like activity into sleep and vice versa, which unveil the specific signatures of SSM. The implications of this work extend from clinical biomarkers to a deeper comprehension of sleep quality and potentially to an understanding of the neural signatures implicated in the metacognitive processes that monitor our inner states of consciousness.

The role of agency in self-motion perception

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Concurrent Session: Agent Theory, Wednesday July 3rd, Seminar Room, Ito International Research Center, 5:00PM-7:00PM

Agentive situations, i.e. situations in which the operator exercises intentional control over an action and its consequences, involve a perceptual modulation associated to the sensory consequences of these actions. Whether we're referring to the phenomena of intentional binding or sensory attenuation, many results suggest that the intentional nature of an action modulates the way the world is perceived. How this perceptual modulation is expressed when it comes to perceiving our own movement, however, remains largely unexplored as the study of visuo-vestibular integration remains largely focused on data collected during passive self-motion conditions. In this context, the work presented in this talk aims to explore the impact of agency on self-motion perception. From a methodological point of view, the impact of action control on self-motion perception was studied in two experiments. In experiment 1, participants had to discriminate between two consecutive longitudinal movements by identifying the larger displacement (displacement of higher intensity). In experiment 2, participants had to identify whether the movements generated at the physical (platform) and visual (virtual reality headset) levels were synchronous. These tasks were performed under two agency conditions: a Passive (automatic) condition where and an Active (manual) condition. We also manipulated the level of ambiguity of the stimuli. In experiment 1, we found an effect of control condition, but not of the level of ambiguity on the way participants perceived the standard displacement, i.e., perceptual bias (Point of Subjective Equality; PSE). Also, we observed a significant effect of interaction between the active condition and the level of ambiguity on the ability to discriminate between displacements, i.e., sensitivity (Just Noticeable Difference; JND) with a higher discriminatory sensitivity in Active condition, particularly in ambiguous context. In Experiment 2, we found that the propensity to experience synchronicity is greater overall in the active condition. In particular, this propensity is greater at the point of subjective simultaneity (or PSS), indicating better detection performance. In addition, the Temporal Binding Window (TBW) size and standard deviation are not modulated in the active condition, unlike in the passive condition. In particular, we observe an increase in standard deviation and an increase in TBW size in ambiguous context only for the passive condition. In other words, temporal discrimination sensitivity and acuity decrease with increasing ambiguity in the passive condition, whereas they remain stable in the active condition. Overall, our results indicate that being in control of our own motion through a manual intentional trigger of self-displacement maintains overall motion sensitivity when ambiguity increases. This condition was also accompanied by greater confidence and better metacognitive reliability. Because the Active condition was characterized by high predictability of the sensory consequences of the action, we therefore hypothesize that a lower prediction error in the Active condition enabled the multisensory mechanisms to be potentiated, leading to better perceptual performance, particularly in an ambiguous context. This raises the question of the extent to which this management of ambiguity could be extended to more ecological conditions such as the spatial disorientation observed in aeronautical context.

Mental action, affordances, and attribution: the case of BCI technology

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Concurrent Session: Agent Theory, Wednesday July 3rd, Seminar Room, Ito International Research Center, 5:00PM-7:00PM

Recent advances in neurotechnology like brain computer interface (BCI) and brain implants have brought attention to questions of mind, consciousness, and mental action (Peacocke, 2021). For instance, person X having Neuralink's implant "telepathy" can move their prosthetic arm simply by thinking of it. The neural activity in X's brain associated with wanting to move the arm allows for the implant to perform this action through its ability to read said neural activity and respond respectively. But is X's neural activity an effect of X's intentional action of wanting to move his arm or an effect of X's affordance of knowing the arm can be moved, i.e., being aware of the arm's "move-ability"? (McClelland, Representing our options: The perception of affordances for bodily and mental action, 2019) Is X's affordance or Telepathy's response considered mental action in such cases?

In this talk I explore the many facets of what mental action truly is by coupling extended cognition (Clarke & Chalmers, 1998) to present a case for mental action using BCI technology. Considering this, I adopt McClelland's Mental Affordance Hypothesis (McClelland, 2020) to consider four cases that bring us closer to understanding the nature of mental action through brain implants.

	Ordinary	Tech Assisted
Agential	Case 1	Case 2
Non-Agential	Case 3	Case 4

The four cases I cover aim to answer three main questions: (i) whether actions caused by a brain implant can be considered as mental action, (ii) whether X's affordance of the arm, i.e., X's knowledge of the move-ability of the arm, is the mental action?, and (iii) whether the definition of mental action itself changes once the implant is a part of X's brain, assuming the extended mind hypothesis. All cases use examples of both: external objects and their affordances, as well as internal affordances related to attending, recalling, and imagining.

Considering all cases, I argue that if the brain implant responds to X's affordance, then the brain implant is a contributor to mental action. Case 4, for instance, highlights such a situation wherein the brain implant does in fact act on X's affordance of the knowledge of the move-ability of the arm. Considering the prosthetic arm is an external object, X has an affordance of its move-ability. The implant's response to this affordance contributes to mental action.

This framework is not paramount with regards to what mental action or mental affordances are, nor does it explicitly state that person X's brain implant is a contributing factor of mental action. What I rather propose is an in-depth study of whether X's brain implant is capable of mental action in such a way assumed under the extended cognition theory. In this talk I dwell deeper into the notion of mental action, affordances, and the case of recall to further understand 4 cases in which one can ascribe mental action to the agent, and in some cases to the brain implant. Finally, I consider the ethical implications of such cases wherein BCI contributes to the patient's mental actions.

In conclusion, the time is ripe for a blueprint of mental action when it comes to brain implants like telepathy, especially since the hope of understanding brain-computer interfaces brings us closer to understanding and defining mental action, intentional action, executive control, and conscious experience in humans.

The Newman Problem of the Brain

Holger Lyre(University of Magdeburg)

Concurrent Session: Agent Theory, Wednesday July 3rd, Seminar Room, Ito International Research Center, 5:00PM-7:00PM

At the boundary of the brain (or the neural system in general) every incoming signal gets translated into one "currency": neural activity. Therefore, any "knowledge" about the nature of the distal causes perturbing the brain at its sensory surfaces gets lost. Moreover, the system works by change detection and relational coding: as our sensory organs are sensitive to changes only and as external changes get translated into changes of neural activity, we have, abstractly speaking, a transformation of external relational properties into internal relational properties. Neural relational coding is much in tune with the general idea of structuralism about the mind, i.e. the view that all mental states, whether intentional or phenomenal, are structurally (or relationally) individuated. For intentional states, this conforms to the notion of structural representation. For phenomenal states, this conforms to the recent proposal of neurophenomenal structuralism about consciousness. Structuralism, however, is vulnerable to a rather generic, model-theoretic problem: the Newman problem. The specific "Newman problem of the brain" takes the following form: from the perspective of the brain, neither the intrinsic nature of any external worldly causes nor their relational nature can be grasped. If this were true, then the brain "knows" nothing, the outside world remains completely hidden (or latent). This is nothing less than a skeptical scenario of the most extreme form. I argue that there is a solution to this conundrum. It works by "spatiotemporal grounding": spatial and temporal relations are indeed invariantly transferred from the external world to the neural system. The former through the multiplicity of neural activities, and the latter through their temporal signature. It remains an open question whether spatiotemporal grounding alone is sufficient to defeat skepticism.

Moore machines that maintain subjective points of view and can act in order to achieve goals

Martin Biehl (Cross Labs, Cross Compass)

Concurrent Session: Agent Theory, Wednesday July 3rd, Seminar Room, Ito International Research Center, 5:00PM-7:00PM

One approach to consciousness is to consider it as a property of systems with internal states, inputs and outputs i.e. open dynamical systems. The problem of defining consciousness then means defining under what conditions a given open dynamical system is conscious. Our findings can be seen as a step towards such conditions but are still far from complete. A prerequisite for there to be something that it is like to have an experience may be that the system maintains (or tries to maintain) a consistent subjective point of view over time. This is reflected for example in the information closure theory of consciousness but also implicit in the Free Energy Principle. Our recent work (Biehl and Virgo, 2022) has proposed a condition for an open dynamical system (in particular a Moore machine) under which it can be seen as consistently updating probabilistic beliefs about the causes of its inputs under the influence of its outputs. Here, consistently updating probabilistic beliefs is taken to mean using Bayesian belief updating. This should be seen as an example of a sufficient condition on Moore machines under which they have a consistent subjective point of view over time. However, it is not a necessary condition since there are alternatives to exact Bayesian belief updating (e.g. approximate Bayes). The condition should also not be seen as sufficient for consciousness since there is no notion of ``what it feels like'' to have such a consistent subjective point of view.

Nonetheless, it is a good starting point for formally investigating what distinguishes consciousness from just maintaining a consistent point of view. While our approach is similar to the Free Energy Principle, in particular because it considers probabilistic beliefs as parameterized by a notion of internal states, there are also some differences. Our approach is formulated for time discrete systems, has a simple formulation for deterministic systems, and only considers exact Bayesian inference. These features simplify the required mathematical and conceptual sophistication. In particular the consistency equation which must have some implicit analogue in the Free Energy Principle can be stated explicitly and without requiring any knowledge of continuous time stochastic processes or variational inference.

A second aspect of our work is that it provides a notion of “actions” that can be distinguished from mere “outputs” of an open dynamical system. A Moore machine consists of two parts, an output function and an update function. If the update function consistently updates beliefs, it does so independently from the way the output function choose outputs. We can then say that an output is an action if it is the optimal choice under the system’s beliefs in order to achieve a goal.

Biehl, Martin, and Nathaniel Virgo. 2023. “Interpreting Systems as Solving POMDPs: A Step Towards a Formal Understanding of Agency.” In Active Inference, edited by Christopher L. Buckley, et. al., 16–31. Communications in Computer and Information Science. Springer Nature Switzerland. https://doi.org/10.1007/978-3-031-28719-0_2.

The role of developing self-awareness in early social cognition

Victoria Southgate (University of Copenhagen)

Concurrent Session: Self and self-consciousness, Wednesday July 3rd, Seminar Room, Ito International Research Center, 5:00PM-7:00PM

Research suggests a common cognitive and neural basis for thinking about self and other (Fleming, 2022), and different positions argue that a self-awareness is necessary for awareness of other minds, or that a self-awareness results from our capacity for mind reading (Carruthers, 2009). In a recent theoretical account, I proposed that an initial absence of cognitive self-awareness in human development fosters conditions that enable infants to prioritize the attention and perspective of other agents, and its emergence in the second year of life initially creates a challenge for social cognition because infants must now confront conflicting perspectives (Southgate, 2020). I will present a series of studies suggesting that indeed, the emergence of self-awareness between 18 and 24 months radically changes infants' prioritization of perspectives. In one set of studies, only infants who evidence cognitive self-awareness show evidence of experiencing perspective conflict when self- and other- perspectives diverge, suggesting that self-awareness is implicated in an understanding of perspective. Using both pupillometry and fNIRS, we found greater pupil dilation in response to an event in which self and other perspectives differed, as well as increased blood oxygenation in right prefrontal cortex, implicated in conflict processing in previous studies with both infants and adults. This suggests that cognitive self-awareness confers awareness of one's own perspective, resulting in a perceived conflict with another agent's perspective. In another study with the same age infants, we investigated the relationship between emerging self-awareness and memory for self and other. Infants who evidenced cognitive self-awareness show the classic memory advantage for self-related items robustly documented in older children and adults. However, infants who do not yet show evidence of cognitive self-awareness show a reverse pattern, prioritising items that are relevant for another agent over items that are relevant for themselves. Together, this work reveals a close developmental relationship between developing self-awareness and infants' encoding of others in their environment and suggests that an emerging cognitive self-awareness initially creates the classic over-reliance on one's own perspective, well-documented in toddlers. Prior to this, infants may benefit from the absence of a cognitive self-awareness, facilitating the efficient tracking of others' attention at a developmental stage where their limited mobility may reduce the need for self-referenced encoding of the environment.

Self-other alignment and cognitive self-awareness in infancy

Dora Kampis (University of Copenhagen), Elisa Wiedemann (Central European University)

Concurrent Session: Self and self-consciousness, Wednesday July 3rd, Seminar Room, Ito International Research Center, 5:00PM-7:00PM

Coordinating self and other is an essential part of human interactions, and therefore of our mental lives. In young infants, recent theoretical proposals (Southgate, 2020) and empirical evidence (Kampis & Kovacs, 2022, Manea et al., 2023) points to an altercentric bias in encoding the world: a pronounced focus on the perspectives of others, and a lack of encoding as mental states as unique to individuals (Kampis et al, 2013). The lack of differentiation between self and other perspective may be linked to the emergence of self-awareness in the second year of life, as indicated by a decrease of altercentrism around infants' second birthday (Kampis et al., 2020). The current presentation will discuss how increased self-other differentiation is linked to the emerging self, and how this self-awareness may be linked to interpersonal alignment.

I will present data from two empirical studies that address how alignment is related to self-awareness in infants. The first probed whether infants are motivated to align with their caregiver and whether this relates to self-recognition (Kampis et al., 2022). Infants (16-26 months) were presented with a sticker on their parent's face. The infant was then offered a sticker, and we observed whether infants spontaneously placed the sticker in the same location on their own face. Infants also participated a mirror self-recognition task (Amsterdam, 1972), a commonly used marker of cognitive self-awareness. About half of the infants spontaneously put the sticker on themselves, and all who did, put it to the matching location as their caregiver. Crucially, children who placed the sticker to the matching location also tended to pass the mirror task (chi-squared (2, N=79) = 3.261, p= 0.035), indicating that their tendency to bring about a state to align with the caregiver is related to their self-awareness.

The second study investigates what mechanisms may facilitate alignment with others, and how this may relate to the development of self-awareness. Moving in synchrony with others fosters alignment, leading to more cooperation and social bonding (Mogan et al., 2017), and more willingness to help others, from 14 months of age (Cirelli et al., 2014). We investigate how interpersonal synchrony affects alignment with an experimenter at the cusp of emergence of cognitive self-awareness. After moving either synchronously or asynchronously with an experimenter, we measure 18-month-olds' motivation to align with her using the sticker task (Kampis et al., 2022), and mirror self-recognition. Data at n=22 infants tested show that mirror-passers in the synchrony group are more motivated to align their appearance with the experimenter's (they select the same sticker as the experimenter wears, chi-squared (1, N=9) = 5.625, p= 0.018), whereas non-passers synchrony shows no effect on alignment (1, N=8) = 1.905, p= 0.168). These data suggest that interpersonal synchrony is a cue to self-other alignment in infants, especially once self-awareness emerges. Together, these investigations speak to an interlinked ontogeny of awareness about oneself from the perspective of others, understanding differences between self and other, and to bring about alignment between self and other in infancy.

Revising Models of Body Ownership: Evidence from the Mirror Box Illusion

Jared Medina(Emory University)

Concurrent Session: Self and self-consciousness, Wednesday July 3rd, Seminar Room, Ito International Research Center, 5:00PM-7:00PM

Previous models of body ownership have proposed a series of comparators that need to be satisfied for embodiment to occur. Based primarily on findings from the rubber hand illusion, these models posit that the external object must have the same visual form and posture as one's own body for it to be embodied. After those comparators are satisfied, then participants refer touch to the location of the external object. Using evidence from the mirror box illusion, we conducted a series of experiments that challenge this model. In our first set of experiments, we used mirrors to create the illusion of a "disconnected hand" with no forearm. To do this, we placed a small mirror in which only their hand reflection was visible - with empty space where their forearm should be - while the participant's actual hidden hand located behind the mirror. We found that bimanual synchronous finger-tapping in this condition created illusory embodiment of the mirror-reflected hand sans-forearm, and (at times) the sense that their forearm was in empty space, demonstrating that embodiment can occur with an impossible visual form. During this illusion, we then touched the hand or forearm behind the mirror and asked participants to localize the touch. When embodying the invisible forearm, participants often reported feeling touch in the empty "forearm" space, suggesting that constraints from the body schema can override visual information, leading to out-of-body touch. Furthermore, participants dissociated where they felt touch versus where they located their hand, often reporting "embodiment" of the mirror-reflected hand while simultaneously localizing the touch to the actual hand location. These results demonstrate that embodiment is not necessary for tactile referral to occur. In a second series of experiments, we examined whether embodiment could occur when viewing a hand in an impossible posture. Participants viewed a biomechanically impossible hand reflection in a mirror directly facing them. After bimanual synchronous tapping, participants reported both embodiment of and tactile referral to the mirror reflected hand. Overall, these results demonstrate that embodiment and referred tactile sensations are separable phenomenon and support a revision of previous models of body ownership.

Lower Confidence and Greater Pupil Size when both Visual Mental Imagery and Working Memory are required for Problem Solving

Emaad Razzak (Columbia University), Tengyu Song (Columbia University), Tim Mousseau (Columbia University), Alfredo Spagna (Columbia University)

Concurrent Session: Mentary Imagery, Wednesday July 3rd, Conference Room, Ito International Research Center, 5:00PM-7:00PM

A chemistry teacher presents a complex molecular diagram asking students to grasp its geometry using mental rotation. Students are then presented with another molecule and are asked about reactivity with the previous diagram. Solving this problem requires visual mental imagery and working memory to visualize, retain, and manipulate the image. This synergy is critical in everyday tasks (e.g., allocating space in a suitcase) yet remains underexplored.

Forty-two participants completed one of four sets of 20 unique prompts, each with or without a relevant diagram shown. Participants read the prompt, referenced the diagram (if present), and provided their best answer out of four choices. Prompts that relied on mental imagery to be answered correctly were categorized as high imagery, as opposed to low imagery prompts. Some prompts were presented as standalone (without a diagram), and thus required no working memory. Other prompts were in a sequential pair. A diagram (required to solve both questions) was only provided during the first of a pair and absent during the second of a pair, necessitating working memory. We measured accuracy (25% chance level), confidence (1: not confident; 7: very confident), and the vividness of mental imagery (1: no imagery; 5: as vivid as real vision). A pilot group of three participants underwent a shortened version of the task with concurrent eye-tracking to replicate previously observed pupil dilation during imagery.

Questions with accuracy below 25% (chance level) were removed. The 3 (Working Memory) x 2 (Visual Mental Imagery) ANOVAs showed a significant interaction on vividness ($p < 0.02$) and confidence ($p < 0.001$), but not accuracy ($p = 0.15$; $\eta 2 = 0.06$). Vividness was greater only in standalone questions with high mental imagery (mean ± SD: 2.06 ± 1.0) compared to low mental imagery (1.46 ± 0.99; $p < 0.05$). Participants were more confident in answering low imagery, second of a pair questions compared to high imagery, second of a pair questions (high: 3.79 ± 1.35; low: 4.69 ± 1.44; $p < 0.001$). Results from the eye-tracking data comparing questions first of a pair versus second of a pair showed that pupil size was significantly larger for high imagery trials ($p < 0.001$) but not for low imagery trials ($p = 0.76$).

We observed a potent synergy between working memory and mental imagery for problem solving. We found decreased confidence and increased pupil size in trials where both processes were required. Interestingly, despite decreases in confidence, we did not observe a difference in vividness for high versus low second of a pair questions. This suggests a potential synergy between these processes, underlying an innate preference for using mental images to solve working memory problems. Alternatively, shared neurocognitive mechanisms could underlie these cognitive functions. Future replications on individuals who cannot conjure mental images (aphantasiacs) could adjudicate between these two explanations by showing an even greater reduction in confidence and no difference in pupil size in this group for trials requiring both mental imagery and working memory.

Temporal Structure of Mental Imagery

Ishan Singhal (IIT Kanpur), Nisheeth Srivastava (IIT Kanpur)

Concurrent Session: Mentary Imagery, Wednesday July 3rd, Conference Room, Ito International Research Center, 5:00PM-7:00PM

Is there a way to demonstrate intersubjective equivalence of imagined contents? Studying the temporal phenomenology of imagination allows exploring whether contents of imagination unfold over consistent temporal regularities across individuals. Moreover, this approach allows us to ask whether imagination and perception share objectively measurable representational formats? In this study, we excavate a structure of temporal phenomenology within imagined contents. To objectively measure the phenomenology of imagined contents, we designed a phenomenological property-matching task. Participants (N = 238) were asked to imagine (eyes closed) a square flickering as fast as possible, and then a cube rotating at maximum speed. After this, a square would appear on the screen, and using a slider, participants were allowed to match its objective flicker-rate to the flicker-rate of their "mind's eye". The same was true for the cube, where the slider could be used to match and report the speed. Thereafter, we showed participants brief clips of a dance and exercise routine. Here, participants reported how smooth or choppy the routine unfolded in their imagination by again adjusting a slider to change the choppiness of the same clip as it looped on the screen. In the final two prompts, we tested the temporal limits of persistence. Participants were shown clips of repeating sequences, a looping GIF of a winding road and a continuously running water-tap. The instructions given to the participants were to notice when the content of their imagination breaks or pauses. Participants adjusted a slider to insert a break inside the same GIF. In all tasks, participants were free to report 'no visualizations', or report a total lack of choppiness or breaks in imagination. Participants' responses gave a direct quantitative value of flicker, speed, smoothness, and persistence of their visual imagination. On average, participants flickered the square in chunks of 220 milliseconds, and could rotate the cube at an average speed of 1.8 rotations/second. The reported smoothness of imagined clips was equivalent to dropping half the frames of the GIF. This indicated a sampling rate of content that was approximately ~5Hz. Finally, the extent over which imagined events persisted was 4.6 seconds. These timescales are consistent with regularities of extensional (~300-500ms) and retentional (~3-5 seconds) modes of temporal phenomenology in regular perception. In addition, we carried out an exploratory factor analysis and multidimensional scaling. Our analysis revealed two latent factors of significance which separately accounted for variance in persistence-smoothness tasks, and the flicker-speed tasks. The interaction of these latent factors mirrors the timescales and nature of a hierarchical interaction between the extended and retentional levels of time-consciousness (see Singhal & Srinivasan, 2021). Where one factor explains variance in the persistence tasks (retentional), and another explains variance in flicker-speed task (extensional; not cinematic like visual perception). Additionally, we find that imagined contents lack the fast- updating transient frame-like phenomenological contents present in perception and are thus structurally different. Moreover, the structure of imagination can be used to equate contents intersubjectively and inform the search for neural markers by restricting the geometry of neural signals.

Opposite gradients of mental imagery and perception in human orbitofrontal and occipitotemporal cortex

Jianghao Liu (Paris brain institute (ICM)), Laurent Cohen (Paris brain institute (ICM)), Minye Zhan (NeuroSpin), Paolo Bartolomeo (Paris brain institute (ICM))

Concurrent Session: Mentary Imagery, Wednesday July 3rd, Conference Room, Ito International Research Center, 5:00PM-7:00PM

Subjective visual experience can be shaped bottom-up by external reality or built top-down in visual mental imagery (1). Specifically, we previously found that mental imagery of faces and colors recruits the relevant domain-preferring ventral occipito-temporal (VOTC) cortical patches (2). We further discovered face- and color-preferring orbitofrontal cortex (OFC) patches in human participants, localized in a medial-lateral fashion similar to those of the VOTC (2).However, how does this OFC activity relate to VOTC activity? How do these patches sustain subjective visual experience through bottom-up and top-down processing? For example, individuals with congenital aphantasia show some visual cortex activation in the absence of subjective imagery experience. Does aphantasia impact neural activity in these patches? We collected 7T fMRI data from 10 typical imagers and 10 aphantasic individuals while they performed mental imagery and perceptual tasks in five different domains of stimuli: faces, object colors, object shapes, words, and a map of France. After scanning, they also arranged experimental items either by semantic features, or by perceived visual features. In individual participants, we identified 4 VOTC face-preferring patches, 3 VOTC color-preferring patches, and 1 OFC patch each for face and color domains. We investigated: activity magnitude, domain selectivity, neural representations (representational similarity analysis) compared to behavioral arrangements, and task-modulated functional connectivity (psychophysiological interaction). We examined differences between patches through repeated-measures ANOVAs and conducted post-hoc gradient tests to identify prevailing trends across posterior to anterior patches, comparing their activity during imagery and perception, in typical imagers and in aphantasic individuals. OFC face-preferring patches were consistently located lateral to the OFC color-preferring patches (x-coordinates, Bayes factor = 12.68), similar to their spatial arrangement in VOTC. Across posterior to anterior VOTC and OFC patches during perception, activity amplitudes were highest at V1, decreased along the VOTC and OFC patches; during imagery however, the activity amplitude showed the opposite pattern, which increased from posterior to anterior patches. Functional connectivity also showed opposite flows between perception and imagery, with OFC patches serving as the apex of the top-down process. Although domain selectivity and the similarity of neural representations to behavioral arrangements increased from posterior to anterior patches, both during perception and imagery. Aphantasic individuals showed comparable activities in the VOTC patches but reduced OFC activities, including reduced activity amplitude, decreased visual color representation in OFC color patches and orbitofrontal-temporal connectivity in both perception and imagery. During visual perception and visual mental imagery of faces and colors, activity of domain-preferring cortical patches is not uniform but follows functional gradients across the ventral visual cortex and OFC cortex. The newly discovered domain-preferring OFC patches seem to be located close to the apex of top-down processing in mental imagery. Aphantasic individuals showed decreased OFC activity in mental imagery, perhaps linked to impaired metacognitive monitoring or read-out activities (3). Thus, aphantasia is associated with altered functioning in the OFC, but not in the high-level visual cortex. 1 Bartolomeo et al. Cortex (2024) j.cortex.2023.10.002 2 Liu et al. bioRxiv (2023) 2023.2006.2014.544909 3 Liu & Bartolomeo Cortex (2023) 166, 338-347

Vividness of Visual Imagery Supported by Intrinsic Structural-Functional Brain Network Dynamics

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Concurrent Session: Mentary Imagery, Wednesday July 3rd, Conference Room, Ito International Research Center, 5:00PM-7:00PM

Vividness of visual imagery is subject to individual variability, a phenomenon with largely unexplored neurobiological underpinnings. By analyzing data from 273 participants we explored the link between the structural-functional organization of brain connectomes and the reported intensity of visual imagery (measured with VVIQ-2). Employing graph theory analyses we investigated both the structural (DTI) and functional (rs-fMRI) connectomes within a network of regions often implicated in visual imagery. Our results indicate a relationship between increased local efficiency and clustering coefficients in the structural connectome in individuals who experience more vivid visual imagery. Increased local efficiency and clustering coefficients were mirrored in the functional connectome with increases in left inferior temporal regions, a region frequently identified as a critical hub in the visual imagery literature. Furthermore, individuals with more vivid imagery were found to have lower levels of global efficiency in their functional connectome. We propose that the clarity and intensity of visual imagery are optimized by a network organization characterized by heightened localized information transfer and interconnectedness. Conversely, an excessively globally integrated network might dilute the specific neural activity crucial for generating vivid visual images, leading to less locally concentrated resource allocation in key regions involved in visual imagery vividness.

Inter-individual variability in resting-state alpha-band activity predicts the TMS-measured phosphene threshold but not visual detection and identification capabilities

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Concurrent Session: Fluctuation of Consciousness, Wednesday July 3rd, Conference Room, Ito International Research Center, 5:00PM-7:00PM

Spontaneous, moment-to-moment fluctuations in the EEG alpha-band activity (7-14 Hz) are known to affect perceptual abilities, with low alpha power facilitating the detection of weak stimuli. Importantly, even though alpha activity is stable enough to constitute an individual “fingerprint” and a trait-like predictor of stimuli detection, not much is known about the impact of inter-individual variability in alpha-band activity on perception. Therefore, in the present study, we analyzed data from a large-scale project, which included resting-state EEG recordings (N = 220), cortical excitability thresholds measured with transcranial magnetic stimulation (TMS), and perceptual thresholds estimated in several detection and identification tasks. We used the FOOOF Toolbox to separate and analyze the periodic and aperiodic components of the signal. The comparison between eyes-open (EO) and eyes-closed (EC) conditions revealed the expected increase in the resting-state alpha power in the latter, particularly regarding the periodic component. Further, in both EO and EC conditions, alpha-band measures exhibited high test-retest reliability for the subset of participants taking part in two sessions, indicating their potential to constitute trait-like predictors. Crucially, we found that greater alpha power, especially the amplitude of its periodic component, was related to higher TMS-measured phosphene thresholds (EO: $r = .37$; $p = .013$; EC: $r = .39$, $p = .008$). However, we did not find any consistent association pattern between alpha-activity measures and perceptual abilities in any of the analyzed perceptual tasks. Therefore, we demonstrate that measures of resting-state alpha-band activity exhibit high test-retest reliability, even though in our project EEG sessions had been conducted three months apart on average. Further, we showed that at the inter-individual level alpha-power is associated with visual cortex excitability but we found no evidence it predicts perceptual thresholds in detection or identification tasks.

Self-evaluations of conscious state when driving are interrelated, but don't correlate with objective performance data: interim analysis from the ODESA study

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Concurrent Session: Fluctuation of Consciousness, Wednesday, July 3, Conference Room, Ito International Research Center, 5:00PM-7:00PM

Introduction Mind-wandering, or experiencing attentional drift to unrelated thoughts from the current task, is a common phenomenon when driving, and is often reported as a concern for the driver's safety. However this has not been empirically tested with real-world data and it is unknown to what extent mind-wandering impacts driving performance. It is possible that individuals can still drive safely on 'auto-pilot' while thinking about off-task mental content. However mind-wandering may indicate performance deteriorating, and driving at a heightened risk of collision. We present data from an interim analysis of the ODESA study, collecting on-road, objective driving data and self-evaluated Temporal Experience Traces (TET's), from patients being screened for Obstructive Sleep Apnoea (OSA, the leading medical cause of daytime sleepiness) at Royal Papworth Hospital's Sleep Centre, Cambridge, UK. We tested to see if self-evaluations of mind-wandering, wakefulness and performance were related, and how they align to objective driving performance measures.

Methods Participants referred for screening for OSA completed the 3 TET's, after journeys driven on public roads. This involved tracing a line across a graph to represent mental state changes over a drive, the x-axis represented position of drive, while the y- axis represented level of state in question. Simultaneously objective driving behaviour measures were recorded for some drives using a smartphone application (Insights 'app' by Sentiance), which collects data from the phone's inbuilt gyroscope and accelerometer, to compute scores of 'hard turns' and 'hard braking/acceleration'. We then compared the mean value of TET's for each drive and matched to the respective objective driving scores.

Results Twenty participants completed TET's after 245 drives. Self-evaluated wakefulness and self-evaluated performance were highly correlated ($R=0.56$, $P<0.00001$). In contrast, wakefulness and mind-wandering ($R=0.03$, $P=0.67$), and mind-wandering and performance ($R=0.0$, $P=0.98$), were not related. 98 of the 245 drives listed above were matched to driving performance measures captured via the Insights app. There were non-significant trends towards relationships between subjective performance evaluations and objective driving measures of hard turns ($R=0.12$, $P=0.2$), and hard braking/acceleration ($R=0.15$, $P=0.13$). Evaluations of wakefulness and mind-wandering were not related to either hard turns ($R=0.02$, $P=0.85$; $R=0.03$, $P=0.79$, respectively), or hard braking/acceleration scores ($R=0.01$, $P=0.90$; $R=0.00$, $P=0.97$, respectively).

Discussion Here we found a strong relationship between self-evaluation of driving performance and self-evaluated wakefulness when driving. However neither of these measures were related to the objective driving performance scores calculated by a smartphone app nor to the subjective mind wandering reports. These interim data suggest that drivers attending the sleep clinic, might interpret level of wakefulness as a reflection of driving safety regardless of their focus of attention, but this is not a true reflection of driving performance, highlighting a dissociation between phenomenology and externally defined performance. These findings will be further explored in results from new participants recruited between March and June. In addition we will present relationships against the additional element of objective neurofunctional data when driving, recorded using low-density EEG, being used by a subset of participants in the ODESA study.

Variations of autonomic arousal mediate the reportability of mind-blanking occurrences.

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Concurrent Session: Fluctuation of Consciousness, Wednesday July 3rd, Conference Room, Ito International Research Center, 5:00PM-7:00PM

Mind-blanking (MB) is the inability to report any mental content. Compared to mental states with content, such as task-engagement or mind-wandering, MB has a discrete neuronal profile characterized by high inter-areal cortical synchronization, high amplitude of the global BOLD signal, whole-brain BOLD deactivations and parietal slow-wave like activity. These results point to brain configurations that do not allow any content to manifest. While these results point to altered cortical arousal correlates of MB, what remains indeterminate is whether physiological arousal contributes to MB occurrence. In this registered report (https://osf.io/nfcvu/), we hypothesized that deviations from baseline levels of arousal would increase MB reports, and that MB could be decoded from unique brain-body configurations. To examine this hypothesis, we combined multimodal physiological recordings (EEG, ECG, EDA, Pupillometry, Respiration) and experience-sampling under different autonomic arousal condition. During baseline measurements, 26 participants (11 female) reported their thoughts every 2 minutes, by opting across a) sensations, b) mind-wandering and c) MB. On subsequent days, they performed the experience-sampling task under a high-arousal (high-intensity exercise) and a low-arousal condition (8-hour sleep deprivation), in a counter-balanced order. As hypothesized, we found that MB reports were more frequent in low compared to baseline ($b = -.794$, $pFDR < .000$) and high arousal ($b = -.968$, $pFDR < .000$). Although our registered analysis did not find any increase in MB reports during high arousal ($b = .173$, $pFDR = .237$), we found that the first 10 trials of experience-sampling following high-intensity exercise had more MB reports compared to the last 10 trials (divergence = 7.39, $p < .000$). Additionally, we found that MB tended to be reported more slowly compared to mental states with content (beta = -.09, $pFDR < .000$). An interaction between mental states and arousal conditions showed that MB was the slowest in high arousal (beta = .3, $pFDR < .05$), but MW was the slowest in low arousal (beta = .06, $pFDR < .000$). To examine whether MB reports could be decoded from a unique brain-body configuration, we opted for a machine learning approach by training a balanced random forest classifier. In line with our hypothesis, a brain-body classifier (balanced accuracy = .66) outperformed both chance level and classifiers trained solely on brain (balanced accuracy = .64) or body features (balanced accuracy = .61). Examining SHAP values, the model makes the decision mostly by analysing EEG spectral power in delta and beta bands, as well as eye openness and heart-rate variability. Training this classifier on different arousal conditions retained high performance but showed different SHAP feature importance for each arousal condition. Our results provide evidence for arousal effects on MB frequency occurrence. Additionally, we provide evidence for unique bodily information of MB that cannot be solely decoded from brain activity. Overall, our results challenge the dominant view of cerebral importance in MB reports and provide an avenue for higher explanatory power of MB.

Towards an evidence-based consciousness science

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Concurrent Session: Theories of Consciousness 1, Thursday July 4th, Fukutake Learning Theater, 2:00PM-3:30PM

As theories of consciousness proliferate, the need to compare and adjudicate amongst candidate theories becomes ever more pressing. However, theory comparison in consciousness science is complicated by fundamental disagreements; e.g., about the kinds of phenomena theories ought to explain, the kinds of explanation such theories ought to afford, and the methodological approaches that ought to be adopted to test them. Here, we present a formal technique for evaluating the evidential support accrued under rival theories of consciousness – one that is unencumbered by foundational disputes about the nature of consciousness itself. Under this scheme, theory comparison is cast as (Bayesian) model comparison, whereby theoretical hypotheses are formalised as prior predictions over critical parameters encoded in generative models. The quality of the fit between model predictions and empirical data is then evaluated using variational inference, thus furnishing a formal estimate of (log) model evidence that optimally balances the trade-off between predictive accuracy and model complexity. Crucially, this estimate can be compared across competing models (theories), and aggregated over disparate datasets (sampling units, experiments, replication sites, etc.), to formally adjudicate theoretical explanations of empirical observations. This approach – which forms part of a broader framework of (Bayesian) adversarial collaboration developed in tandem with the Templeton World Charity Foundation's initiative to Accelerate Research on Consciousness – thus renders a common metric for tracking scientific progress in consciousness research.

Integrated Information Theory (IIT) with Simple Maths

David Rudrauf (Université Paris-Saclay), Tonglin Yan (Université Paris-Saclay), Nils Ruet (Université Paris-Saclay), Kenneth Williford (University of Texas at Arlington), Grégoire Sergeant-Perthuis (Université Paris-Sorbonne)

Concurrent Session: Theories of Consciousness 1, Thursday July 4th, Fukutake Learning Theater, 2:00PM-3:30PM

Integrated Information Theory (IIT) is a complex and controversial theoretical framework that contends to offer an account of consciousness (Tononi et al, 2016; Albantakis et al, 2023; Merker et al 2022). In particular, the formalizations of IIT 3.0 and 4.0 may appear opaque and difficult to access for newcomers (Albantakis et al, 2023). We propose a synthetic mathematical formulation of IIT in a brief and accessible format in order to facilitate its assessment and interpretation as a contender for a mathematical theory of consciousness. Our primary focus will be on the formal aspects of IIT rather than its motivation and rationale, ignoring so-called axioms and postulates, which surround but do not constitute the core mathematical structure of the theory. The only prerequisites are the notions of Markov Kernel, conditional expectation, and independence of two random variables. We build upon the work of Johannes Kleiner and Sean Tull: “The mathematical structure of integrated information theory” (Kleiner & Tull, 2021) and Albantakis et al (2023). Kleiner and Tull have done an excellent job in clarifying IIT’s presentation by distinguishing the general features of the theory and its specificities across versions. Their contribution offers a general and unifying mathematical framework for understanding IIT, allowing for a quantitative formulation of the theory. It remains however quite sophisticated and difficult to process for a less mathematically knowledgeable audience. To make the theory more accessible and widely disseminated, we aim for a formulation that is less abstract but sufficiently general to capture in a concise way the formalism and concepts at the core of IIT, with the least possible number of concepts, and in a manner that remains valid irrespective of the specifications of IIT across its various versions. We focus on IIT from the standpoint of classical information theory and probability, setting aside quantum frameworks emerging in the literature. We envision our presentation as an easy and low-cost entry point for accessing the underlying mathematical and computational aspects of IIT in order to foster interest and heuristic discussion about the substance of the theory from computationally driven researchers. --- Tononi, G., Boly, M., Massimini, M., & Koch, C. (2016). Integrated information theory: from consciousness to its physical substrate. Nature Reviews Neuroscience, 17(7), 450-461. Albantakis, L., Barbosa, L., Findlay, G., Grasso, M., Haun, A. M., Marshall, W., ... & Tononi, G. (2023). Integrated information theory (IIT) 4.0: formulating the properties of phenomenal existence in physical terms. PLoS Computational Biology, 19(10), e1011465. Merker, B., Williford, K., & Rudrauf, D. (2022). The integrated information theory of consciousness: a case of mistaken identity. Behavioral and Brain Sciences, 45, e41. Kleiner, J., & Tull, S. (2021). The mathematical structure of integrated information theory. Frontiers in Applied Mathematics and Statistics, 6, 602973.

Artificial Intelligence and the dimensions of consciousness

Karina Vold (University of Toronto)

Concurrent Session: Theories of Consciousness 1, Thursday July 4th, Fukutake Learning Theater, 2:00PM-3:30PM

Within scientific and philosophical studies of consciousness there has been a move towards pulling apart different dimensions of phenomenal consciousness. As one influential example, Birch, Schnell and Clayton (2020) have presented a multidimensional framework for understanding interspecies variation in states of consciousness. Their framework distinguishes five key dimensions of variation: perceptual richness, evaluative richness, integration at a time, integration across time, and self-consciousness. For them, the framework is useful for constructing a consciousness profile for each species by assessing a given species against each of the five dimensions. They argue that each species has its own distinctive consciousness profile, such that there is no single scale along which species can be ranked as more or less conscious. In this talk, my aim is to identify the potential dimensions of consciousness profiles in artificial intelligences (AIs). This includes both current systems, which can be assessed for evidence of consciousness, and hypothetical future systems, which might display non-traditional consciousness profiles. My methodology will involve surveying several theories about the dimensions of consciousness, with the goal of identifying the best indicator properties for dimensions of phenomenal consciousness in AI systems. I will then use these indicator properties to, first, assess several recent advanced AI systems (e.g., foundation models such as GPT-4, Dall-E) and, second, to consider how future systems might implement them. Even if no current AI systems are conscious, which my analysis thus far suggests, there are still important philosophical insights to be drawn through the method of considering what dimensions might emerge in near-term non-biological (AI) systems.

Qualia as Meta-Representations of Processes

Ryota Takatsuki (Araya Inc.), Ippei Fujisawa (Araya Inc.), Ryota Kanai (Araya Inc.)

Concurrent Session: Theories of Consciousness 1, Thursday July 4th, Fukutake Learning Theater, 2:00PM-3:30PM

In this study, we explore how the notion of meta-representations in Higher-Order Theories (HOT) of consciousness can be implemented in computational models. HOT suggests that consciousness emerges from meta-representations, which are representations of first-order sensory representations. However, translating this abstract concept into a concrete computational model, such as those used in artificial intelligence, presents a theoretical challenge. For example, a simplistic interpretation of meta-representation as a representation of representation makes the notion rather trivial and ubiquitous. Here, we propose a refined interpretation of meta-representations. Contrary to the simplistic view of meta-representations as mere transformations of the first-order representational states or confidence estimates, we argue that meta-representations are representations of the processes that generate first-order representations. This presents a process-oriented view whereby meta-representations capture the qualitative aspect of how sensory information is transformed into first-order representations. To concretely illustrate and operationalize thus formulated notion of meta-representation, we constructed “meta-networks” designed to explicitly model meta-representations within deep learning architectures. More specifically, we constructed meta-networks by implementing autoencoders of first-order neural networks. In this architecture, the latent spaces embedding those first-order networks correspond to their meta-representations. Applying meta-networks to neural networks trained to encode visual and auditory datasets, we show that they successfully capture the qualitative aspects of the first-order networks by separating the visual and auditory neural networks in the meta-representation space. We argue such meta-representations would be useful for quantitatively comparing and contrasting the qualitative differences of computational processes. While whether such meta-representational systems exist in the human brain remains an open question, this formulation of meta-representation offers a new empirically testable hypothesis that there are brain regions that represent the processes of other brain regions. Furthermore, this form of meta-representation might underlie our ability to describe the qualitative aspect of sensory experience or qualia.

Empirical Construction of the Topology of Broader Qualia

Youngzie Lee (University of California, Los Angeles), Norie Kawamura (Advanced Telecommunications Research Institute International), Naotsugu Tsuchiya (Monash University), Martin M. Monti (University of California, Los Angeles)

Concurrent Session: Theories of Consciousness 1, Thursday July 4th, Fukutake Learning Theater, 2:00PM-3:30PM

To date, attempts at characterizing the structure of human phenomenological experience in a so-called 'qualia space' or 'qualia structure' have been generally focused on specific aspects of conscious experience, such as color or emotion experiences (e.g., Kawakita et al., 2023; Cowen & Keltner, 2021). While characterization of individual modalities of experience is empirically more tractable, such disparate studies accumulate into incommensurable descriptions that fail to account for the phenomenology of conscious experience integrated across these modalities. This necessitates the construction of a qualia structure of 'qualia in the broad sense', i.e., entire conscious experiences consisting of sensory, cognitive, and affective modalities (Kanai & Tsuchiya, 2012). In this study, we aim to build a structural description of the phenomenology of such global states of consciousness as well as establish a systematic method for quantifying first-person experiential data that is reflective of this broader and unified qualia structure. We propose a method that leverages a large sample of linguistic descriptions of experience from existing phenomenological questionnaires and large language models (LLMs).

In our recent work, we prompted an LLM (specifically, GPT3.5 and 4) to generate semantic features that describe the phenomenal characteristics of various perceptual, affective, cognitive, and physiological experiences expressed in sentences. Generated features included words and phrases related to physical sensations, emotions, thoughts, etc., constituting 40 dimensions of phenomenal features that represent aspects of experience such as vividness of imagery, mental clarity, and emotional distress. Each sentential description of experience could then be encoded with these dimensions, allowing us to derive the structural relations among the experiences based on the similarity of their phenomenal qualities, beyond the semantic similarity of their linguistic descriptions. Such meaningful relationships could not be obtained solely from linguistic features of the sentences, highlighting the utility of using features to encode the phenomenal profile of experience.

We conduct a series of behavioral experiments to assess whether the LLM-generated features, dimensions, and similarity structure accurately describe human phenomenology. Participants are asked to evaluate or generate semantic features that describe the phenomenal character of an experiential description, or to provide direct similarity ratings between them. The resulting data are directly compared to the LLM results to construct the final model. This human-validated model will then be used to propose a tool for the systematic characterization of subjective experience across various states and individuals.

This project takes steps towards the empirical construction of a "global" topological space of qualia, which is imperative for the systematic investigation of the link between phenomenology and its underlying neural activity. This also prompts important inquiries regarding the structural organization of broader qualia, such as the relationship and interplay between sensory content and cognitive processes in the composition of conscious experiences.

Bridging the free energy principle and integrated information theory

Yusuke Hayashi (AI Alignment Network)

Concurrent Session: Theories of Consciousness 1, Thursday July 4th, Fukutake Learning Theater, 2:00PM-3:30PM

In this research, we explore two simple questions based on the physics of the free energy principle. The first question asks what physical quantity, found in existing physics theories, corresponds to the variational free energy. The second question investigates whether physical systems that reduce variational free energy can be explained using current physics theories. Through a reformulation based on stochastic mechanics of Langevin equations, which describe physical systems that follow the free energy principle, we provide affirmative answers to both questions. This reformulation reveals the relationship between variational free energy and physical quantities, and links the free energy principle to integrated information theory. Non-equilibrium free energy is associated with variational free energy, and we interpret this non-equilibrium free energy as a form of information content. We also present theoretical evidence supporting prior research indicating that integrated information quantity increases as learning progresses in FEP agents. We believe that the novel definition of integrated information unearthed through this study aligns well with existing physical theories. It also casts new light on the debate concerning an objective metric for consciousness.

The role of recurrent feedback in conscious perception

Janis K Hesse (UC Berkeley), Frank Lanfranchi (UC Berkeley), Yuelin Shi (UC Berkeley), Doris Y Tsao (UC Berkeley, HHMI)

Concurrent Session: Perception 2, Thursday July 4th, Ito Hall, Ito International Research Center, 2:00PM-3:30PM

Perception is not a passive process but rather actively generated. Here, we investigate the hypothesis that conscious perception is due to recurrent feedback interpreting and recreating incoming sensory inputs. To reveal the mechanisms of how new conscious percepts are generated and coordinated across different nodes of the cortical hierarchy, we employ newly developed primate Neuropixels probes to simultaneously record from thousands of neurons across different multiple patches in macaque inferotemporal cortex while presenting ambiguous stimuli such as degraded faces and binocular rivalry. Moreover, we causally perturb feedforward and feedback pathways using microstimulation and psychedelic drugs. We find several lines of evidence suggesting that IT cortex alternates between a feedforward mode representing visual processing of the stimulus and a recurrent mode representing conscious perception: First, for degraded faces, an initial feedforward wave is followed by a second recurrent wave, at which time representation of face identity becomes invariant to degradation. Second, during binocular rivalry the brain multiplexes representations the physical stimulus, i.e., a mixture of suppressed and perceived stimuli with representations of conscious percept. Finally, psychedelics specifically eliminate top-down feedback effects induced by microstimulation, providing a useful tool for studying the brain in a pure feedforward mode. Taken together, the experiments above offer a unique window on how the generative model in our brain generates the coherent interpretation of the world that we consciously experience.

Walking in wireless virtual reality reveals rhythmic modulations of visual and auditory perception according to stride cycle phase.

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Concurrent Session: Perception 2, Thursday July 4th, Ito Hall, Ito International Research Center, 2:00PM-3:30PM

Although we are inherently active beings, most of our knowledge regarding perception stems from a tradition of seated laboratory experiments that restrict natural movement. This approach precludes a holistic understanding of how perception may operate in more ecologically valid contexts, such as during dynamic activity or everyday behaviour. Here, we leveraged advances in wireless virtual-reality (VR) to present tightly controlled stimuli during steady-state walking. Participants performed various perceptual tasks while walking on a smooth-level path at a constant walking speed, and by combining psychophysics with motion tracking and body-kinematics, we finely sampled task performance according to the phase of an individual's stride cycle. In a first series of visual detection experiments, we observed sinusoidal oscillations in accuracy, reaction-time, and response likelihood, with best performance at the group-level during the swing-phase of each step. At the participant level, Bayesian inference of population prevalence revealed highly prevalent oscillations in performance that clustered in two idiosyncratic frequency ranges (2 or 4 cycles-per-stride), with a strong phase alignment across participants. In a second series of experiments, we extend this result to other visual, visuomotor, auditory, and higher-order tasks. This generalised effect, showing that walking rhythmically modulates perception, demonstrates the importance of studying conscious experience during more naturally and ecologically valid forms of behaviour, and could lead to new conceptual understanding of the links between mind and body.

Perceptual filling-in from adaptation of inhibition in visual cortex

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Concurrent Session: Perception 2, Thursday July 4th, Ito Hall, Ito International Research Center, 2:00PM-3:30PM

Perceptual filling-in is an illusion that dissociates conscious experience from stimulus contents. After prolonged gaze fixation, static visual features appear to spread across space. An influential model proposes two sequential processes whose neural mechanisms are still unclear. First, a perceived boundary between two distinct surfaces fades due to neuronal adaptation in the absence of eye movements. Once this boundary is no longer detected, a second stage generates the filled-in percept of one uniform surface. The second stage may involve stimulus-evoked signals spreading across the weakened boundary representation in retinotopic cortex ("neural filling") and/or via a top-down inference of visual uniformity.

To clarify the neural mechanisms of this two-stage model, we investigated how visual input signals adapt and interact before filling-in of the Uniformity Illusion using human magnetoencephalography (MEG), Rapid Invisible Frequency Tagging (RIFT), and fixational eye tracking. 29 participants viewed a large grey disk displayed in the center of a purple background. The center disk and periphery flickered imperceptibly at 64 Hz and 56 Hz, respectively, and we extracted the degree of phase-locking between the MEG signal and stimulus flicker (the "RIFT response"). This frequency tagging served as a read-out of excitability in stimulus-responsive neurons. Participants were instructed to fixate their gaze at the center of the screen and report with a button press when they perceive the two stimulus regions fully merge together, i.e., perceptually fill-in. We predicted that just before a report of filling-in, both RIFT responses would decrease in their respective regions of retinotopic visual cortex due to adaptation. Based on the neural filling hypothesis, we also predicted increased RIFT responses in their opposite brain areas (e.g., 64 Hz central flicker in peripheral cortex) and increased power at the 8 Hz intermodulation component. Finally, because microsaccades made during fixation delay filling-in, we tested whether microsaccades counteract any observed neural correlates of filling-in. Contrary to our expectation, both RIFT responses significantly increased in both central and peripheral cortex across ~2 seconds before a report of perceptual filling-in, suggesting a blanket increase in bottom-up excitability. We attribute this result to adaptation of neuronal inhibition—specifically, a shift in excitation-inhibition balance towards excitation. In support of this interpretation, we also observed slow decreases in two other MEG measures of relative inhibition in visual cortex: alpha-band power and aperiodic activity parameters (exponent and offset). These effects were not present in a control condition with no filling-in experience. Microsaccades conversely increased aperiodic exponent and offset, reflecting restored inhibition. We found no evidence for passive neural filling as the intermodulation component did not increase in either signal power or 8 Hz phase-locking. These results show that boundary fading results from adaptation of inhibitory processing in visual cortex, not of retino-cortical excitation as commonly assumed. This notion explains prior counterintuitive findings that attention facilitates filling-in, because attention also reduces relative inhibition. Further, the lack of intermodulation in our data suggests that a higher-order trigger subsequently generates conscious perceptual filling-in.

Subjective sensory experience and objective perceptual processing: intersections and dissociations in consciousness

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Concurrent Session: Perception 2, Thursday July 4th, Ito Hall, Ito International Research Center, 2:00PM-3:30PM

Our sensory experiences shape the way we interpret the world. In this sense, consciousness and perception are inextricably linked. Differences in sensitivity to sensory input have been found across both healthy and clinical populations, which raises interesting questions about individual differences in conscious experience more broadly, as well as providing potential insights into factors impacting psychopathology. Sensory sensitivity has typically been examined using either phenomenological methods that probe subjective experience, or psychophysical methods that attempt to measure the basic perceptual processes underlying those experiences. Very little work has combined these approaches. As a result, it is unclear to what extent 'subjective' and 'objective' sensory sensitivity are related, or what inferences about one can be drawn from measurement of the other. The aim of this project was to investigate whether subjective reports of sensory sensitivity relate to empirical perceptual sensitivity measures. It examined sensory sensitivity as a multidimensional construct in order to enable more fine-grained inferences to be drawn about how its different components relate to each other, as well as to objective measures of perceptual sensitivity, and to high-prevalence psychopathological symptoms. To do this the project utilised a range of validated self-report measures designed to capture different elements of sensory sensitivity across multiple sensory modalities, alongside psychophysical tests that were custom-designed to objectively probe visual, auditory, tactile and cross-modal perceptual sensitivity. Subjective sensitivity was first assessed in two independent general population samples (N>500). Results from both samples indicated strong relationships between multiple dimensions of self-reported sensitivity, and with certain symptoms of psychopathology. Relations between these subjective self-report measures and objective perceptual sensitivity were then examined in a third sample (N = 50) who completed a range of psychophysical tasks to determine participants' auditory, visual and tactile perceptual thresholds and assess cross-modal integration of audio-visual stimuli, or 'polysensory sensitivity'. Subjective perceptual sensitivity was also measured in this sample via suprathreshold method-of-adjustment tasks and participant ratings of stimuli. Results indicated a clear lack of relationship between objective perceptual thresholds and subjective perceptual experiences, but some interesting relationships between self-reported and task-indexed subjective sensitivity, suggesting that conscious, suprathreshold perceptual sensitivity is related to subjective sensory experiences while low-level sensory processing is not. Similarly, while objective perceptual measures failed to predict psychopathology outcomes, a number of subjective sensitivity measures were predictive of depression, anxiety and or schizotypy symptoms. Findings will be discussed in the context of the ways in which intersections and dissociations between physiological and phenomenological sensory experiences influence our conscious experience of the world around us.

Neural correlates of gradual awareness in the absence of decision-making

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Concurrent Session: Perception 2, Thursday July 4th, Ito Hall, Ito International Research Center, 2:00PM-3:30PM

In the neuroscience of consciousness, it is still debated whether visual awareness emerges during early sensory or late distributed processing. Accordingly, the main event-related potential (ERP) candidates for neural correlates of consciousness (NCC) are the early visual awareness negativity (VAN) and the late positivity (LP). Another central question is whether perceptual awareness is a graded or an all-or-none phenomenon. While recent studies have demonstrated that both VAN and LP gradually increase with the level of awareness, they systematically confounded conscious perception with task-related post-perceptual processes (e.g., decision-making). Thus, the present study investigated neural correlates of gradual awareness in the absence of decision-making. Awareness of high-contrast pictograms was manipulated using the attentional blink (AB), where conscious perception of a first visual target (T1) impairs reporting a second target (T2) presented in rapid succession. In order to impede decision-making processes at the time of T2 presentation, we omitted a discrimination task on T2 stimuli and rendered their relevance uncertain. Importantly, unlike in no-report studies with limited awareness assessment, participants reported the subjective visibility of T2 using a four-level perceptual awareness scale (PAS) in each trial. The analysis of T2-locked ERPs as a function of subjective visibility revealed that awareness in the absence of decision-making was associated with a VAN and – in contrast to a LP – a late centroparietal negativity. Moreover, both early and late negativities gradually increased with the level of awareness. Thus, our results support the VAN and challenge the LP as NCC and suggest that both early and late awareness-related brain activity occurs in a gradual rather than dichotomous manner.

Within- And Cross-modality Cognitive Aggregation: subconscious cognitive processing of stimulus in unattended modality

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Concurrent Session: Perception 2, Thursday July 4th, Ito Hall, Ito International Research Center, 2:00PM-3:30PM

Human cognitive processes consciously or unconsciously gather information from multiple sources and different modalities, like vision and audition. Among them, the conscious processes usually require multiple systems working together, such as perception, attention, and working memory. In most cases, these resources are limited and subject to error: perception from different modalities can interfere with others; paying attention to one modality result in ignoring stimulus from other modalities; working memory is inherently with small capacity and subject to perturbation. Hence, these systems are nearly exclusively occupied by conscious processes. However, can unconscious processes also utilize these systems, when conscious process has already occupied them? To test it, in our study, we designed a novel experiment of cross-modality counting task. We recruited 26 subjects for 240 cross-modality counting experiment trials. In each trial, participants were first asked to attend to one modality (vision or audition). This is called the to-attend modality. Subsequently, the stimulus that compositing both visual flashing disk on the screen and "beep" in earphones was presented. In rare trials (20%), the visual and auditory stimuli were synchronized without distraction associated with the other modality; in most trials, the audio-visual stimuli were asynchronous in time. Hence the participant must pay attention to the instructed modality to overcome the interference. Lastly, participants were asked to report the number of stimuli in the to-report modality. Mostly, the to-report modality is congruent with the to-attend modality, where the data is to measure how the participant is prone to cross-modality interference. However, in a few trials, the participants were asked to report the modality they were not instructed to attend to. After the report of each trial, the participants were asked to evaluate whether their answers were correct. Our findings demonstrated that although the participants were more active in tracking the to-attend modality, they also subconsciously tracked the other modality stimulus, as shown by their high reporting accuracy of the unattended stimulus (accuracy of attended: 92.27%; unattended: 78.61%, $p<0.001$), albeit their reaction are significantly slower when reporting the unattended modality (mean response time of attended: 671.8ms; unattended: 997.7ms; $p<0.001$). Furthermore, confidence has a strong correlation with correctness in each trial ($r=0.52$, $p=0.0061$), which shows that metacognition is still monitoring those unconscious cognitive processes. In addition, consistent with previous studies, we also found that most subjects have better performance in counting auditory stimuli (accuracy of reporting auditory: 95.38%; visual: 83.69%, $p<0.001$). Our study showed that while the participant is consciously counting one modality stimulus, they are also unconsciously monitoring the other modality. The unconscious cognitive process can share the cognitive resources occupied by conscious processes and can be tracked by metacognition, implying that the gap between conscious and subconscious processes is narrower than we expected.

Changes in Cortical Effective Connectivity in Connected vs. Disconnected Consciousness During REM Sleep

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Concurrent Session: State of Consciousness 2, Thursday July 4th, Gallery 1, Ito International Research Center, 2:00PM-3:30PM

Introduction: A frequent feature of rapid eye movement (REM) sleep is a "perceptual disconnection" from the physical environment, with the failure of external stimuli to be incorporated into the contents of consciousness (dreaming experiences). This study aims to characterize changes in cortical effective connectivity underlying the awareness vs unawareness of tones during REM sleep. Methods: We collected hdEEG from N=22 subjects (N=11 per condition) during REM sleep. A roving auditory oddball sequence was played for six minutes. Participants were subsequently awakened and reported whether they were conscious or not before awakening, and if so, whether they heard the tones (connected consciousness (CC)) or not (disconnected consciousness (DC)). With dynamic casual modelling (as implemented in SPM12) we quantified the evidence for 10 increasingly complex models, varying in their anatomical sources and connections. The full model included left and right primary auditory (A1) cortex, left and right superior temporal gyrus (STG), left and right inferior parietal lobule (IPL), left and right inferior frontal gyrus (IFG), connected with feedforward, feedback and intrinsic connections present on all sources. We used a Parametric Empirical Bayes (PEB) approach to detect consistent differences in individual connections between CC and DC, when comparing deviant to standard sounds. To further investigate the impact of the physiological state on REM CC, we conducted similar analyses between the 11 CC participants recorded during REM and the same 11 participants recorded, under the same experimental conditions, during wakefulness. Results were thresholded (free energy) for very strong evidence ($Pp > .99$). Results: Random-effect Bayesian model selection identified the full model as having the highest evidence in both the CC and DC group individually, as well as when they were pooled together, indicating some preserved involvement of both frontal and parietal areas as well as feedback connections during DC. However, the PEB analysis revealed distinct variations in connectivity strength among sources between the two groups. In CC compared to DC we found increased feedforward connection from left STG to left IPL and increased feedback connections from left IPL to left STG and from right IPL to right STG. Interestingly, when comparing wakefulness to REM CC, we observed increased feedfoward connection from left STG to left IPL, increased inter-hemispheric connectivity between left and right IPL and increased feedback connection from left IFG to left IPL. Discussion and conclusion: Increased feedforward/feedback connection to and from STG in CC compared to DC aligns with previous findings implicating the STG in various aspects of auditory awareness, such as the discrimination of sound features and segregation of sounds in complex auditory environments. The increased connection from left STG to left IPL during CC compared to DC also aligns with the purported role of parietal regions in awareness. Thus, the increased connection within this temporoparietal loop appears to enable CC participants to consciously perceive auditory stimuli while dreaming. The increased feedback connectivity from frontal to parietal areas during wakefulness compared to REM CC suggests that this lack of modulation does not hinder the conscious perception of auditory information.

How does consciousness reboot? Tracking human single neuron activity during emergence from propofol anesthesia

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Concurrent Session: State of Consciousness 2, Thursday July 4th, Gallery 1, Ito International Research Center, 2:00PM-3:30PM

Introduction. Although much is known about the molecular and cellular effects of general anesthetics, the neural mechanisms underlying loss and recovery of consciousness during anesthesia remain elusive. Time to emergence from anesthesia is variable between patients and may influence postsurgical cognitive outcomes. During emergence, the brain appears to traverse metastable network states, but whether there is a consistent and specific spatiotemporal sequence of neuronal activity during emergence is unclear. Previously, we investigated the dynamics of human cortical network reorganization during induction of propofol anesthesia and overnight sleep using recordings of local field potentials (LFPs) in neurosurgical patients (Banks et al., 2020, NeuroImage 211:116627; Krause et al., 2023, Cereb. Cortex 33:9850-9866). However, emergence is not simply the exact reverse process of induction due to the phenomenon of 'neural inertia', and LFPs do not offer sufficient spatial and temporal resolution to identify the regional sequence of restoration of brain activity during the transition to waking consciousness. Here, we examined the activity of single neurons in medial temporal, prefrontal, and parietal cortex while patients transitioned from propofol anesthesia to an awake, responsive state.
Methods. Participants were adult neurosurgical patients with intracranial electrodes undergoing chronic monitoring for refractory epilepsy. Data were obtained immediately following electrode implantation as patients emerged from propofol anesthesia. Single unit activity was recorded using Behnke-Fried microwire bundles that extend beyond the tip of the clinical recording electrodes. After research recordings had begun, propofol was continued for 5 minutes and then turned off. Administered muscle relaxants were fully reversed before propofol was stopped. Patients were monitored continuously for spontaneous movement and response to verbal commands. Data were common-average re-referenced, spike-sorted with a recently developed method optimized for detecting low-amplitude signals (Kovach et al., 2023, doi: 10.13140/RG.2.2.28352.40967), and curated for well-isolated single neurons. A total of 136 single neurons were isolated from 4 participants. The firing rates of these neurons were examined over the entire time course of emergence from anesthesia, as well as within specific windows of interest after propofol cessation and behavioral response.
Results. Across all isolated neurons, firing rates were 2.58 Hz at baseline (IQR: 2.83), 2.55 Hz immediately following propofol cessation (IQR: 2.47), 3.70 Hz prior to responses to command (RC; IQR: 3.83) and 4.05 Hz following RC (IRQ: 3.67). The earliest increases in activity occurred prior to overt RC and were observed in the hippocampus, amygdala and parahippocampal gyrus. Although the majority of neurons increased their activity prior to or following RC relative to baseline, others within the same brain regions demonstrated decreases, suggesting heterogeneity across the neuronal population.
Conclusions. We obtained intracranial recordings from single neurons during emergence from propofol anesthesia and found heterogeneous activity, with most neurons in medial temporal regions showing increased firing before patients were responsive to verbal commands. Thus, brain activity in high order medial temporal regions may presage restoration of consciousness after anesthesia. To our knowledge, this is the first report of single neuron activity recorded in humans throughout emergence from general anesthesia.

Local and inter-areal communication of prediction error information is selectively modulated by attention: a human ECoG study

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Concurrent Session: State of Consciousness 2, Thursday July 4th, Gallery 1, Ito International Research Center, 2:00PM-3:30PM

A major question in consciousness science is what kind of neural dynamics underlie our awareness of sensory stimuli. The current study employs information theoretic methods to unravel how information about auditory prediction errors is encoded across the cortical hierarchy, and how this encoding is modulated by attention. As attention is a vital factor modulating our awareness, our research provides novel information about what kind of neural dynamics underlie conscious awareness of the sensory world. We present results from 11 patients with intracranial electrodes (ECoG) across their cortical hierarchy performing an auditory oddball task with an additional visual attention task. The participants are either attending to a stream of auditory stimuli (roving oddball task, consisting of deviant and non- deviant tones), or the auditory stimuli is played to them while they are attending to an unrelated visual attention task. By computing mutual information (MI) between the ERP-signals of electrodes from canonically relevant cortical areas (temporal and frontal) and the experimental stimuli (deviant/non-deviant auditory tones) we show that local communication of prediction error information is selectively modulated by attention. Diverting attention away from the auditory stream to the visual task increases prediction error encoding in the temporal cortices but reduces encoding in the frontal cortex. By computing co-information, an information theoretic measure capable of decomposing signals into redundant and synergistic information, we show that the information about prediction errors is encoded both redundantly and synergistically across the cortical hierarchy, and that both redundant and synergistic information is modulated by attention. Moreover, this modulation happens both within and between cortical areas: attending to the competing visual task modulates redundant and synergistic information encoding not only locally, but it also affects the information that is encoded between temporal and frontal cortices. In addition to the experimental approach, we employ a brain-constrained neural network to simulate the experimental task. This neurocomputational approach shows that in a brain-constrained model synergistic information only emerges with strong, higher-order forward and backward links, suggesting that similar mechanisms in the brain might be giving rising to the synergy observed in the neural data. Thus overall, we present three primary findings: (1) Both local and inter-areal communication of prediction error information is selectively modulated by attention, (2) This modulation is present in both redundant and synergistic information encoding in the brain, and (3) A synergistic information encoding in the brain might reflect strong, higher-order forward and backward links that are known to exist in human/primate physiology. Our findings provide novel information about the information dynamics underlying attention and predictive processing, and thus our awareness of the sensory world. Moreover, our neurocomputational results provide potential neurophysiological candidate mechanisms that might explain the emergence of synergistic information in neural data.This can inform other research employing multivariate information theory in consciousness science.

Modulation of auditory novelty processing by dexmedetomidine and natural sleep: A human intracranial electrophysiology study

Kirill V. Nourski (The University of Iowa), Mitchell Steinschneider (The University of Iowa), Ariane E. Rhone (The University of Iowa), Rashmi N. Mueller (The University of Iowa), Hiroto Kawasaki (The University of Iowa), Matthew I. Banks (University of Wisconsin - Madison)

Concurrent Session: State of Consciousness 2, Thursday July 4th, Gallery 1, Ito International Research Center, 2:00PM-3:30PM

Loss of consciousness (LOC) is characterized by diminished cortical sensory processing. LOC induced by propofol is associated with loss of responses to short-term auditory novelty (local deviance, LD) outside canonical auditory cortex (Nourski et al, J Neurosci 2018, 38:8441-52). This loss may represent a biomarker of LOC. By contrast, responses to long-term novelty (global deviance, GD) are more sensitive to propofol, becoming abolished at subhypnotic doses. Unlike propofol, which modifies GABA-ergic inhibition, the alpha-2 adrenergic agonist dexmedetomidine induces sedation that closely resembles non-REM sleep. This study examined whether the changes in cortical auditory processing observed with propofol could be generalized to dexmedetomidine and to natural sleep. Intracranial recordings were obtained in neurosurgical patients undergoing chronic monitoring for refractory epilepsy. Stimuli were sequences of vowels incorporating within- and across-sequence deviants (LD and GD, respectively). Participants were presented with stimuli while awake, during administration of dexmedetomidine, and during daytime sleep. Using the Observer's Assessment of Arousal/Sedation (OAA/S) scale, dexmedetomidine infusion was titrated to target two arousal states: sedation with responsiveness to command (OAA/S ≥ 3) and unresponsiveness (OAA/S ≤ 2), interpreted as corresponding to LOC. Neural responses were examined in auditory cortex on the superior temporal plane and lateral superior temporal gyrus (STG), as well as other temporal, parietal, prefrontal and sensorimotor areas. Averaged evoked potential (AEP) and high gamma (70-150 Hz) band power were used to assess responses to the vowels and LD/GD effects. Dexmedetomidine sedation had a variable time course across participants; LOC occurred at infusion rates between 0.7-2 μg/kg/hr. AEP responses to vowels and LD/GD effects were more broadly distributed across recording sites compared to high gamma responses. The effects of dexmedetomidine were generally consistent with those previously observed with propofol. Subhypnotic doses led to decreased vowel responses and LD effects in medial temporal and prefrontal cortex and caused a near-complete loss of GD effects. LOC was associated with loss of vowel responses and LD effects in prefrontal cortex and loss of LD effects in temporal auditory-related areas. Within canonical auditory cortex, vowel responses and LD effects were resilient to the drug. Vowel responses, LD, and GD effects during daytime sleep were similar to those observed with dexmedetomidine with the exception of a greater reduction in LD effects within lateral STG during sleep. The results expand previous work on LOC induced by propofol and support the generalizability of changes in cortical sensory processing to dexmedetomidine and natural sleep. LD effects in areas outside canonical auditory cortex may represent a biomarker of conscious auditory novelty processing. Variable reduction in LD effects within lateral STG indicates that disruption of sensory processing may not follow identical trajectories with different anesthetic agents and during sleep, warranting a more nuanced description of circuit disruption associated with LOC.

Subjectivity vs. Phenomenal Character

Andrew Y. Lee (University of Toronto)

Concurrent Session: Metaphysical Theories, Thursday July 4th, Seminar Room, Ito International Research Center, 2:00PM-3:30PM

Phenomenal consciousness is often described as an inner light: if there's something it's like to be an entity, then the inner light is on; if not, then all is dark inside. The aim of this paper is to disentangle two senses of 'phenomenal consciousness', which correspond to two distinct ways of interpreting this metaphor. On the one hand, consciousness might be identified with the inner light itself. On the other hand, consciousness might be identified with the illuminated room (including the light).

I'll use subjectivity to express the sense of 'consciousness' that corresponds to the inner light, and phenomenal character to express the sense of 'consciousness' that corresponds to the illuminated room. These terms can be defined as follows:

subjectivity definition: what makes an entity feel some way at all metaphor: the inner light

phenomenal character definition: the way it feels to be an entity metaphor: the illuminated room

To illustrate the distinction, consider global workspace theory, according to which an entity is conscious just in case it has a "global workspace" (a central executive system whose information is available to a wide range of other cognitive systems). Suppose that global workspace theory is true. Well, what is consciousness, according to the theory? There are two natural answers.

On the one hand, you might think of consciousness as the global workspace itself. That's a natural answer, since having a global workspace is what divides the class of conscious entities from the class of non-conscious entities. But on the other hand, you might think of consciousness as the representations in the global workspace (alongside the global workspace itself). That's also a natural answer, since those representations are what determine what it's like to be an entity. The first answer interprets 'consciousness' as expressing subjectivity; the second answer interprets 'consciousness' as expressing phenomenal character.

Subjectivity is itself a dimension of phenomenal character. Because of this, it'd be incorrect to think of subjectivity and phenomenal character as independent aspects of consciousness. Instead, the relationship is more analogous to the relationship between color and hue. Everything that's colored has a hue value, but two objects could differ in color (for example, by differing in saturation or brightness) without differing in hue. Every illuminated room has an inner light, but two rooms could differ (for example, by differing in the objects within them) without differing in the how they're illuminated.

The goal of this paper is to first develop this distinction in detail, and to then put the distinction to work. I'll start by substantiating the distinction and showing how it arises across a broad spectrum of theories of consciousness. Then I'll explain how the distinction clarifies some live philosophical questions about (1) whether consciousness comes in degrees, and (2) whether consciousness is multidimensional.

Can Zombies Pay Attention?

Carolyn D Jennings(Professor of Philosophy, University of California, Merced)

Concurrent Session: Metaphysical Theories, Thursday July 4th, Seminar Room, Ito International Research Center, 2:00PM-3:30PM

The zombie thought experiment posed by Chalmers was recently used in an experiment by Fischer and Sytsma (2021). Fischer and Sytsma found that intuitions on this thought experiment are sensitive to the word “zombie,” with “zombies” conceivable for 30–40% of participants, but “duplicates” conceivable for only 15–20% (2021, 13). Fischer and Sytsma convincingly explain this difference through a framing effect: the linguistic salience bias. They found that participants associated zombies, but not duplicates, with other features of zombies that should have been ruled out by the thought experiment. Importantly, this type of framing effect has been found to occur in philosophers. This challenges the claim that a majority of philosophers take physical duplication without conscious duplication to be conceivable.

Interestingly, participants in Fischer and Sytsma’s study treated consciousness as similar to other psychological states (e.g. “would think and be intelligent”). To test this further, I enacted my own survey. This survey followed Fischer and Sytsma in using the language of “duplicate” or “replica” while trying to otherwise stick as close to Chalmers’ original text as possible.

The hypothesis going into this survey was that consciousness would be treated as similar to attention, in contrast to the soul. The idea behind this is that the soul is strongly associated with dualist intuitions, and so should be easy to conceive as absent from a physical duplicate. If I am right about the relation between the subject of attention and consciousness, it should be equally difficult to conceive of consciousness as absent from a physical duplicate as attention—both would be missing in the absence of a subject. Importantly, workers on Amazon Mechanical Turk are likely to be theory naïve, unlike philosophers, and so are unlikely to have experienced the linguistic salience bias documented by Fischer and Sytsma.

The hypothesis was supported by the results. Of those who passed the comprehension questions and minimum time requirements ($n=40$), 70% selected that they could conceive of the soul as absent from their duplicate, while 50% could conceive of either attention or consciousness as absent.

To test the significance of these differences, I used a statistical model. There was no difference in this study between whether participants could conceive of attention or consciousness as absent, and the p-value provided by this test was thus 1. In contrast, the p-value for the difference between whether participants could conceive of consciousness or the soul as absent was significant, with $p<.04$. I ran a separate, pre-registered version of the study on a different platform, and got the same overall result.

In this study, it appears that consciousness is treated as equivalent to attention when it comes to physical duplicates, or “zombies,” and not as like the soul. I will discuss the implications of this finding in the talk.

The Self and The Synchronic Unity of Consciousness

Katie Carpenter (Princeton University)

Concurrent Session: Metaphysical Theories, Thursday July 4th, Seminar Room, Ito International Research Center, 2:00PM-3:30PM

This paper is about the phenomenal self and the synchronic unity of phenomenal consciousness. Those who defend the existence of a phenomenal self are thought to defend a middle position between those who defend the existence of a substantial self, such as a soul or Cartesian ego, and those who deny the existence of a self altogether. The phenomenal self is not thought to be an entity distinct from conscious experience, one that has the property of being conscious. Rather, defenders of the phenomenal self argue that it is conscious experience itself (Fasching 2012, Sartre 2003, Strawson 2010, Zahavi 2010)*. I show that if these theorists are correct, then an issue arises. The common approach to the synchronic unity of phenomenal consciousness is a bottom-up pluralistic approach: the global unified experience of a subject at t is thought to be somehow "built-up" from a multitude of local conscious experiences of that subject at t. But if the phenomenal self is identified with conscious experience, then for each conscious subject at t, there will be many selves at t. Moreover, there is no way to explain how the many selves combine to get our experience of being one unified self at t. In light of this, I argue that defenders of the phenomenal self ought to endorse a top-down monistic approach to explaining the synchronic unity of phenomenal consciousness. I then offer a 'priority monism' inspired account of the synchronic unity of phenomenal consciousness that, combined with the phenomenal self view, gives a plausible explanation for a subject's global unified experience at t. Moreover, it avoids the problem of many selves, and thus the combination problem that arises from it.

*Fasching, Wolfgang 'On the Advaitic Identification of Self and Consciousness'.Irina Kuznetsova, Jonardon Ganeri, Chakravarthi Ram-Prasad (eds.): Hindu and Buddhist Ideas in Dialogue. Self and No-Self. Farnham: Ashgate 2012, 165-180; Sartre, Jean-Paul (2003), Being and Nothingness (London: Routeledge); Strawson, Galen (2010). Radical self-awareness. In Mark Siderits, Evan Thompson & Dan Zahavi (eds.), Self, No Self?: Perspectives From Analytical, Phenomenological, and Indian Traditions. Oxford University Press; Zahavi, Dan (2010). The Experiential Self: objections and clarifications. In Mark Siderits, Evan Thompson & Dan Zahavi (eds.), Self, No Self?: Perspectives From Analytical, Phenomenological, and Indian Traditions. Oxford University Press.

Vividness as a content-invariant property of experience

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Concurrent Session: Metaphysical Theories, Thursday July 4th, Seminar Room, Ito International Research Center, 2:00PM-3:30PM

Vividness is a fundamental feature of conscious awareness. Recently, there has been more intensive discussion about the concept in the science of consciousness (Fazekas 2023; Bourget 2017). Vividness has been applied particularly in psychophysics and cognitive neuroscience, but in different contexts and with different meanings (Smith and Over 1987; Lacey and Lawson 2013; Cornoldi et al. 1991); often as subjective ratings of awareness and visibility (Andersen et al. 2016; Dijkstra et al. 2021). In terms of the content of our experience, there is debate about whether vividness is part of perceptual content (as claimed by Fazekas 2023; Cornoldi et al. 1991; Hishitani and Murakami 1993) or it is not (as stated by Lau 2019 and Morales 2018), or whether this notion should be rejected due to its vagueness (Kind 2017). The paper argues that vividness is not a content determining but a quantitative constituent of phenomenal experience. First, I introduce a two-factor model (dual model) of phenomenal consciousness, which proposes to understand phenomenal character as separable from consciousness (Marvan and Polák 2017). One possible consequence of the separation is the controversial thesis that phenomenal aspects of our subjective experience may be constituted already at the unconscious level of processing in the brain. In order for the two-factor model to be an acceptable alternative to the traditional notion that phenomenal character is by definition conscious, it is necessary to revise the meaning of other terms that appear in the discourse on phenomenal consciousness (Polák 2024). The revised meaning of what-it's-like (WIL) optimally fitting the two-factor model shows that the structure of WIL can be constituted of two components: phenomenal character and vividness.

Second, Fazekas (2023) in his discussion of vividness distinguishes between its two components: subjective intensity and subjective specificity. Subjective-specificity properties are content properties that perceptual apparatus attributes to parts of the perceived scene (i.e. contrast, saturation, and brightness). Fazekas, however, also considers subjective-intensity properties (i.e. precision, blurriness, detailness) to be content properties. Although both types of properties are specific, sui generis, they constitute the representational content of experience. The two properties then constitute vividness.

Leaving aside the question of whether subjective-specificity properties are representational or rather phenomenal (representationalism vs. phenomenism), I argue that subjective-intensity properties are necessary in shaping the WIL experience, but they are not representational-content properties. On my view, vividness refers to subjective-intensity. Unlike Fazekas, I think that the category of vividness does not involve content properties. Vividness is a universal, content-invariant and modality-non-specific property that is present whenever WIL experience takes place. Vividness is a necessary condition for WIL experience to occur, but it is not a necessary condition for us to have subjective-specificity properties (qualities). We can have those qualities unconsciously (dual model).

I will conclude by noting that representational similarity and signal-decoding analysis of certain experimental results (Andersen et al. 2016; Dijkstra et al. 2021) demonstrate that there is an empirical evidence for content-invariant neural signature of perceptual vividness distributed across visual, parietal, and frontal cortices. (Barnett et. al. 2024)

How does the enactivist view explain dreaming experiences?

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Concurrent Session: Metaphysical Theories, Thursday July 4th, Seminar Room, Ito International Research Center, 2:00PM-3:30PM

A typical enactivist account interprets conscious experiences as interaction between the subject's body and the physical environment (i.e., the body-environment interaction). In this case, dreaming experiences pose a direct challenge to the enactivist view: during dreaming states, the subject is largely cut off from the environmental stimuli, in which case there is minimal body-environment interaction; however, in dreams, the subject can still have vivid experiences in the phenomenal sense. This threatens the integrity of the enactivist account. In this paper, I present an enactivist account of dreams as a response to this challenge by analyzing a critical distinction between dreaming and waking experiences: the disrupted subjective perspective in dreaming experiences that 1) makes the dream content fail to follow sensorimotor rules and 2) makes the subject fails to be aware that she is dreaming (i.e., the partial lack of self-awareness). I suggest that this critical distinction in the phenomenal sense is associated with the physical fact that during dreaming states, the body-environment interaction is disrupted because of the lack of environmental stimuli and bodily reactions to those stimuli. With the lack of body-environment interaction differentiating dreaming from waking experiences, the enactivist view is compatible with the dreaming phenomenon. In the first section of this paper, I explain the enactivist account in detail. In particular, I explain the differentiation and relationship between conceptualizable (i.e., the content that can be conceptualized and reported by the subject) and preconceptual content (i.e., the content that includes the ambiguities in the perceived world that await further explorations in the continuous interaction between the body and the environment) of perceptual experience. I suggest that the preconceptual content, which is missing in dreaming experiences, is closely related to the disrupted subjective perspective in dreams and essential to explaining the absurdity of dream content and the partial lack of self-awareness in dreams. In the second section, I analyze the limitations of the previous enactivist accounts of dreaming experiences by suggesting that the previous accounts failed because they relied on dream reports when analyzing dream content. And the dream reports are unreliable because they fail to reflect the phenomenal consequence of the lack of preconceptual content essential to interpreting the differences between dreaming and waking experiences. In the third section, I present my enactivist account of dreaming experiences, which interprets dreams as centrally generated mental imagery without body-environment interaction. I argue that the lack of body-environment interaction has made dreaming experiences a significantly different phenomenon from waking experiences. In particular, dreaming experiences embed a disrupted subjective perspective due to the lack of preconceptual content, which leads to 1) inconsistencies in dream content and 2) failures to detect these inconsistencies and to realize dreams are not reality. I conclude that this enactivist interpretation of dreaming experiences can explain dreaming experiences without threatening the integrity of the theoretical framework of enactivism because the phenomenal differences between dreaming and waking experiences are successfully identified and explained by the physical differences specified from the enactivist perspective.

When James meets Libet: thought transitions as the result of a mental urge to move

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Concurrent Session: Decision and Volition, Thursday July 4th, Conference Room, Ito International Research Center, 2:00PM-3:30PM

In recent years, considerable progress has been made in the scientific investigation of the dynamics of spontaneous thoughts (e.g. Andrews-Hanna et al. 2021, Kim et al., 2022, Sripada & Taxali, 2020). Most paradigms up to now require participants to verbalize their thought content, and rely on retrospective ratings. Here, we propose a new way to study the dynamics of spontaneous thoughts that overcomes the limitations of these methods by focusing on thought transitions. To do so, we developed an online segmentation protocol where participants press a key when they feel that their thought just changed. We moved beyond word production tasks by including inner word production and inner thoughts conditions. Participants (N=58) completed 3 blocks of 4 tasks forming a gradient towards probing pure thought segmentation: 1) vocal free word production (FWP), 2) vocal FWP + online segmentation, 3) inner FWP + online segmentation, 4) inner thoughts + online segmentation. In addition, we collected offline, retrospective segmentations on series with vocal production, and we measured trait inattention and tendency for mind-wandering using questionnaires (ADHD Self-Report Scale, ASRS, Adler et al. 2006; Mind Excessively Wandering Scale, MEWS, Mowlem et al., 2016). First, we assessed the consistency between third and first person measures. Online and offline segmentations aligned closely, and were congruent with objective measures of response times and consecutive semantic similarities in the conditions where words were produced. We also found a positive correlation between the number of thought changes and trait tendency for mind-wandering in the “inner thoughts + online segmentation” condition only, suggesting that this condition captured thoughts segmentation as expected. Next, we analyzed the durations of thought episodes to uncover the processes underlying decisions to report transitions. We reasoned that transitions would be reported after a sufficient number of mental events had occurred, so that each key press could be seen as the outcome of an accumulation process to a threshold. This concept is reminiscent of the decision-making process for initiating movements observed in Libet experiments (Schurger et al., 2012). We therefore applied sequential sampling modeling (Laming, 1968) to thought durations as well as to word onset asynchrony, which served as a benchmark. Our analysis revealed consistent patterns of evidence accumulation rates within participants across word production and thought segmentation tasks, suggesting consistent individual characteristics. We further tested whether trait tendency for mind-wandering was associated with a higher rate of evidence accumulation or to a lower threshold. Our results demonstrate the potential of subjective segmentation tasks for accessing the rhythms of the stream of thought

When prospective metacognition works better: Bet tells more than confidence rating

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Concurrent Session: Decision and Volition, Thursday July 4th, Conference Room, Ito International Research Center, 2:00PM-3:30PM

In uncertain environments, individuals rely on both external information and internal states, such as confidence, to flexibly control their behavior. This ability, known as metacognition, especially the aspect concerning future actions, prospective metacognition, plays a crucial role in adaptive behavioral control. Metacognition manifests itself indirectly through the outcome of decisions. Conversely, it has been suggested that expressing confidence directly through linguistic representations can facilitate collective decision making (Shea et al., 2014). However, the impact of these different modes of expression on prospective metacognition performance remains unclear. If metacognitive performance varies with its mode of expression, this finding could help improve prospective metacognition, which is typically less accurate than retrospective metacognition (Siedlecka et al. 2016). Here, we investigated these differences by giving participants the same behavioral tasks, varying only the instructions to modify their metacognitive strategies.

A total of 173 participants (ages 19-50, 102 males, 70 females, and 1 non-respondent), recruited via crowdsourcing, participated in an online auditory delayed matching-to-sample task with bet or confidence rating, as described by Yuki et al. (2019). In this task, participants were presented with two sound stimuli with a delay in between them and were asked to judge whether the stimuli were identical. Participants were divided into two groups: the confidence group, in which they rated their confidence in the recallability of the stimuli after listening to a sample stimulus, and the bet group, in which they wagered points to choose between low or high risk/reward for the following judgment. After the judgment, both groups directly rated their confidence in the judgment. In addition, to examine the context dependence of each metacognition, the memory difficulty of the stimuli varied across blocks. The stimuli consisted of sequences of seven tones, each with six harmonic components, and the memory difficulty was manipulated by the similarity of the tone sequences, classified as $0.1 \leqq r \leq 0.35$ (easy) or $0.7 \leqq r \leqq 0.95$ (difficult).

The results showed that both behavioral performance and retrospective confidence were affected by difficulty, but there was no difference between task instructions. In addition, prospective confidence remained unchanged across difficulty levels and task instructions. Interestingly, in the low difficulty condition, the standard deviation of prospective confidence was greater in the bet group than in the confidence group. Next, we applied Fleming’s (2017) hierarchical Bayesian model to estimate metacognitive performance (meta-d’/d’). The analysis indicated that, in the low difficulty condition, prospective metacognitive performance was superior in the bet group than in the confidence group.

Our findings support previous research showing that retrospective metacognitive performance is superior to prospective metacognitive performance, as retrospective confidence was correlated with behavioral performance. On the other hand, in the low-difficulty condition, prospective metacognition in the bet group improved. Given the large variation in the bet group and the maximization of reward in betting, this suggests that prospective metacognition through betting increases the diversity of participants’ behavior and is improved by reference to useful information such as past history.

Common neural choice signals reflect (error) evidence, not confidence

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Concurrent Session: Decision and Volition, Thursday July 4th, Conference Room, Ito International Research Center, 2:00PM-3:30PM

Most decisions are accompanied by a sense of confidence. While much research has investigated decision confidence, its neural underpinnings remain unclear. Specifically, given that confidence is often higher for trials with stronger evidence, it is unclear whether previously identified signals reflect evidence strength or confidence. Here, we capitalize on our recent finding that a causal manipulating of prior beliefs induces confidence bias, while leaving objective task performance unaffected. Using EEG recordings, we then tested whether neural signals known to correlate with confidence (P3 and Pe) reflect evidence accumulation or confidence. We replicated the behavioural finding that the prior beliefs manipulation lead to significant differences in confidence without changing objective task performance. The EEG data showed a monotonic relation between confidence levels and both the P3 and Pe amplitudes, with lower levels of confidence being associated with lower P3 and higher Pe activity. Critically, there was no significant difference for both components depending on prior beliefs. Fits of a computational model couched within the principles of evidence accumulation showed that both components reflect the accumulation of (error) evidence, which are then combined with prior beliefs to compute confidence. These findings are in line with recent views suggesting that the Pe reflects post-decisional evidence accumulation, which is combined with prior beliefs to form a confidence judgment.

Exploring the Temporal Dynamics of Voluntary Decision-Making across Stable and Dynamic Contexts

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Concurrent Session: Decision and Volition, Thursday July 4th, Conference Room, Ito International Research Center, 2:00PM-3:30PM

Voluntary decisions are endogenously driven, conscious decisions that are often mediated by subjective goals and preferences. In dynamic environments, continuous re-evaluation of choices is essential in response to new information, such as changes in available options. For example, when new options become available, we can commit to our initial choice to reinforce our original goals or flexibly change our intentions to pursue an alternative choice. Findings from prior fMRI studies suggest key brain regions involved in encoding choice options during voluntary decision-making. However, precisely how voluntary decisions unfold in the brain over time remains unknown, particularly in dynamic contexts where decisions may be revised. We used high temporal resolution electroencephalography (EEG) recordings to capture the underlying neural signatures associated with voluntary decisions in stable and dynamic contexts. Participants (N=35) completed a two-phase colour decision task. In the first phase (the stable context), participants freely chose between two of four coloured balloons (blue, green, orange or pink) in one condition. In another condition, they were forced to select a sole colour option that was presented. In the subsequent phase (dynamic context) occurring in half of trials, either a new option was introduced (in trials where only one option was presented in the first phase) or one of the two options initially available was removed (when participants initially had two choice options). This meant that participants could either maintain their original colour choice or switch to an alternative colour. We observed slower response times (RTs) for free compared to forced choices, subsequent compared to initial choices, and switched compared to maintained choices. Temporal costs indexed by longer RTs suggest additional cognitive demands when making voluntary (i.e., free) choices and subsequent choices, and when abandoning initial choices compared to committing to original choices. Multivariate pattern analysis was used to decode differences in neural patterns for free and forced choices in the initial and subsequent choice phases. In the initial decision phase, forced choices were decodable above chance between 240 – 320ms and 380 – 450ms, indicating critical periods for instructed decisions. However, free choices were not decodable above chance throughout the epoch, possibly due to increased neural noise individual differences in decision strategies (e.g., colour preferences, avoiding picking the same colour consecutively). In the subsequent decision phase, above-chance decoding was not observed for either free or forced choices. Taken together, although voluntary decisions were successfully decoded in previous fMRI studies, neural signatures of voluntary decisions in both stable and dynamic contexts remain elusive in EEG signals, possibly due to diverse individual differences and complexities of voluntary decisions over time, which remain challenging to examine at a group level. A natural next step would be to conduct a more in-depth examination of neural signatures through time-frequency analyses and to explore individual differences through behavioural modelling of RTs.

Sequential effects in decision making: the role of slow fluctuations in decision criterion

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Concurrent Session: Decision and Volition, Thursday July 4th, Conference Room, Ito International Research Center, 2:00PM-3:30PM

Every day, we have to make numerous decisions based on noisy perceptual input. These decisions are not only influenced by the immediate sensory input but also depend on the broader context, such as the choice history, decision confidence, and the previously seen stimuli. The influence of experimental history, broadly referred to as sequential effects, is observed across tasks and species, and seems to be a fundamental feature of decision making. Whereas previous work developed highly specialized and complex mechanisms to often explain only one modulating factor of sequential effects, we propose a far simpler mechanism that explains a wide range of sequential effects. We show that fluctuations in the decision criterion, modelled as an autoregressive process, are sufficient to explain three key sequential effects. Importantly, whereas previous models relied on a causal effect of experimental history to explain sequential effects, these results suggest that sequential effects are the consequence of a fluctuating process independent from experimental history. In order to measure these slow fluctuations in decision criteria in empirical data, we developed the Hierarchical Model for Fluctuations in Criterion (hMFC). To empirically test the slow fluctuations account, we fitted hMFC on 23 datasets from the confidence database. Model fits across datasets showed that indeed slow fluctuations explained some, but not all, of the sequential effects. These results suggest that some sequential effects in decision making are not the result of a causal updating process, but instead result from slow fluctuations in criterion.

Light-independent pupillary fluctuations predict sensory perceptual sensitivity, MEG, and whole brain fMRI signals

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Concurrent Session: Decision and Volition, Thursday July 4th, Conference Room, Ito International Research Center, 2:00PM-3:30PM

Sensory perceptual sensitivity – the probability of perceiving a sensory event – is dynamic. Fluctuation of perceptual sensitivity is partly linked to arousal state. Primary regulators of arousal are neuromodulatory networks with major hubs in the thalamus and brainstem. These areas may act to shape the state of cortical networks, including those relevant for conscious perception-linked processing of sensory stimuli. While arousal networks can be challenging to record from, pupil size offers an accessible marker of arousal and proxy for widespread cortical and subcortical activity. To better understand the relationship among pupillary fluctuations, brain activity, and perceptual sensitivity, we aimed to (1) examine if perceptual sensitivity follows pupil size trends (e.g., dilations, local maxima, constrictions, and local minima) and (2) map and track the brain activity associated with pupil size trends. Healthy adult participants (N = 13; Target N = 35) completed closed-loop visual and auditory perception tasks with concurrent pupillometry (EyeLink 1000 Plus; SR Research, Inc.) and magnetoencephalography (MEG; 275-channel system; CTF Systems, Inc., Canada). The high-temporal resolution of MEG allowed studying the cortical activity linked with pupil size trends. Participants were administered detection tasks for near-perceptual threshold stimuli (images or tones) that were trigger when the target pupil size trends were detected using a custom real time pupillometry software. To map the brain networks linked with trends in pupil size, including subcortical regions inaccessible with MEG, we analyzed the whole brain activity correlated with pupil size trends in a large (N > 100) healthy, adult human resting state fMRI dataset with concurrent pupillometry (7T; Human Connectome Project [HCP]. Behavioral results support that pupil size trends correlate with sensory perceptual sensitivity for auditory and visual stimuli – perception rate increased for stimuli shown during pupil dilation. Preliminary MEG signal analyses reveal diverging cortical activity preceding the dilation and constriction pupil size trends, particularly over parietal and occipital regions of the scalp. fMRI signal analyses reveal that preceding and following pupil phase events there is modulation of the thalamus and brainstem specific to each pupil size trend. In conclusion, this experiment supports pupil size trends as a proxy marker of multimodal perceptual sensitivity and subcortical and cortical brain activity that may be relevant in conscious perception. Future investigation can interrogate how the modulation of pupil-linked brain networks may influence conscious perception.

Transcranial ultrasound stimulation to central thalamus decreases arousal in healthy volunteers

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Concurrent Session: Attention & Working Memory, Thursday July 4th, Fukutake Learning Theater, 4:30PM-6:00PM

Here, we present the first causal data in healthy humans linking the thalamus to arousal and visual attention using transcranial focused ultrasound (tFUS). Non-human animal models and uncontrolled observations with human patients provide us with strong expectations about the contributions of thalamic regions to healthy human cognition. However, this research is the first to test the causal roles of central thalamus, an area implicated in arousal and consciousness level, and pulvinar, a nucleus associated with visual and visuospatial attention, in healthy volunteers. Taking a within-subjects design, 27 healthy volunteers completed the Psychomotor Vigilance Task (PVT), a measure of arousal and sustained attention, and the Egly Driver Task (EDT), a measure of visuospatial attention, before and after inhibitory tFUS to central thalamus, inhibitory tFUS to pulvinar, and sham stimulation (on different days and in a counterbalanced order across subjects). tFUS modulated performance on both tasks in accordance with the expected functions of the targeted structures. Specifically, tFUS to central thalamus impaired responsiveness in both the PVT and EDT compared to sham and pulvinar stimulation, reflecting decreased arousal. Pulvinar tFUS, however, was associated with subtle deficits on the EDT compared to sham, consistent with a more selective modulation of visual attention (and not arousal). These novel causal data corroborate previous work, but also demonstrate that tFUS can be used to map the brain in healthy volunteers with unprecedented spatial resolution. The targeted regions are only a few centimeters apart, which is an unmatched spatial dissociation for deep-brain tFUS neuromodulation to our knowledge.

Visual Working Memory Performance is Affected By Visual Field Asymmetries – Insights from Behavioral and MRI Analysis

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Concurrent Session: Attention & Working Memory, Thursday July 4th, Fukutake Learning Theater, 4:30PM-6:00PM

It is known that perceptual performance is not uniform across the visual field. It is best at the center of our gaze and deteriorates gradually towards the periphery. Yet, this is not the only factor known to affect this non-uniformity. Perceptual performance is likely to be better along the horizontal than the vertical meridian, and the lower half compared to the upper half of the vertical meridian of the visual field. These asymmetries have been successfully studied with the use of human and animal models and linked to differences in the retinal organization. They are also known to manifest in both structure and function of the early visual cortex. While it has been shown that the effects of perceptual asymmetries carry over to cognitive processes such as attention, we haven't yet explored in depth if they impact visual working memory. This would be particularly important because visual working memory is hypothesized to rely heavily on the same neural mechanisms in the early visual cortex as perception itself. We applied a visual working memory task that allowed us to test for performance differences across the visual field. The study was conducted on a large sample (N = 292) as part of the SkuldNet consortium and COST Action CA18106. The behavioral results replicate findings from an earlier study and confirm the largest effect size for performance differences along the horizontal versus vertical axis (Cohen's d = 1.53). Notably, this effect was mainly carried by a right versus down asymmetry (Cohen's d = 1.56). Moreover, the asymmetry within the vertical axis was opposite to effects known from the literature, with notably superior performance in the upper half compared to the lower half of the vertical meridian. Each participant underwent an MRI scan. For analysis, we used quantitative Multi-Parameter Mapping, a technique known to be sensitive to various aspects of microstructural tissue differences in white and grey matter. We checked for interindividual differences in brain tissue organization linked to behavioral performance patterns, particularly in the early visual cortex. We found significant results in R2* maps, which are sensitive to accumulated iron content. This ties in with previous findings linking iron accumulation in the brain to the deterioration of memory functions and neurodegenerative disorders. In conclusion, our findings contribute to the clarification of the relationship between working memory and sensory processing and their shared neural substrate.

Subjective inflation under inattention is robust across stimulus types and performance levels, for both threshold and suprathreshold stimuli

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Concurrent Session: Attention & Working Memory, Thursday July 4th, Fukutake Learning Theater, 4:30PM-6:00PM

Background: Findings of subjective inflation, in which subjective reports of unattended, peripheral stimuli are stronger than the accuracy of sensory processing would suggest, have motivated higher-order theories of consciousness. However, empirical tests of subjective inflation have been surprisingly limited. Generally they have used a single pair of near-threshold stimulus strengths–weaker for attended and stronger for unattended–to equate objective performance, leaving it unclear whether inflation arises from decision biases and whether inflation extends beyond threshold perception. Goal: In a preregistered adversarial collaboration, we rigorously tested whether attention dissociates subjective reports and objective performance across a range of stimulus strengths and types. Methods: In four experiments, human observers (n=30 per experiment) performed a spatial attentional cueing task. On each trial, observers viewed up to four peripheral targets, which varied independently across 7 stimulus strengths. Targets were texture-defined figure-ground ovals (Experiments 1 and 2) or contrast-defined gratings (Experiments 3 and 4), presented at threshold (Experiments 1 and 3) or suprathreshold (Experiments 2 and 4) stimulus strengths. A central precue (60% valid, 20% neutral, 20% invalid) directed attention to one or all target locations. A response cue instructed observers to simultaneously make 1) an objective orientation report and 2) a subjective visibility report about one target location. The subjective report was threshold detection (Experiments 1 and 3) or suprathreshold visibility comparison (Experiments 2 and 4) ("overall visibility"). In Experiments 1, 2 and 4, observers additionally reported whether or not they saw the specific feature relevant for the orientation report, which was the oval shape or grating tilt ("task-relevant feature visibility"). To assess subjective inflation, we developed a quantitative approach to relate objective and subjective reports across stimulus strengths for a matched range of orientation discrimination performance under different levels of attention. Results: We observed robust subjective inflation for overall visibility across all experiments. Across a range of threshold and suprathreshold stimulus strengths and different stimulus types, overall visibility was reported as higher for unattended vs. attended stimuli across a matched range of orientation discrimination performance. The size of the inflation effect for overall visibility was larger for suprathreshold than threshold-level stimuli. Whereas overall visibility showed strong subjective inflation across all stimuli and threshold regimes, the degree of inflation for task-relevant feature visibility depended on the experiment, ranging from no subjective inflation to inflation similar to that found for overall visibility. We replicated all effects of attention across two experimental sites. Conclusion: Inattention robustly inflates overall subjective visibility reports, and inflation is not confined to threshold vision. Whether sensory signals are sufficient for explaining subjective visibility reports when they come apart from objective performance may help arbitrate between competing theories of consciousness.

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The Observant Attention Trait: Are some individuals more prone to noticing?

Sophie Forster (University of Sussex), Chris R. H. Brown (University of Roehampton)

Concurrent Session: Attention & Working Memory, Thursday July 4th, Fukutake Learning Theater, 4:30PM-6:00PM

The characteristic of being observant is a widely acknowledged socio-cultural construct, referring to an individuals' general tendency to become aware of information in their surrounding environment. However, despite a large existing literature on individual differences in attention and awareness, the construct of observant attention does not clearly map on to any formally recognised form of trait variation: Arguably the closest established construct is Inattentional Blindness (IB), but the binary and single trial nature of IB measures make them poorly suited to individual differences research. The current study sought to test for an 'Observant Attention' trait. To this end, we established a novel self-report measure across seven separate large samples (total N = 2,053, predominantly undergraduate students). Within this measure there appeared to be an underlying 'Observant Attention' factor reflecting the variation in awareness of external stimuli. The Observant Attenton factor was composed of three subfactors, reflecting the ability to notice subtle less relevant details in the environment ('Noticing awareness'), becoming aware of unexpected salient motivationally relevant stimuli ('Alerting awareness'), and the ability to become aware of olfactory stimuli ('Olfactory awareness'). There was also an additional Distractibility factor reflecting general uncontrolled lack of focused attention, which was independent of the other factors. The factor structure and reliability of this four-factor scale was replicated across samples using confirmatory analysis. Further test-retest analysis revealed that even after a year the measure showed consistent responses, indicative of a stable trait-like phenomenon. Observant Attention showed either no relation or modest correlations with existing attentional traits, suggesting that it is not adequately indexed by these existing measures, and was also modestly related to patterns of neurodiversity and social distancing failures. We also found a modest positive relationship between Observant Attention (in terms of both the overall score and the noticing subscale) and noticing the unexpected critical stimulus on an IB task, as well as confidence ratings among those who noticed the stimulus. However, self-reported Observant Attention was also inflated among those who reported noticing the IB critical stimulus but incorrectly reported its location. The current investigation hence establishes a reliable measure of individual differences in observant attention that can be used to examine both the mechanisms and real world consequences of this trait.

Waves of attention: Tracking the neural correlates of sustained attention with Magnetoencephalography

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Concurrent Session: Attention & Working Memory, Thursday July 4th, Fukutake Learning Theater, 4:30PM-6:00PM

Sustained attention is a foundational aspect of our conscious experience, facilitating not only a coherent and continuous focus on environmental tasks or events but also enabling optimal information processing, thereby critically influencing our moment-to-moment perception and understanding of reality. Behavioral variability during sustained attention tasks has been thought to reflect fluctuations in cognitive states that are associated with optimal and sub-optimal attentional performance. These cognitive states are supported by an intricate interplay of neural activities across a diverse set of brain networks. Previous work on sustained attention suggests that this ability relies on oscillatory mechanisms that regulate the excitation and inhibition of sensorimotor systems to preserve performance from internal and external distractions. Interestingly, non-oscillatory (aperiodic) activity is also involved in the brain's excitation/inhibition balance and might obfuscate the analysis of oscillatory power. Yet, the spectral correlates (periodic and aperiodic) of fluctuations in sustained attention performance are still poorly understood. In this work, we acquired magnetoencephalography (MEG) data in 32 healthy participants during the gradual onset Continuous Performance Task (gradCPT), a sustained attention task that allows the continuous sampling of attentional states. We selected periods of low and high behavioral variability (aka "in-the-zone" and "out-of-the-zone", respectively), and conducted subject-level and epoch-level spectral analysis while separating periodic from aperiodic activity. We found that optimal performance was associated with increased power in the alpha and low beta bands and that apparent decreases in the gamma range could, in fact, be attributed to changes in the slope exponent of aperiodic activity. Furthermore, we showed that lapse trials were associated with a broadband increase in spectral power during optimal performance as well as stronger modulations of the aperiodic component, supporting the notion that errors are the consequence of distinct failures in optimal and sub-optimal performance. Finally, using supervised machine learning, we showed that single-feature classification was able to successfully discriminate between optimal and sub-optimal performance at the epoch level and that classification scores in alpha and beta bands were improved after slope correction. Overall, our results demonstrate the utmost importance of accounting for periodic and aperiodic activity in the spectral analysis of MEG signals when studying sustained attention. Furthermore, they suggest that the periodic and aperiodic activities may have dissociable and complementary roles in mediating sustained attention. These insights into sustained attention unlock new avenues for investigating the complex interplay between attention, consciousness, and higher cognitive processes.

Gene-expression analysis of (un)conscious-related visual-attention experimental paradigms suggests unique biological pathway signatures for the different paradigms

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Concurrent Session: Attention & Working Memory, Thursday July 4th, Fukutake Learning Theater, 4:30PM-6:00PM

Conventional belief suggests that visual attention processes primarily rely on mechanisms associated with action potential propagation and synaptic transmission. However, multiple biological processes support the function of neurons as biological cells, and it is interesting to know if other biomolecular and cellular processes also contribute to the performance in some psychological experiments. To check this possibility, we used the publicly available RNA expression data from the Allen Brain Human Atlas together with published evidence about fMRI brain activity or brain stimulation effect (TMS, tDCS) for two commonly used experimental paradigms in the field of consciousness studies, namely, Attentional Blink and Change Blindness. We extracted RNA levels from the Allen Brain Human Atlas using the publicly available ABAGEN python package. We curated published fMRI data and used the meta-analysis NiAMARE tool to extract the Z-values relatedness of fMRI activity for these two experimental paradigms. We also used a simulation tool (SimNIBS) to stimulate the expected electric field in the brain from published brain stimulation experiments that were shown to affect the outcome of Attentional Blink and Change Blindness. Finally, we parceled all these data resources into the parcels of commonly used brain atlases (cortical – Kong et al. (Shaffaer100), 2021; subcortical – Tian et al., 2020; cerebellum – Buckner et al. 2011). To identify biomolecular and cellular patterns associated with Attentional Blink and Change Blindness, we run a linear correlation analysis for the parceled RNA levels and the parceled levels of fMRI or the brain stimulation expected electric field for these two paradigms. This analysis resulted in a list of genes and the associated correlation P-values for each of the two paradigms for different brain regions. Next, we used pathways-enrichment-based tools (g:Profiler, GSEA, and EnrichmentMap) to identify genes and biomolecular or cellular pathways that are especially enriched among the genes mostly correlated with the fMRI or brain stimulation results. This analysis suggests that genes mostly correlated with Attentional Blink are not the expected ones in some brain regions, i.e., genes for action-potential propagation or synaptic transmission. As a consistency check, brain activity for Change Blindness did suggest enrichment of genes associated with synaptic transmission. Similarly, genes associated with synaptic transmission were primarily enriched in other brain regions for Attentional Blink. Overall, our results suggest different biomolecular pathways that support visual attention processes in the brain for different paradigms. In addition, our results pave the way for a broader understanding of conscious processes beyond their neural correlates.

Can structural correspondences ground representational content in Large Language Models?

Iwan Williams(Monash University)

Concurrent Session: AI and Consciousness 2, Thursday July 4th, Ito Hall, Ito International Research Center, 4:30PM-6:00PM

Large Language Models (LLMs) such as GPT-4 produce compelling responses to a wide range of prompts. But their representational capacities are uncertain. Many current LLMs have no direct contact (via perception or action) with extra-linguistic reality: their inputs, outputs and training data consist solely of text, raising the questions (1) can LLMs represent anything and (2) if so, what? I will present work assessing the merits of a structural-correspondence based account of representation in LLMs. In the philosophical literature on mental representation in biological organisms, one popular family of approaches appeals to structural correspondences. On this view, representations are grounded partly in a morphism, resemblance, or mirroring between (on the one hand) a set of internal states or vehicles and (on the other) a set of entities in some worldly domain. These accounts look well-placed to ground representation and content in LLMs for two reasons. Firstly, unlike causal-informational accounts, it is not obvious that structural correspondences require direct perceptual or behavioural contact with the represented entities. Secondly, there is some empirical evidence that suggests that the activation state spaces of LLMs structurally correspond to real-world relations. I will argue that, despite the apparent promise of a structural-correspondence based account of representation in LLMs, any defensible version of such an account must deny that a structural-correspondence between internal states and external conditions is *sufficient* for representation. When we look carefully at what the most plausible accounts demand in addition to structural correspondences, the verdict with respect to LLMs is mixed: some of the necessary conditions are met by current, cutting-edge LLMs; other conditions are clearly not met; yet others require further investigation.

Thoughts without sensory grounding: the argument from duplication

Joe Y. F. Lau(The University of Hong Kong)

Concurrent Session: AI and Consciousness 2, Thursday July 4th, Ito Hall, Ito International Research Center, 4:30PM-6:00PM

A recent controversy in AI revolves around the question of whether large language models (LLMs) can possess genuine thoughts and understanding without sensory capacities. Many argue that sensory capacities are essential for semantic grounding, which links representations to the external world. Chalmers (2023) addresses this issue by exploring the idea of a "pure thinker". He argues that (1) Pure thinkers may only have structural concepts, but lack singular concepts of objects in the external world; (2) AI systems that receive linguistic inputs can potentially acquire singular concepts that a pure thinker cannot. I agree with (2) but disagree with (1). In my presentation, I examine how duplicating a cognitive agent can preserve some of the concepts it possesses. This demonstrates that while sensory capacities may serve as the initial semantic source for a wide range of singular concepts, they are not strictly necessary for possessing these concepts. The implications of this conclusion for AI will also be discussed.

Human-like dissociations between confidence and accuracy in convolutional neural networks

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Concurrent Session: AI and Consciousness 2, Thursday July 4th, Ito Hall, Ito International Research Center, 4:30PM-6:00PM

Prior research has shown that manipulating the energy of a stimulus by changing both stimulus intensity and variability results in confidence-accuracy dissociations in humans. Specifically, even when performance is matched, higher stimulus energy leads to higher confidence. The most common explanation for this effect involves the assumption that confidence relies on selective, high-level mechanisms – such as the positive evidence heuristic where confidence neglects evidence that disconfirms the choice. Another high-level theory proposes that humans are blind to noise arising from their own cognitive computations, resulting in a neglect or down-weighting of stimulus variability. However, an alternative low-level explanation for this effect is the signal-and-variance-increase hypothesis, according to which these dissociations arise from changes in the separation and variance of perceptual representations. Because artificial neural networks lack built-in confidence heuristics, they can serve as a test for the necessity of confidence heuristics in explaining confidence-accuracy dissociations. Therefore, we tested whether confidence-accuracy dissociations induced by stimulus energy manipulations emerge naturally in convolutional neural networks (CNNs). We found that, across three different energy manipulations, CNNs produced confidence-accuracy dissociations similar to those found in humans. This effect was present for a range of CNN architectures from shallow 4-layer networks to very deep ones, such as VGG-19 and ResNet-50 pretrained on ImageNet. Further, we traced back the reason for the confidence-accuracy dissociations in all CNNs to the same signal-and-variance increase that has been proposed for humans: higher stimulus energy increased the separation and variance of the CNNs' internal representations leading to higher confidence even for matched accuracy. Further, these networks captured another behavioral signature of confidence that has been attributed to the positive evidence mechanism. These findings cast doubt on the necessity of the high-level mechanisms to explain human confidence and establish CNNs as promising models for adjudicating between low-level, stimulus-driven and high-level, cognitive explanations of human behavior.

Integrating Neuroscientific Theories of Consciousness with AI: Unveiling Sensorimotor Representations in Global Latent Workspaces

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Concurrent Session: AI and Consciousness 2, Thursday July 4th, Ito Hall, Ito International Research Center, 4:30PM-6:00PM

In the aftermath of the success of attention-based transformer networks, the debate over the potential and role of consciousness in artificial systems has intensified. Prominently, the global neuronal workspace theory emerges as a front-runner in the endeavor to model consciousness in computational terms. The theory suggests the brain has specialized modules connected by neuronal long-distance links. Based on the current context, inputs and tasks, content from one module is broadcasted and shared with others (also referred to as global ignition). This shared content, termed the global neuronal workspace, represents our conscious awareness. A recent advancement in the direction of mapping the theory onto state-of-the-art machine learning tools is the model of a global latent workspace (GLW). It introduces a central latent representation around which multiple modules are constructed. A semi-supervised training process molds the latent representation enforcing cycle consistency such that the content from any one module can be translated to any other module and back with minimal loss. Consequently, the central representation mediating this process forms an optimal compromise. Comparable to Occam's razor, from each module it integrates just as much information as necessary. The access rights to this global latent representation are determined by transformer like attention mechanisms. We investigate the representational and behavioral dynamics of a virtual embodied reinforcement learning agent equipped with a minimal GLW setup involving one deep visual sensory module and one deep motor module. A standard PPO algorithm in combination with internal cycle consistency and layer specific attention mechanisms leads to the emergence of complex goal directed behavior. Training in the benchmark Obstacle Tower Challenge environment leads to the emergence of sensorimotor representations in the latent layer connecting both modules. Remarkably, the topology of the latent space clusters representations of semantically similar rather than visually equivalent contexts and objects. Moreover, the GLW remains sparse in comparison to autoencoders or supervised visual deep nets. In the recent discourse on neuroscientific theories of consciousness, one notably cited theory has been sidelined. The sensorimotor contingency theory proposes law-like changes of sensory input in relation to motor output (or efferent copies) to constitute the neuronal correlate of phenomenal conscious experience. Despite strong empirical support and a solid theoretical foundation, which includes a precise mathematical framework, leveraging dynamical system theory for sensorimotor manifold learning, technical applications have been mostly limited to early-stage prototypes. Here, the natural appearance of global latent sensorimotor representations links two major neuroscientific theories of consciousness in a powerful machine learning setup. As one of several remaining questions it may be asked, can such a representation in silico be sufficient for the phenomenal perception of space? Opponents advocating neurobiological implementation as necessary criteria must present compelling arguments based either on functional advantages or other foundational premises.

Now I see human, now I see chatbot: Linguistic and contextual cues used to evaluate the presence of mind

Rose E. Guingrich (Princeton University), Michael S. A. Graziano (Princeton University)

Concurrent Session: AI and Consciousness 2, Thursday July 4th, Ito Hall, Ito International Research Center, 4:30PM-6:00PM

What linguistic or contextual cues do people draw upon in conversations when determining whether the mind of a conversational agent is human or artificial? We devised an implicit theory of mind task to understand how people differentiate between a real and an artificial mind in agents within a text-based conversation when no other cues are present. Alan Turing devised a test in 1950 to determine whether a computer was able to deceive as well as or better than a human. In the next decade, the first AI developers lined up to try to make an artificial agent that could "pass" the Turing test. Despite the test being passed in 2012, we do not yet know much about what linguistic or contextual cues people draw upon when evaluating whether the agent they are conversing with has a human or machine mind. In our research, we devised a task aimed at measuring implicit ascriptions of mind or consciousness to a conversational agent. Participants (N=104) read conversations (N=9) between a person and an artificial intelligence chatbot. They had to decide which agent was the chatbot and indicate why they made that decision. Participants on average were correct in their decisions only 65% of the time, and confident 72% of the time. Further, our results suggest that people draw upon similar contextual cues when they make the correct versus incorrect decision about the mind of an agent, as well as when they switch throughout the course of a conversation between perceiving the mind of an agent as artificial or human. The linguistic and contextual cues people drew upon fell into a mix of categories: general human likeness, grammar, formality, emotion, learning and adaptability, randomness and repetition, and humor or sarcasm. Notably, people relied on comparing agents to determine which one was more humanlike. When people made the wrong decision compared to the correct one, they were more likely to indicate randomness and irrelevance in the conversation. This study sheds light on how people use linguistic cues in human or artificial mind ascription in the absence of all other cues.

How consciousness-inspired architectures can address the hard problems of AI

Adam Safron (Indiana University), Zahra Sheikhbahaee (University of Montreal and Mila)

Concurrent Session: AI and Consciousness 2, Thursday, July 4, Ito Hall, Ito International Research Center, 4:30PM-6:00PM

Our group has been developing meta-learning agent architectures for autonomous systems. Of particular note is our work with world modeling (and "dreaming") architectures involving information bottlenecks and latent spaces capable of learning complex sets of structured features via nonparametric Bayesian learning. While our architectures likely do not entail phenomenal consciousness, we will describe how functions associated with models of conscious processes can be useful for AI/ML for enhancing adaptivity to dynamic environments, including those involving other agents. We will discuss the ways in which our architectures reflect a "consciousness prior" in which the formation of reduced-dimension representations can allow systems to focus on the most useful information in any given context (cf. "independently controllable factors" and the "affordance competition hypothesis"), and also share this with others (cf. consciousness as "social sharing device"). Finally, we will briefly describe how we are attempting to expand this work by using generative flow networks in the context of cooperative inverse reinforcement learning (CIRL)--and as high-level controllers over attentional policies, so affording agents that may operate according to principles of Attention Schema Theory--with potentially important implications for developing and aligning increasingly advanced AI systems in accordance with human intentions and values.

Metacognitive confidence and affect - two sides of the same coin?

Alan Voodla (University of Tartu, KU Leuven), Andero Uusberg (University of Tartu), Kobe Desender (KU Leuven)

Concurrent Session: Metacognition 2, Thursday July 4th, Gallery 1, Ito International Research Center, 4:30PM-6:00PM

It feels good when you think that you made a correct decision, however, there is not a lot of overlap between research on affect and decision confidence. Decision confidence is a prototypical metacognitive representation that is thought to approximate the probability that a decision is correct. At the same time, perceived accuracy has also been associated with affective valence, such that being correct feels more positive affect and vice versa. This suggests that, similarly to confidence, affective valence might reflect the same metacognitive signal that tracks the probability that a decision is correct. Here we test this proposal in 2 perceptual decision-making experiments, where we compare the relationship between decision-level variables (e.g. evidence, accuracy, and expectancy) and confidence versus affect ratings. The findings indicate that confidence and affect ratings both track the subjective probability that a decision is correct and are similarly sensitive to changes in accuracy, evidence, and expectancy. We discuss various mechanisms and future directions that could clarify the cognitive and affective aspects of confidence and highlight the need for stronger interactions between the respective fields

Differences in self-beliefs, and local and global metacognition across the lifespan

Astrid Emilie Lund Lund (King's College London), Juliet Foster (King's College London), Charlotte Russell (King's College London)

Concurrent Session: Metacognition 2, Thursday July 4th, Gallery 1, Ito International Research Center, 4:30PM-6:00PM

Metacognition is our ability to monitor own cognitive processes (Flavell, 1979; Fleming et al., 2012). In the current study we aimed to investigate the relationship between different levels of metacognition (i.e., local trial-level judgements, global task-level judgements and self-beliefs) and how these may change with age. There are mixed results regarding differences in metacognition across the lifespan (Cauvin et al., 2019; McWilliams et al., 2023), and much remains unknown about the interaction between ageing and the different levels of metacognition (Seow et al., 2021). The current study is therefore an important extension to our understanding of these two questions. We recruited 36 young participants (age 18-34 years) and 40 older participants (age 65-91). Participants performed nine different tasks measuring episodic memory, semantic memory and visual perception, with 105 trials in each domain. These tasks included three novel naturalistic episodic tasks, three semantic memory tasks covering different domains of knowledge and three visual Gabor tasks. Each trial consisted of a two-alternative forced choice question, followed by a 5-item confidence scale. In addition to these measures, participants completed pre- and post-task global metacognitive reports and a questionnaire on self-beliefs of memory ability. Older individuals had higher cognitive performance across the semantic memory tasks ($F(1,68)=35.436$, $p<.001$), whereas younger participants had higher performance in the episodic memory tasks ($F(1,68)=13.738$, $p<.001$). Examination of metacognition showed that younger participants had higher metacognitive bias (i.e., tendency to report higher confidence) for episodic memory ($F(1,68)=19.459$,$p<.001$) and visual perception ($F(1,68)=7.527$, $p=.008$), and a tendency for higher metacognitive efficiency (i.e., confidence accuracy according to cognitive performance) across all tasks e.g., semantic memory (group-level HMeta-d', Young: 1.391, Old: 1.065.). Age differences were also found at higher levels of metacognition, as younger participants indicated higher pre- and post-task global reports for episodic memory and visual perception, and higher memory self-beliefs ($F(1,68)= 6.453$, $p=.013$).
Further, using multiple linear regression, we examined how self-beliefs of one's memory ability develop and whether this varies across age groups. Here we found that among young participants, memory self-belief was strongly predicted by cognitive episodic memory performance ($\beta=7.90$). This prediction was weaker among old participants ($\beta=3.27$) and instead a spread of cognitive and metacognitive variables predicted self-belief. This suggests that younger individuals efficiently base their self-beliefs on relevant information. The decreased tendency to rely on task-specific information and therefore a shift to domain-general processes in older age, has been described as dedifferentiation (Baltes et al., 1980; L√∂vd√©n & Lindenberger, 2005). Network analysis was employed to further explore potential dedifferentiation, and as expected strong correlations were observed among cognitive and metacognitive variables across task domains in the older adults but not younger adults. In summary, our findings support clear differences in how older and younger adults construct their metacognitive beliefs, which may be influenced by dedifferentiation processes.

Metacognitive awareness of memory distortion during recall

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Concurrent Session: Metacognition 2, Thursday July 4th, Gallery 1, Ito International Research Center, 4:30PM-6:00PM

When we recall a past event, we reconstruct the event based on a combination of episodic details and semantic knowledge (e.g., prototypes). Relying too greatly on prototypes during recall intuitively compromises the veracity of the reconstructed event; however, it remains unclear whether we are metacognitively aware of such prototype-based distortions in long-term memory. To address this, we conducted six experiments in which participants learned object-colour or object-location pairs and subsequently recalled the associated colour/location when presented with the object as a cue. Leveraging unsupervised machine learning algorithms, we extracted participant-specific prototypes and embedded participant responses in two-dimensional space to quantify prototype-based distortions in individual memory traces. Our findings reveal robust and conceptually replicable evidence to suggest that prototype-based distortion is accompanied by a reduction in self-reported confidence - an implicit measure of metacognitive awareness. Critically, we find that this reduction in confidence stems from the retrieval of prototypical memories rather than a lack of confidence driving more prototypical responses. Collectively, these findings suggest that we possess metacognitive awareness of the veracity of our memories, providing insights into the existential question of whether we should trust our mental autobiographies.

Bidirectional interactions between local and global confidence explain the pervasive effect of confidence biases

Hélène Van Marcke (KU Leuven, Ghent University), Senne Braem (Ghent University), Kobe Desender (KU Leuven)

Concurrent Session: Metacognition 2, Thursday July 4th, Gallery 1, Ito International Research Center, 4:30PM-6:00PM

Metacognition is commonly measured through decision confidence, which is the local confidence about the correctness of a single decision. In recent years there has been an increased interest in global confidence as well, i.e. the general feeling one has about their ability to perform a task. When lacking external feedback, global confidence is formed by integrating multiple local confidence judgements. Conversely, local confidence is influenced by global confidence, as the initial feeling one has about their ability to perform a task can result in pervasive local confidence biases. However, it currently remains unclear what mechanism causes these local confidence biases to persist across time, such as consistently being underconfident about your decisions. Here, we hypothesised that the pervasiveness of confidence biases stems from continuous, bidirectional interactions between local and global confidence. We tested 42 healthy adults in a perceptual decision-making scenario, querying local confidence ratings on each trial and global confidence ratings every few trials. Results from a multiple regression analysis demonstrate that global confidence was strongly predicted by the preceding local confidence ratings while hardly influenced by accuracy or RTs. In turn, local confidence ratings were also informed by preceding global ratings, over and above the expected influences of accuracy and RTs. To understand the cognitive mechanisms underlying these bi-directional influences between local and global confidence, we fit our data to an extended drift-diffusion model that explicitly represents its global confidence as the expected probability of being correct. This representation is continuously updated based on the prediction error between the expected global confidence and local confidence in the model. Global confidence then informs the local confidence in turn, resulting in continuous interactions between both. Our extended DDM successfully captured the effects seen in the behavioural data, explaining pervasive confidence biases as the result of bidirectional local-global confidence interactions. Taken together, our study provides a computational framework and clear mechanistic insight into how interactions between local and global confidence can result in confidence biases that persist over time. More broadly, our account is in line with recent proposals that depict a metacognitive hierarchy with multiple interacting levels of confidence.

Differential effects of negative valence and memory type on accuracy, confidence, and metacognitive efficiency

Juan Castillo (Harvard University), Patricia Sieweyumptewa (Harvard University), Elizabeth A. Phelps (Harvard University)

Concurrent Session: Metacognition 2, Thursday July 4th, Gallery 1, Ito International Research Center, 4:30PM-6:00PM

Emotional responses to stimuli presented in the laboratory consistently amplify later subjective experiences of recollection for those stimuli. However, enhanced recollective experiences are not always accompanied by improved memory accuracy for negatively valenced emotional items (Sharot et al., 2008), and in some instances, are associated with decreased memory accuracy for associated details (Rimmele et al., 2011). Our longitudinal 2-day study consisted of an incidental encoding session on day one followed 24 hours later by a surprise memory test which assessed recognition and subjective confidence in memory for 60 previously presented and 60 novel images, as well as an associated contextual detail – a colored border surrounding the stimuli. During the memory test participants were tasked with distinguishing between items they had seen before (old) and new items. Additionally, participants had to discriminate old from new colored borders previously paired with presented items. In our analysis, we include a total of 40 eligible participants and leverage signal detection theory frameworks to characterize recognition judgments in memory, as well as investigate the metacognitive efficiency of metamemory confidence judgments. This strategic experimental design enabled us to reliably characterize mnemonic decisions while accounting for response biases, precisely quantify how the association between metamemory confidence and memory accuracy changes when exposed to negatively valenced information, and evaluate whether these associations are consistent across memory types (item, associated detail). The findings replicate previous research demonstrating that compared to neutral stimuli (d' = 1.99 ± 0.45), arousing and negatively valenced items are positively associated with increased discrimination performance (d' = 2.34 ± 0.54, M = 0.35, HDI89% [0.22, 0.47]). We also provide novel evidence demonstrating that metacognitive efficiency differs across valence for item memory with the metacognitive efficiency of metamemory confidence judgments associated with negatively valenced items (M-Ratio = 0.73 ± 0.083) being 1.08x greater than neutral items (M-Ratio = 0.63 ± 0.17, M = 0.12, HDI89% [0.00, 0.26]). These results contrasted with the effect of negatively valenced information on mnemonic decisions for associated details. Compared to details associated with neutral stimuli, discrimination performance (d' = 0.71 ± 0.88) and metacognitive efficiency (M-Ratio = 0.82 ± 0.15) did not differ for details paired with negatively valenced stimuli (d' = 0.79 ± 0.77, M = 0.07, HDI89% [-0.30, 0.15]); M-Ratio = 0.60 ± 0.067, M = -0.17, HDI89% [-0.49, 0.16]).This study is the first to precisely delineate associations between metamemory confidence judgments and memory accuracy using signal detection theory frameworks, and notably demonstrates a specificity for the effect of valence on mnemonic decisions for item memory. Additionally, metacognitive efficiency was found to differ across memory types with the metacognitive efficiency of item memory (M-Ratio = 0.52 ± 0.12) being 3.06x greater than associative memory (M-Ratio = 0.17 ± 0.12, M = 0.37, HDI89% [0.23, 0.48]). These results indicate that the metacognitive efficiency of metamemory confidence judgments is not domain general.

Learning how to compute confidence

Pierre Le Denmat (KU Leuven), Kobe Desender (KU Leuven), Tom Verguts (Ghent University)

Concurrent Session: Metacognition 2, Thursday July 4th, Gallery 1, Ito International Research Center, 4:30PM-6:00PM

When making a decision, individuals usually experience a feeling of confidence. According to Bayesian decision theories, confidence reflects the posterior probability of making a correct response, given available data. Consistent with this proposal, individuals tend to be more accurate when they report higher confidence in their decision. Confidence thus holds valuable information about one's performance that can, and in fact is used in adaptive processes such as learning, information seeking and speed-accuracy tradeoff adjustments. Given its adaptive role, confidence should be well-calibrated, that is, it should track as closely as possible the true posterior probability of making the correct decision, given relevant data. In the context of accumulation-to-bound decision models (such as the drift diffusion model, DDM), this probability is determined by both the total amount of internal evidence sampled from a stimulus and accumulation time. In order to adequately compute confidence, one thus needs to learn how to properly map their readout of their decision process (i.e. evidence and time) to the corresponding probability of the decision being correct (further referred to as the confidence mapping). The exact mechanical underpinnings of this learning process are currently being overlooked by existing computational models of confidence, for which the learning is often implicitly assumed to be terminated. As agents living in complex, volatile, and often new environments, it appears much more likely that humans instead constantly learn and update their confidence mapping to maintain adapted to the environment's demands. In this work, we present a new modelling framework where the confidence mapping is continuously updated according to feedback. We tested this model as well as the proposal that humans continuously learn the confidence mapping from feedback in two perceptual decision making experiments where participants were alternating between two different feedback contexts throughout the experiment. In both contexts, feedback was generated from our model and manipulated such that feedback in one condition was generally higher than in the second alternating condition. As predicted, confidence ratings progressively increased (resp. decreased) after switching into high (resp. low) feedback blocks. This effect could not be explained by changes in objective performance, as feedback did not influence accuracy nor reaction time. Importantly, our learning model was able to precisely capture this evolution of confidence over time. Overall, this work highlights the importance of taking into account the dynamics of the computation of confidence, and sheds new lights on how confidence biases and other metacognitive inefficiencies may emerge.

Unconscious perception of visual stimuli: alteration of functional dynamics in blindsight patients

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Concurrent Session: Perception 3, Thursday July 4th, Seminar Room, Ito International Research Center, 4:30PM-6:00PM

Contemporary neuroscience is replete with examples of visual stimuli which are processed without being consciously perceived. Possibly, the most insightful and direct access to non-conscious perception of visual signals is provided by studies of patients with lesions to the primary visual cortex (V1), resulting in a phenomenon called Blindsight. However, the mechanism of plasticity by which a blindsight patient retains the ability to process visual stimuli is still debated. In this study, we implemented a Dynamic Functional Connectivity (DFC) analysis, to look at the brain dynamics and their relationship to blindsight functions. Our DFC analysis involved 16 patients with unilateral V1 lesions and 17 healthy subjects (HC). To assess the residual visual ability of the lesioned patients and categorize them into blindsight positive (B+) and blindsight negative (B-), we employed an established Gabor detection task. Through a Leading Eigenvector Dynamic Analysis (LEiDA) we defined a set of metastable states of brain dynamics, also known as dynamic attractors. Each state is defined in terms of highly synchronized brain regions. Then, we characterized how these attractors differ between the three groups, studying both their dynamic properties (e.g., attractor's lifetime, percentage of occupancy and probability of transition, and topological features exploiting graph theory. Based on clustering analysis of brain dynamics we found 4 metastable states. The state in which the somato-motor regions show high synchronization plays a key role in discriminating between B+ and B-. In particular, in B- this metastable attractor has a higher lifetime and probability to move toward a global signal state compared to B+. Moreover, from a topological standpoint, the somato-motor state in B+ patients exhibits a higher integration capacity compared to the same state in B- patients, in addition to a stronger cortico-subcortical connectivity. By comparing DFC related indexes between our groups (HC, B+, B-), we found that in B- a dynamic attractor involving somato-motor areas shows an enhanced stability. Within this specific neural configuration, the study of the topological properties unveils that B- incorporate weaker integration capabilities with respect to B+. Thus, the possibility to integrate residual visual information with somato-motor regions represent a keystone in the emergence of residual visual ability of B+ patients, working as a functional hub and allowing visuo-motor transformation. The presence of strong cortico-subcortical connections for B+ in the somato-motor state is a further clue, providing a foundational bridge with the actual theories which outline the key contribution of V1-independent subcortical bypass for blindsight.

The full body illusion in Anorexia Nervosa: The effects of owning a different body on body image and conscious - unconscious visual processing of food

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Concurrent Session: Perception 3, Thursday July 4th, Seminar Room, Ito International Research Center, 4:30PM-6:00PM

The virtual-reality full-body illusion (FBI) paradigm (i.e., the illusory ownership over the avatar's body) can modulate the cognitive, attitudinal, and behavioral components associated with that kind of body. For instance, the FBI paradigm with an avatar having either a slimmer or a larger body seems to modulate body image perception, but studies have conflicting findings. Most importantly, the manipulation triggers changes in implicit attitudes towards food so that the illusory feeling of owning a slimmer body increases the avoidance of high-calorie food. Capitalizing on the fact that body size and eating behavior are highly associated with eating disorders and especially anorexia nervosa (AN), here we investigated whether and to which extent the FBI could modulate both implicit approach/avoidance tendencies and visual awareness of food stimuli with different caloric content. 30 normal-weighted females (control group) and 30 females with AN (experimental group) were administered the FBI paradigm with slim and large bodies in two different sessions. Before and after the FBI, we tested the implicit approach/avoidance tendencies to pictures of high and low-calorie food stimuli with the Food Preferences Approach-Avoidance Test (FP-AAT) and the visual awareness of the same food categories. In order to gain access to both conscious and unconscious food processing, we administered the breaking-Continuous Flash Suppression (bCFS) and the Binocular Rivalry (BR) paradigms. Results showed that in patients with AN, compared to healthy controls, food stimuli dominated more conscious perception. Moreover, high-calorie food dominated longer the visual awareness after the FBI, regardless of the avatar's size, in AN. We strongly believe that targeting implicit attitudes passing through unconscious levels could recalibrate patients' distorted perceptions. Since AN is a mental disorder characterized by high preoccupation about food and distorted eating, we consider that such findings may be used as a strategy to monitor food exposure in these patients and alternate their dietary habits. Last but not least, AN is associated with high mortality and there has been no effective treatment until now. For this reason, we suggest that this training has the potential to be a valuable treatment for body image disturbances characterizing life-threatening mental health conditions such as anorexia nervosa.

Executing actions guides the eyes towards body part images in the absence of visual awareness

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Concurrent Session: Perception 3, Thursday July 4th, Seminar Room, Ito International Research Center, 4:30PM-6:00PM

The eyes can be guided towards or away from emotional but not neutral faces even when these faces are entirely suppressed from visual awareness (Vetter*, Badde*, et al., 2019, eLife). This unconscious oculomotor guidance might be driven by neural pathways specific to threat or may depend on the strength of the image representation in the brain. Here, we tested the latter possibility by combining action images with actions. Given that visual representations of an action can be strengthened by performing the action depicted in the image, we hypothesised that performing an action could guide the eyes to images congruent to the action, even in the absence of visual awareness. Thus, we suppressed images of snapping fingers, tapping feet and immobile noses from visual awareness using continuous flash suppression. While images were suppressed, we tracked participants' eye movements and asked them to snap their fingers, tap their foot or execute no action. The performed action could be congruent or incongruent with the suppressed image. After each trial, participants were asked to rate the image's visibility (subjective measure of awareness) and localise the image and identify its content (objective measures of awareness). During full suppression of visual awareness, i.e., when participants rated the image as invisible and performed at chance level when first localising and then categorising it, we found that the eyes were attracted towards foot images when participants tapped their foot or snapped their fingers, and towards finger images when participants snapped their fingers. In contrast, images of the immobile nose did not guide the eyes differentially, nor were the eyes driven towards or away from foot or hand images when no action was executed. Thus, the eyes were attracted to mobile body part images only when a (mostly) congruent body part action was performed, even in the absence of visual awareness. These results show that strengthening image representations by actions has a specific effect on oculomotor behaviour in the absence of visual awareness.

EEG Network Deviation from Criticality Differentiates Arousal Levels Across Anesthesia

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Concurrent Session: Emerging Methods, Thursday July 4th, Seminar Room, Ito International Research Center, 4:30PM-6:00PM

Background: Quantifying conscious level with brain activity is essential for the scientific study of consciousness. However, current methods relying on subjective responsiveness often lack reliability and universality. We propose a novel approach leveraging criticality - a universal phenomenon at the boundary of phase transitions, associated with optimal information processing in the brain. Recent studies suggest criticality may be necessary for consciousness emergence, and altered states like anesthesia and coma deviate from this state. The brain's optimal information processing under criticality likely manifests as a specific functional network structure shaped by an individual's unique anatomical connections and dynamics. We hypothesize that during perturbations like anesthesia, systematically modulated conscious level will be reflected by measurable deviations of the EEG network from criticality. Method: To investigate this during anesthesia, we measured EEG network dynamics in 10 male rats across four arousal levels: awake, sedated (sevoflurane 1.2%), anesthetized (sevoflurane 2.4%), and recovery. In the sedated state, rats exhibit reduced mobility while retaining some arousal. In the anesthetized state, rats completely lose their righting reflex. Baseline awake EEG segments, determined to be critical via neuronal avalanche analysis, were compared to sequential EEG windows from the other states using Topographic Similarity (TS). TS, calculated as the Pearson correlation coefficient between node degrees of two comparing EEG networks, measured deviation from criticality. EEG networks were constructed with weighted phase lag index (wPLI) among EEG signals. We compared the performance of TS in quantifying change of conscious level with conventional EEG measures across different frequency bands. Results: TS successfully differentiated sedated, anesthetized, and awake states consistently across all frequency bands (delta, theta, alpha, beta, and gamma). Conventional EEG measures (spectral power, variability, connectivity, and Lempel Ziv-complexity) had variable changes across frequency bands and failed to differentiate the sedated and anesthetized states. This highlights TS as a robust, frequency band-independent, EEG indicator of consciousness level, eliminating outcome variability that may be otherwise produced by frequency band selection. Conclusion: By measuring the brain's deviation from criticality during anesthesia, we demonstrated the ability to quantitatively differentiate between sedated and anesthetized states. The EEG-based TS measure, independent of frequency bands, holds potential for measuring consciousness level across diverse states like sleep, anesthesia, and coma, each with distinct neurophysiology and EEG spectral signature. Moreover, its basis in the universality of criticality suggests application to various individuals and species with the same consciousness assessment criteria.

Emergent higher-order interactions across global states of consciousness.

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Concurrent Session: Emerging Methods, Thursday July 4th, Seminar Room, Ito International Research Center, 4:30PM-6:00PM

Recently, there has been growing interest in describing higher-order interactions beyond pairwise measures in brain data. A promising approach is provided by Dynamical Independence (DI) - a formal information-theoretic measure quantifying the emergence of macroscopic dynamics. Recognising that DI, by design, is a tool for information-theoretic linear dimensionality reduction, we can discover low-dimensional macroscopic variables that appear to be functionally independent from their microlevel constituents. We illustrate this method by application to continuous-valued EEG time-series from different global states (levels) of consciousness. We analyse source-reconstructed electroencephalographic (EEG) data across wake (n=14), sleep (n=4), propofol- (n=5), xenon- (n=5), and ketamine- (n=5) induced anaesthesia. Leveraging DI, we define emergent Functionally Independent Neural Dynamics (FINDs) as coarse-grained macroscopic variables for which self-prediction of their evolution is not enhanced by knowledge of the historical dynamics of their microlevel constituents. FINDs are then discovered directly from source-reconstructed EEG by minimising the dynamical dependence (a measure of departure from dynamical independence) at varying spatial scales. Group-level analyses reveal that emergent FINDs in sleep, propofol, and xenon show lower dynamical dependence on the microlevel constituents than those identified in wake and ketamine across all scales. We further computed the degree to which individual brain regions contribute to FINDs across scales and conditions. Results suggest a higher contribution of prefrontal and cingulate regions to emergent FINDs in wake and ketamine, and a decrease of the contribution of these regions during anaesthetic states of xenon, propofol, and sleep. Altogether, we show that FINDs reveal aspects of the emergent dynamical organisation of global states of consciousness from EEG data. FINDs represent lower-dimensional subspaces that capture the dynamics constrained by a coarse-graining function, and as such can be interpreted as identifying core functional processes. Our results indicate that FINDs capture higher-order interactions by discovering these functional cores of brain activity directly from neurophysiological data.

Koopman Operator Based Dynamical Similarity Analysis for Data-driven Quantification of Distance between Dynamics

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Concurrent Session: Emerging Methods, Thursday July 4th, Seminar Room, Ito International Research Center, 4:30PM-6:00PM

Quantifying distance between two dynamical neural systems is a fundamental problem in neuroscience and machine learning fields. Measuring distance of dynamics enables, for example, quantifying differences between dynamics associated with consciousness and unconsciousness, which can help understanding consciousness better. Neural dynamics are known to possess nonlinear features, which makes comparison between systems difficult. Recently, a promising method to quantify such distance between dynamics called Dynamic Similarity Analysis (DSA) was proposed (Ostrow et al., 2023). Given a pair of dynamical data, DSA measures distance in the following two steps. (1) Perform Hankel Alternative View of Koopman (HAVOK) analysis (Brunton et al., 2016) to each dynamics. HAVOK is a method to analyze nonlinear dynamics, and gives linear drift matrices in time delay embedding space. (2) Compute the distance between the pair of matrices obtained in HAVOK. The distance of matrices applied here is called Procrustes Analysis of Vector Field (PAVF), and identifies orthonormal coordinate transforms of systems. DSA reportedly succeeds in distinguishing dynamics that are similar in a geometric sense and yet own different dynamical properties, and identifying dynamical systems of similar dynamical properties that possess different geometrical features. Although being a strong method, DSA is not free from problems. First, HAVOK lacks mathematical underpinnings, resulting in obscure interpretability. Second, PAVF fails to satisfy the triangle inequality among matrices of different dimensions. As satisfaction of the triangle equality is a desirable property as a distance metric (Williams et al., 2021), its breaching may not be suitable for distance measure. Thirdly, PAVF takes long computational time, as one has to resort to iterative optimization methods including gradient descent. To address these problems, we propose a novel modified version of DSA. In our modified version of DSA, the aforementioned two steps are updated as follows. (1) Compute finite dimensional approximation of the Koopman operators for each system. The Koopman operator is a linear operator that drives dynamics in a nonlinearly mapped space. Each approximated Koopman operator is then described as square matrices. (2) Measure distance between Koopman approximant matrices with an extended version of PAVF, termed modified PAVF (M-PAVF). Our updated version of DSA has the following three merits. First, measuring distance between Koopman operators results in better interpretability as distance of linear operators that drive dynamics in mapped spaces. Secondly, M-PAVF is shown to satisfy the triangle inequality even among matrices of different dimensions. Lastly, M-PAVF allows extremely fast computational time, thanks to its accessible analytical solution. We tested our method and classical DSA using the Lorenz system (Lorenz, 1963) of various parameters and found that our method revealed clusters with respect to parameters and dynamical properties, while the original DSA failed to do so. We also applied our method to calcium imaging data of *C.elegans* and showed how awakening and sleep (lethargic) states appear as clusters in the space of dynamics. With theoretical underpinnings of Koopman operators and matrix distance, we propose our approach as an effective method to quantify distance between dynamics, such as neuronal dynamical systems.

Evaluating the Memory Theory of Consciousness

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Concurrent Session: Theories of Consciousness 2, Thursday July 4th, Conference Room, Ito International Research Center, 4:30PM-6:00PM

Objective: To develop experimental methods that will test the newly proposed Memory Theory of Consciousness (MToC), a theory that explains the majority of the scientific data, including the slow speed of consciousness, postdictive effects, and our unified subjective experience. Methods: Review of the scientific literature and experimental design. Outcomes: In brief, MToC argues: (1) All forms of explicit memory—including sensory, working, episodic, and semantic memory—can be conceptualized as part of one system based on the way they work together in a healthy individual. (2) Consciousness binds the elements of an experience together allowing for the creation of a memory trace that can include multisensory details. (3) Consciousness provides a medium in which the multisensory traces can be replayed. (4) Conscious perceptions, decisions, and actions are memories of unconscious sensations, decisions, and actions. (5) Conscious deliberation can influence the unconscious decisions and actions that are made. (6) As consciousness is part of explicit memory, the value or purpose of consciousness is thus identical with that of episodic memory and the other explicit memory systems, which is to use prior experience to increase our understanding of the present moment, make predictions about the future, and plan accordingly. (7) The neuroanatomical localization of consciousness is the neuroanatomical localization of explicit memory, which is the entire cerebral cortex, (8) and regions/networks of cortex can be autonomously conscious. (9) Different cortical regions/networks enable different aspects of consciousness. (10) Each aspect of consciousness has its own neural correlate of consciousness. (11) Animals with hippocampus and cerebral cortex (or analogous structures) will experience some form of consciousness, on a continuum. (12) Disorders of the cerebral cortex will disrupt consciousness including epilepsy, migraine, cortical strokes, Alzheimer's disease and other cortical dementias. (13) Individuals with delirium are awake but not fully conscious. Methodologies to test aspects of MToC include the following: (A) We will quantify the degree of consciousness present in an individual using a questionnaire that was developed for memory research but evaluates both subjective experience and factual details of a narrative. (B) We will test this narrative scoring technique in young individuals when they are fully conscious (fully awake) and less than fully conscious (drowsy in the early morning or late evening) while they are viewing, hearing, and describing photographs plus consistent audio designed to stimulate rich subjective experiences. We will also use this technique to evaluate patients with (C) dementia of various types and levels of impairment, and (D) strokes in various lobes. (E) We will perform a TMS study to create virtual lesions while healthy subjects do this task, applying an iTBS and cTBS protocol on stimulation sites DLPFC, IPL and V1. (F) We will also simultaneously measure EEG while participants undergo this task to generate event-related potentials (ERPs) and to conduct a frequency analysis. Conclusion: While MToC can explain many previously unexplained phenomena, here we propose additional methods to support or refute its tenets. Presenting this theory and methods at this conference will stimulate collaborations with other attendees.

Three Potential Tests for Consciousness in Infants

Claudia Passos Ferreria (New York University)

Concurrent Session: Theories of Consciousness 2, Thursday July 4th, Conference Room, Ito International Research Center, 4:30PM-6:00PM

Can there be a test for consciousness in infants? In the absence of verbal reports, there is no straightforward test; the most promising tests involve neurophysiological and behavioral markers of consciousness suggested by theories of consciousness. I will investigate current markers and discuss whether they are reliable guides to consciousness in infants. I will focus on three potential markers: functional connectivity networks (Hu, Cusack, and Naci 2022); P300-like waves (Moser, Schlegera, Weiss, Sippela, Dehaene-Lambertz, and Preiss 2020); the attentional blink (Hochmann and Kouider 2022; Dopierala and Emberson 2022). I will review current evidence from global workspace theory and other theories of consciousness that might support these markers while also considering potential evidence against them, giving a philosophical analysis of what this evidence establishes. My conclusion is that, as yet, we do not have a reliable marker of consciousness in infants, but it's not impossible that we could develop one. I conclude by discussing how current evidence bears on the initial emergence and the developmental trajectory of consciousness.

On the possibilities of testing theories of consciousness regarding their predictions about the neural correlates of phenomenal structure

Lukas Kob (Otto-von-Guericke University Magdeburg)

Concurrent Session: Theories of Consciousness 2, Thursday July 4th, Conference Room, Ito International Research Center, 4:30PM-6:00PM

The science of consciousness has made considerable progress in developing theories (Seth and Bayne 2022). However, attempts to directly test theories against each other have been rare and have only recently been undertaken (Cogitate Consortium et al. 2023). There is an urgent need to design further experiments that pit theories against each other. I argue that theoretical developments in explaining the relationship between general mechanisms of consciousness and neural encodings of the structure of phenomenal experience (Fink et al. 2021) potentially provide an additional area for testing theories of consciousness. This approach requires developing the implications of the main theories of consciousness (hereafter ToCs) for the relationship between general mechanisms of consciousness and neural underpinnings of phenomenal structure. Crucially, the main ToCs differ in their implications for the relationship between the neural correlates of consciousness and phenomenal structure, which provides a basis for testing the ToCs against each other. While some theories argue that explanations of phenomenal structure and general mechanisms of consciousness can be separated, others deliberately explain consciousness and phenomenal structure through a single account (Marvan and Pol√°k 2020). The former typically emphasises the importance of sensory areas in shaping phenomenal structure, while consciousness is explained by a different mechanism. The latter explains the emergence of consciousness through the same mechanisms that explain the structure of experience. Importantly, the middle ground between these extremes has not been sufficiently explored. Although the mechanisms underlying phenomenal structure may be distinct from the general mechanisms of consciousness, the two may interact and modulate each other. Recent findings on decoding of conscious vs. unconscious in sensory areas (Sanchez et al. 2020) and IT cortex (Hesse and Tsao 2020) support this idea. Taxonomizing different possibilities of interaction between consciousness and phenomenal structure at the neural level provides a basis for potentially testable hypotheses. By discussing the relationship between general mechanisms of consciousness and neural encodings of phenomenal structures, I outline possible hypotheses about the relationship between neural mechanisms of consciousness and phenomenal structure in the light of different theories. I will also discuss some caveats to the empirical testing of these hypotheses. Nevertheless, clarifying the implicit hypotheses of ToCs about the relationship between phenomenal structure and general consciousness may advance the field, as skilful experimental designs and future methods may allow the hypotheses to be tested in the near future. Therefore, I argue that the role of phenomenal structure in theories of consciousness should be considered in the development of further adversarial collaborations.

Don’t be afraid of Transcendental Idealism! An epistemology for Predictive Processing

Tobias Schlicht(Ruhr-University Bochum)

Concurrent Session: Theories of Consciousness 2, Thursday July 4th, Conference Room, Ito International Research Center, 4:30PM-6:00PM

The popular Predictive Processing (PP) framework posits prediction error minimization as the sole neural mechanism that can account for all mental phenomena (Hohwy 2013, Clark 2016), including consciousness and guide search for its neural correlates (Hohwy & Seth 2020). The brain contains generative models of world, self, and body, which constantly yield predictions about sensory inputs that are then matched against actual inputs. Mismatches lead to prediction errors, model updates and then new predictions. This “leaves phenomenology at one remove from the world”, since “content is the predictions of the currently best hypothesis about the world” (Hohwy 2013, 48). Consequently, Seth (2021, 186) conceives of perception as “controlled hallucination” and agrees with Clark (2023, xiv/24) that “what we see is never simply how things are”; “we never experience the world as it is” (Seth 2021, 92). Framed in terms of the free-energy principle, Friston (2013, 2) also holds that the external states (of the world), separated from the brain’s internal states, remain “hidden (insulated)” and can only be seen “through the Markov blanket”, while external states causally affect internal states. All main proponents of PP thus agree that we do not perceive the world as it is, but only the brain’s best guess. In this talk, I connect this to the epistemological stance of Transcendental Idealism (TI), introduced by Kant (1781), but not very popular among cognitive scientists – yet. I argue that drawing the proper lessons from the PP framework is to submit that Kant’s epistemology is the adequate companion for PP’s way of thinking about perception. For this purpose, I outline the proper interpretation of TI by introducing the central and controversial distinction between appearances and things in themselves. Rather than conceiving of this as a separation of two worlds, it is best understood as a “distinction between things as objects of experience and the very same things as things in themselves” (Kant 1781, Bxxvii). We can only try to abstract away from our subjective point of view and cognitive machinery in thinking about things as they are rather than appear to us. Famously, for Kant knowledge requires both sensory input from the world and our subjective contribution in the form of concepts, which together give us appearances. According to PP and Kant, the raw sensory signal is not itself experienced (Clark 2023, 27, 30; Kant 1781, B152). Yet, PP proponents, while pointing in the direction of TI, may still find Kant’s implied epistemological restriction either unacceptable or misunderstand it for Berkeley’s radical idealism. To counter this, it must be emphasized that Transcendental Idealism is accompanied by Empirical Realism, according to which empirical objects are perfectly real and mind-independent from the perspective of fundamental ontology (Abela 2002, Jauernig 2021). Thus, Kant’s point that, in conscious experience, we cannot abstract away from our cognitive machinery, is therefore analogous to Nagel’s (1974) argument that even if we could install in us and make use of echolocation, we could never find out what it is like to be a bat.

Expanding Sensorimotor Theories of Perceptual Consciousness with Action-Selection Capacities

Zhiguo Huang(Philosophy Department, Rutgers University New Brunswick)

Concurrent Session: Theories of Consciousness 2, Thursday July 4th, Conference Room, Ito International Research Center, 4:30PM-6:00PM

What is it like to have a certain type of perceptual experience? In some recent literature, this character question has been framed in terms of well-attended, "vivid and clear" cases of visual perception. This presentation focuses on an often overlooked aspect: different modes of presentation of the same object that can constitute phenomenal character, including sensory modalities, perspectival information, phenomenal salience, etc. Sensorimotor-enactivist theories emphasize the role of the subject's sensorimotor interaction with the environment in constituting its mental faculties; therefore, these theories are taken to be natural candidates for explaining perceptual modes of presentation. This presentation first reviews the ongoing sensorimotor project. In explaining perceptual modes of presentation, one explanatory advantage of sensorimotor-enactivist theories is their dynamic and embodied nature. Meanwhile, one conceptual difficulty emerges as current sensorimotor theories hold onto a narrow conception of sensorimotor understanding. Specifically, there is a critical case of phenomenal character that current sensorimotor theories cannot account for. Experimental studies have shown that covert voluntary attention can affect the phenomenal character of visual and auditory perceptions, most distinctly in terms of phenomenal contrast. The sensorimotor system is minimally involved in covert voluntary attention, so merely appealing to the organism's sensorimotor profile is insufficient. On top of motor actions, mental actions like voluntary attention and imagination, which are hardly explicable in pure sensorimotor terms, are also part of the explanatory basis for conscious perceptual experience. This presentation offers an alternative approach, in the spirit of sensorimotor-enactivist theories, that is grounded in action-selection capacities. We can refer directly to the subject's capacity to solve Selection Problems, namely to choose from various object-affordance combinations. Action-selection capacities replace the vague notions of "sensorimotor understanding" or "practical grasp of sensorimotor contingencies," and they can be invoked to explain perceptual modes of presentation in cases such as covert voluntary attention, perspectival information, and phenomenological shifts in perceptual learning. The approach from action-selection capacities is compatible with various metaphysical views of perception, and it suggests that cognitive sciences can start building empirical theories of phenomenal consciousness by understanding action-selection capacities in biological and artificial agents.

The extrapolation problem for consciousness science: how can we infer consciousness in non-standard populations?

Niccolo Negro (Tel Aviv University), Liad Mudrik (Tel Aviv University)

Concurrent Session: Theories of Consciousness 2, Thursday, July 4, Conference Room, Ito International Research Center, 4:30PM-6:00PM

The epistemological problem of consciousness concerns the justification of attributions of consciousness to non-standard systems like artificial intelligent systems, non-human animals, brain organoids, foetuses, and patients with disorders of consciousness. Consciousness researchers have proposed several consciousness tests that can be applied to such non-standard systems given the currently available knowledge about consciousness in neurotypical adult humans. However, it remains unclear whether insights gained from the study of consciousness in neurotypical adults can be extrapolated to these diverse contexts. We thus frame the epistemological problem of consciousness in non-standard systems as an extrapolation problem: how can one justifiably generalize from an epistemically privileged domain to a less epistemologically privileged domain? In this paper, we contend that progress on this issue can be achieved by delineating the logical structure of reasoning that is necessary to confer the highest degree of justification to our attributions of consciousness. This project is distinct from determining the types of evidence necessary to project consciousness from one domain to another. And yet, it is important because a thorough assessment of arguments employed to attribute consciousness to non-standard systems requires clarifying the logical structures of those arguments. The paper is structured in three parts. First, we consider two prominent approaches to addressing the philosophical problem of extrapolation, namely the analogical reasoning and the reasoning from the inference to the best explanation (IBE-based reasoning, for short). Second, we show that these approaches cannot meet the two challenges for successful extrapolations in consciousness science, namely the problem of difference (i.e., why we are justified in projecting consciousness from one domain to another given substantial differences between the two domains) and the extrapolator's circle (i.e., how to justifiably project consciousness to a target domain without assuming it occurs in the target domain to begin with). Third, we propose that these two challenges can be met by combining elements of analogical reasoning and IBE-based reasoning. Thus, we introduce the analogical abductive argument and argue that it confers the strongest degree of justification in our attributions of consciousness to non-standard systems. We then clarify how the argument can be practically applied, and evaluate its strengths and its limitations. We conclude that while analogical abductive arguments leave some open questions on how they can be practically applied, they represent the most promising method for addressing the epistemological problem of consciousness in non-standard systems.

The human brain integrates heartbeat and auditory inputs upon regularity processing in wakefulness, sleep, and coma

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Concurrent Session: Disorders of Consciousness 2, Friday July 5th, Fukutake Learning Theater, 2:00PM-4:00PM

As the human brain processes stimuli from the external world, it also receives continuous internally generated inputs from organs such as the heart. In a series of closed-loop studies, we acquired simultaneous electroencephalography and electrocardiography data, and investigated whether the brain utilizes heartbeat signals to facilitate auditory regularity encoding in a variety of consciousness states. The first series of experiments sought to determine whether local violations of a fixed relationship across cardiac and auditory signals would trigger surprise responses in neural and cardiac activity upon altered consciousness. We thus tested a group of healthy volunteers (N=26) during wakefulness and overnight sleep, as well as patients on the first day of coma after cardiac arrest (N=48). We administered three conditions of auditory sequences interspersed with unexpected sound omissions: in a synchronous condition, sounds were temporally locked to the ongoing heartbeat; in the isochronous condition, sound-to-sound intervals were fixed; in the control condition, there was no specific regularity. During wakefulness, we observed a neural surprise response ($p<0.05$, two-tailed) to unexpected omissions during the isochronous condition at 114-159ms and the synchronous condition at 107-165ms following omission onset. During N2 sleep, omissions induced a neural differential response at 83-226ms and at 281-449ms for the isochronous and synchronous conditions, respectively. Similarly, and only in coma survivors, we observed a differential neural omission response at 275-458ms, but only for the synchronous condition. Furthermore, cardio-audio regularity encoding yielded a heartbeat deceleration upon omissions in the synchronous condition ($p<0.001$) in healthy volunteers across wakefulness and all sleep stages, and in coma survivors. In a new experiment, we then investigated whether cardio-audio regularity encoding may cause more global modulations of physiological signals. In a cohort of healthy volunteers (N=30) during wakefulness and two overnight sleep sessions, we administered the same synchronous, isochronous and control auditory sequences, now without omissions. We observed increased heart rate variability in the synchronous and isochronous ($p<0.01$), but not in the control condition, compared to baseline periods without auditory stimulation. In both nights, this increase occurred during N2, N3, and phasic REM sleep. Finally, we tested whether increased cardiac variability reflected higher arousal in sleep upon auditory regularity encoding by extracting microarousals across the two sleep nights. Linear mixed-effects models with microarousal frequency as the dependent variable, Auditory Condition and Night as the fixed-effects and Subject as the random effect revealed significant ($p<0.05$) main effects of Auditory Condition, Night, and their significant interaction, due to higher microarousal frequency ($p<0.01$) in the synchronous vs the baseline condition on the first night, and in both synchronous and isochronous conditions on the first vs the second night. Our results suggest that humans integrate cardiac and auditory inputs upon encoding regularities independent of vigilance, with both local and global changes in neural and peripheral signals. We propose a novel computationally efficient mechanism by which the human brain utilizes continuously monitored cardiac signals to sample and optimally adapt to its environment.

Consciousness improvements following vagal nerve stimulation in severe brain injuries: Preliminary results from a randomized controlled trial in the intensive care units.

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Concurrent Session: Disorders of Consciousness 2, Friday July 5th, Fukutake Learning Theater, 2:00PM-4:00PM

Background: Patients with disorders of consciousness (DoC) such as the minimally conscious state (MCS) and the unresponsive wakefulness syndrome (UWS) are a challenging population lacking effective treatment options. Among neuromodulation techniques, trans-auricular vagal nerve stimulation (taVNS) may act non-invasively through a bottom-up manner to modulate thalamo-cortical connectivity and promote the recovery of consciousness in the acute phase of severe cerebral damage. In this clinical trial, we aim to characterize the clinical short and long-term effects of taVNS in patients with DoC and determine the phenotype of clinical responders.

Methods: We are conducting the first randomized placebo-controlled double-blind clinical trial assessing the effects of taVNS in 44 acute to sub-acute DoC patients. In this study, patients randomly receive either 5 days of active bilateral vagal stimulation for 45 minutes a day (3mA; 200-300µs current width, 25Hz) or sham stimulation. Behavioural measures (Coma Recovery Scale-Revised, CRS-R) are collected twice at baseline as well as at the end of the treatment. Moreover, patients' long-term evolution at 3 months after the end of the treatment period is assessed through outcome measures performed with family or caregivers (Glasgow Outcome Scale - Extended, GOS-E; Disability Rating Scale, DRS).

Results: Groups are not statistically different in terms of patients age, sex, time since injury, etiology and baseline scores or diagnosis. Results on 32 patients show a significant difference in the behavioral score evolution (post compared to pre-treatment) between the active and sham groups following the 5-day intervention period ($W=172.5$; $p=0.009$). Within groups analyses also conclude that patients in the active taVNS group show significantly increased CRS-R total scores post-treatment compared to baseline (median pre-treatment=8 [IQR 5]; median post-treatment=11 [IQR 12]; $V=5.5$; $p=0.016$), while patients from the sham group do not display such difference (median pre-treatment=5.5 [IQR 5.25]; median post-treatment=6 [IQR 3.25]; $V=18$; $p=0.633$). Moreover, in the active group ($n=14$), 7 patients displayed at least one new sign of consciousness (identifying as clinical responders) and 4 improved their diagnosis, among which 3 even emerged from DoC. In the placebo condition ($n=18$), 2 patients improved and only one changed diagnosis. Furthermore, at this stage, response to treatment appears to be significantly associated with baseline diagnosis (UWS vs. MCS), as all clinical responders were MCS ($p=0.021$), but not with etiology (focal vs. widespread injuries) ($p=1$).

At 3 months follow-up, no statistical difference between the groups could be detected anymore according to the GOS-E ($W=46$, $p= 0.4919$) and the DRS ($W=62$; $p= 0.9474$,).

Conclusion: Our preliminary results show that compared to sham, repeated taVNS might promote consciousness recovery in the early phase following severe brain injury, especially in MCS patients. However, taVNS might require to be consistently applied over time in order to allow patients to benefit from longer-term effects. This study will contribute to define the role of taVNS for the treatment of these challenging conditions and identify patients' clusters for responses to treatment.

Targeted Dream Incubation of positive emotional content and EEG correlates of the dreaming mind: Preliminary findings.

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Concurrent Session: Disorders of Consciousness 2, Friday July 5th, Fukutake Learning Theater, 2:00PM-4:00PM

Several empirical studies have demonstrated the relevance of dream content and dream emotions for our waking affective states by influencing our mood. Generating or positively altering dream emotions and content could serve as a complementary tool for treating mood disorders such as depression, which often exhibit more negative dream content and nightmares compared to the general population (Akkaoui et al., 2020). In this presentation, we share preliminary findings from a study aimed at inducing positive emotional content in dreams. We adapted the Targeted Dream Incubation (TDI) protocol originally introduced by Horowitz et al. (2020). After an adaptation night in the lab, four participants spent a second night wearing headphones while undergoing polysomnography. During this period, a protocol of repeated awakenings was implemented (several times for each participant). In Stage 1 (S1), participants received specific verbal instructions through the headphones, referring to a positive image previously chosen by each participant, for example: “Imagine yourself being happy in the forest”. Thirty seconds after entering Stage 2 (S2), participants were asked to report their dream content, as well as its intensity using a 7-point scale and valence. The rate of dream content versus non-content after incubation was high: 76% versus 24%. But while Horowitz et al. (2020) achieved approximately a 67% success rate in relating dream content to the incubation instructions in 25 participants, our results showed only an 15% success rate (if partially related content is included; if not, 8%).This variation may be attributed to factors such as the number of participants, individual differences among participants, discrepancies in the complexity of instructions, and differences in the sleep stages whose dream content was analyzed (S1 for Horowitz et al., 2020, compared to S2 in our study). Additionally, the average intensity of reported dreams was below 3.5, with 57,5% of dream content having emotional valence (35% positive vs. 22.5% negative), and 42.5% neutral in valence. Due to the challenges encountered in inducing specific dream content and emotions with explicit short instructions, as well as in generating more intense and positive dream content, we decided to modify the protocol and explore dream incubation through more immersive experiences. Furthermore, EEG correlates of reported dream content in Non-REM sleep exhibited some differences compared to previous findings. According to Siclari et al. (2017), the EEG correlates of dream content in Non-REM sleep are characterized by a decrease in power density in low-frequency bands (0.5-4Hz) and an increase in high-frequency bands (30-45Hz) in a specific area known as the ‘Hot-Zone’ (parieto-occipital region). However, we observed these changes across all EEG sensors used (F3, F4, C3, C4, P3, and P4, according to the International 10–20 System). Similarly, although one participant did not show differences between content and non-content periods, an increase in high frequencies during periods of higher intensity was observed across all sensors. The variance between our results and Siclari et al.’s (2017) findings may be attributed to the fact that we incubated content immediately before subjects entered Stage 2 (S2) sleep, whereas they did not incubate content.

Good vibrations: thalamic sonication in chronic disorders of consciousness

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Concurrent Session: Disorders of Consciousness 2, Friday July 5th, Fukutake Learning Theater, 2:00PM-4:00PM

Over the last 25 years, the science of disorders of consciousness (DoC) such as coma, the vegetative state and the minimally conscious state, has greatly advanced. Translation to neurorestorative interventions, however, has remained comparatively elusive. A range of experimental and clinical interventions have converged on an understanding of DoC as a cortico-striato-thalamo-cortical mesocircuit disconnection syndrome—demonstrating efficacy (at least in some subset of patients) ostensibly via upregulation of this neural circuit. For example, direct thalamic stimulation with Deep Brain Stimulation (DBS) has demonstrated some effectiveness in restoring purposeful behavior, in chronic DoC patients. Nonetheless, a prospective clinical trial shows that less than 15% of evaluated DoC patients are eligible for such an intervention. Following-up on a prior first-in-human proof of concept clinical trial providing support in both acute and chronic populations, in the present work we use low intensity transcranial focused ultrasound (tFUS) to directly modulate thalamus in an additional sample of chronic DoC patients and assess, longitudinally, its effects on well-known DoC biomarkers. Specifically, we enrolled 15 DoC patients for a 10-day open-label protocol featuring 4 days of baseline assessments with gold-standard clinical (i.e., Coma Recovery Scale Revised), electrophysiological (EEG), and metabolic (PET) measurements, exposure to thalamic tFUS, and then 6 further days of repeated testing with the same measurements. With respect to clinical assessments, we find the intervention to mitigate the depth of the impairment of consciousness as shown by a significant increase in patient responsiveness over time. Comparison of resting EEG power spectrum density right after tFUS exposure, compared right before exposure, shows a significant decrease in slow-to-fast frequency ratio, indicating a shift of towards faster frequencies, which has recently been identified as a particularly robust and universal marker of cortical arousal. In addition, the degree of this shift is significantly associated – positively – with the degree to which patients' clinical scores ameliorate over the following six days. This finding thus links the effects observed at intervention with subsequent clinical changes. Finally, comparison of FDG-PET following tFUS, compared to baseline, shows a significant increase in mediofrontal metabolism. These findings show that thalamic tFUS is effective at increasing responsiveness and modulating well-known biomarkers of impaired consciousness following severe brain injury.

Hemispherotomy: cortical islands of deep sleep in awake humans

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Concurrent Session: Disorders of Consciousness 2, Friday July 5th, Fukutake Learning Theater, 2:00PM-4:00PM

Hemispherotomy is a surgical procedure performed in individuals with severe focal refractory epilepsy, aimed at disconnecting a significant portion of the cerebral cortex effectively isolating it from cortical and subcortical inputs. Since the disconnected cortex is isolated from behavioral assessments, inferring whether it supports consciousness represents a unique challenge with significant ethical implications (Bayne et al., 2020). Previous functional MRI studies have shown preserved resting-state networks within the disconnected hemisphere, leading to the hypothesis that it might support an 'island of awareness' (Blauwblomme, Demertzi et al., 2020). However, these networks can be preserved also during unconscious states, such as anesthesia and deep sleep (Boly et al., 2008), thus prompting the need for further investigations. In this study, we explore the capacity of the disconnected cortex to support consciousness by examining for the first time its electrophysiological activity before and after hemispherotomy in ten awake pediatric patients. Following surgery, the disconnected cortex – but not the contralateral – showed EEG activity characterized by the predominance of slow oscillations (<2 Hz), akin to those seen during deep sleep. Moreover, only the disconnected cortex exhibited a broad-band EEG slowing: a redistribution of spectral power from higher to lower frequencies, also seen during deep sleep, anesthetic-induced loss of consciousness, and in disorders of consciousness. We quantified this broad-band EEG slowing through the spectral exponent, a validated marker of consciousness reflecting the 1/f-like decay of the power spectral density. This quantitative index attained levels typical of unconscious states, such as those of brain-injured and anesthetized adults. Finally, a comparison of the patients' data with a reference pediatric cohort (N = 44) (previously studied in Favaro et al., 2023) revealed spectral exponent values consistent with wakefulness in the contralateral cortex, but characteristic of deep sleep in the disconnected cortex. Altogether, our findings suggest that the disconnected cortex enters in an electrophysiological state typically found in unconscious conditions. This study expands upon prior fMRI investigations and provides an example of how diverse brain-based assessments can contribute in an iterative process to address questions regarding consciousness in challenging cases. -Bayne T, Seth AK, Massimini M. Are there islands of awareness? Trends in Neurosciences. 2020 Jan 1;43(1):6-16. -Blauwblomme T, Demertzi A, Tacchela

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The use of coalitional game theory to identify the brain correlates of visuo-spatial neglect sheds further light on the neural basis of conscious perception

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Concurrent Session: Disorders of Consciousness 2, Friday July 5th, Fukutake Learning Theater, 2:00PM-4:00PM

Visuospatial neglect is a pathological condition present in the acute phase of almost half of stroke patients with right hemisphere damage. This clinical population displays an unconscious right-ward attentional orienting bias perceiving and acting in their daily environment while omitting information incoming their left hemispace and hemibody. This behavioral pattern makes of visuospatial neglect an interesting model to study unconscious operations and their neuroanatomical correlates. Regardless, the potential of this condition to further disentangle the anatomical underpinnings of perceptual consciousness remains to be fully exploited. Here we applied multiperturbation Shapley value Analysis (MSA), a coalitional game theory-based multivariate approach with the ability to infer regional and network causal contributions to specific behavioral outcomes on the basis of a limited sets of associations between post stroke anatomical damaged regions (players) assessed in T1 MRI sequences and functional deficits measured with pen and pencil clinically relevant tests. Lesion and behavioral data from n=25 stroke patients evaluated in three cardinal visuo-spatial attention tasks (line bisection, bells cancellation, and letter cancelation), allowed the identification of grey matter nodes and white matter bundles involved in visuo-spatial attention and served to characterize a map of their interactions. Specifically, we estimated the percentage of damaged MRI voxels of five cortical regions of the right hemisphere encompassing seven Brodmann Areas (BA): Frontal Eye Fields (FEF-BA6), Intraparietal Sulcus (IPS-BA7), Inferior Frontal Gyrus (IFG-BA44/BA45), Temporo-Parietal Junction (TPJ-BA39/BA40), and Inferior Occipital Gyrus (IOG-BA19). Using the same method, we also estimated the contributions of 11 white matter bundles to these same function: the three branches of the superior longitudinal fasciculus (SLF), the inferior fronto-occipital fasciculus (IFOF), the inferior longitudinal fasciculus (ILF), interhemispheric commissural projections of the corpus callosum (CC), the posterior segment of the arcuate fasciculus (APS), the anterior thalamic projections (ATP), the anterior cingulum (CA) and the posterior cingulum (CP), and the optic radiations (OR). Our approach identified the right IPS as the main gray matter contributor to attentional orienting and revealed additional synergistic right hemisphere interactions between the IPS, the TPJ, and the IOG and between the TPJ and the IFG. Out of the 11 white matter bundles included in our MSA coalitions, the OR, the IFOF and the CA displayed task-invariant contributions (positive, positive, and negative, respectively) to the above-mentioned clinical tests, whereas task-dependent influences were identified for the branches of the superior longitudinal fasciculus and the posterior cingulum. We conclude that the reported gray matter nodal contributions and patterns of interaction mediated by white matter tracts linking cortical nodes

throughout visuo-spatial attention systems help to better characterize the anatomical networks underlying conscious and unconscious perception. Additionally, our results could also contribute to the customization of brain stimulation approaches for the rehabilitation of visuospatial neglect and other visual awareness impairments.

Behavioral and cortical arousal from sleep, muscimol-induced coma, and anesthesia by direct optogenetic stimulation of cortical neurons

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Concurrent Session: Disorders of Consciousness 2, Friday July 5th, Fukutake Learning Theater, 2:00PM-4:00PM

The cerebral cortex is widely considered part of the neural substrate of consciousness. However, while several studies have demonstrated that stimulation of subcortical nuclei can produce electroencephalographic (EEG) activation and restore consciousness, so far no direct causal evidence has been available for the cortex itself. Previous studies show that arousal from non-rapid eye movement (NREM) sleep and/or anesthesia can be triggered from several distinct brainstem nuclei, but only when their stimulation leads to broad activation of the cerebral cortex. If the cortex is the core substrate of consciousness and the reticular activating system is only a “background condition” (Koch et al., 2016), it should be the case that the direct activation of cortical neurons is sufficient for arousal from unresponsive states, including from brainstem coma, when the function of the reticular activating system is impaired. Here we tested in mice whether optogenetic activation of cortical neurons in posterior parietal cortex (PtA) or medial prefrontal cortex (mPFC) is sufficient for arousal from three behavioral states characterized by progressively deeper unresponsiveness: sleep, a coma-like state induced by muscimol injection in the midbrain, and deep sevoflurane-dexmedetomidine anesthesia. Adult CaMKIIŒ±::ChR2 mice of both sexes (> P56, n = 12, 5 females) were chronically implanted with optic fibers for optogenetic stimulation of PtA or mPFC, intracortical laminar probes and surface electrodes for EEG recordings, bilateral cannulas aimed at the midbrain for muscimol injection, and muscle electrodes. We found that cortical laser stimulation (square pulses or 4-8 Hz train pulses lasting 1-5 sec) always awakened the mice from NREM sleep (8 mice, 15 experiments), with PtA requiring weaker/shorter light pulses than mPFC (p = 7.7e-5). In a total of 28 mice that received muscimol injection in the mesencephalic reticular formation, a coma-like state was induced for 1.5-4.5 hours before animals spontaneously recovered their normal behavior the next day. This coma-like state was characterized by loss of righting reflex, significantly reduced responsiveness to a custom battery of stimuli compared to NREM sleep (p = 2.9e-13), and an EEG pattern dominated by slow waves activity (SWA; 0.5-4 Hz). Thus, muscimol induced a state of long-lasting unresponsiveness that was deeper than NREM sleep. In 12 mice the induction of coma-like state was followed by cortical optogenetic stimulation in PtA or mPFC using square pulses (0.25 or 0.5Hz, lasting 1-2 sec) or trains (10ms; 4, 5, or 8Hz). In most cases, light pulses produced both cortical activation (SWA decrease) and behavioral arousal (recovery of righting reflex) from brainstem coma. In 9 mice that received stimulation during anesthesia (1-2% sevoflurane, 70-100ug/kg dexmedetomidine), cortical activation was observed most of the time. These findings provide evidence that direct activation of cortical neurons is sufficient for behavioral and/or cortical arousal from sleep, brainstem coma, and anesthesia.

Characterizing epileptic auras with phenomenology and intracranial EEG.

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Concurrent Session: Disorders of Consciousness 2, Friday July 5th, Fukutake Learning Theater, 2:00PM-4:00PM

Epileptic auras are specific sensations or dream-like experiences occurring during and/or preceding epileptic seizures. In fact, many patients who present to an epilepsy clinic after the occurrence of severe seizures with impaired consciousness report experiential auras without motor symptoms for up to a decade before. Prompt screening and detection of patients with auras may help with early referrals and improve treatment outcomes. While epileptic individuals can clearly report reversible changes in their consciousness state, exploring the underlying physiological mechanisms can provide an understanding of their neuronal correlates.

In this study, we evaluated structured questionnaires of subjective experiences from seven epileptic patients administered following seizures, after awakenings from sleep dreaming, and during wakefulness. Moreover, we quantified intracranial EEG (iEEG) signals in 18 epileptic patients, comparing focal aware (FA) seizures (i.e., those occurring with epileptic auras but without loss of consciousness) to light sleep at the end of the night (with a prevalence of dreaming) and wakefulness. We contrasted slow wave activity (SWA, i.e., delta power, 1 – 4 Hz), and high-gamma power (80 – 150 Hz) sampled from multiple brain regions.

We found significantly ($p < 0.01$) more reports involving metacognition, negative emotions, and less focus on the external environment during seizures (epileptic auras) compared to wakefulness. There were also more bodily self and bizarreness reports during seizures compared to light sleep and wakefulness ($p < 0.01$). We detected an increase in high-gamma power in the medial prefrontal cortex and amygdala during FA seizures ($p < 0.01$), while a respective decrease during dreams ($p < 0.05$) as compared to wakefulness. The first effect might be related to the increase in metacognition and negative emotions (fear and anxiety) observed during epileptic auras. Moreover, we found an increase in SWA in somatosensory areas and in the precuneus in FA seizures and dreaming as compared to wakefulness ($p < 0.01$), which might be related to increased disconnection from the environment (focus on self) and increased bodily-self experiences in epileptic auras.

These results are clinically relevant as they demonstrate that a quantitative content analysis of subjective reports obtained from epileptic patients can inform the likelihood of epileptic vs. non-epileptic events. Moreover, they support the feasibility of contrasting subjective reports of specific contents of consciousness, e.g., disconnection from the environment, which occurs in this clinical population, with underlying neural activations. In future studies, we will investigate neural correlates of epileptic auras, dreaming, and daydreaming in relation to phenomenology on a larger sample. Additionally, we aim to compare these findings with unit activity patterns and to contrast patients' reports with those of their relatives.

(Un)controllability and perception of task difficulty differently shape the implicit sense of agency

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Concurrent Session: Sense of Agency and Volition, Friday July 5th, Ito Hall, Ito International Research Center, 2:00PM-4:00PM

Numerous findings in experimental psychology have shown that the experience of uncontrollability is aversive and has many negative consequences. It can also strengthen the need to restore a threatened sense of control and boost performance when the experience is transient. Our previous work (Soral, Kofta, Bukowski, 2021) suggests that control deprivation decreases an implicit sense of agency (SoA), measured subsequently with the intentional binding (IB) effect. However, the dynamics and factors contributing to agency loss and restoration are poorly understood. In the current study, we aimed to continuously track SoA across two tasks and probe the dynamics of these processes with greater resolution.

In a preregistered experiment (N = 108), participants were first exposed to Behavioural Helplessness Training (BHT), a well-established procedure reducing a sense of control, consisting of 6 concept-formation problems. Participants in the Uncontrollable condition experienced non-contingency between their actions and outcomes (in contrast to the fully contingent Controllable condition). In the second task - Voluntary Task Switching (VTS) - all participants performed relatively easy task switching with valid feedback, recovering SoA. Estimations of action-feedback intervals (IB) were given on each trial in both BHT and VTS. Subjective ratings of control, effort, and perceived task difficulty were also measured.

The results show that the (un)controllability manipulation impacted the explicit sense of control, with considerably lower ratings after the BHT ($t = -9.1$, $p < .001$, $d = -1.74$) in the Uncontrollable (vs Controllable) condition but a boost of sense of control in the following VTS task ($t = 3.8$, $p < .001$, $d = .73$).

Crucially, the manipulation of uncontrollability influenced IB in BHT. An interaction between Condition, Problem number, and Perceived difficulty was observed ($\beta = -.02$, $p = .021$). Participants in the Uncontrollable condition showed the strongest IB early in BHT, but only when the task was perceived as difficult. With time, IB decreased (z ratio = 2.1, $p = .034$). In the Controllable condition, on the other hand, the strongest IB was observed early in BHT when the task was perceived to be easy. Here, IB also decreased with time (z ratio = 3.9, $p < .001$). Moreover, explicit ratings of control did not predict IB and averaged IB scores did not correlate with any of the explicit ratings.

Our results indicate that the context of controllability and perceptions of task difficulty shape implicit SoA differently. In usual controllable circumstances, firm SoA initially unfolds but then recedes, consistent with the idea that automatization leads to less deliberate actions and with results showing that agency decreases with skill and practice. When faced with uncontrollability, an initial increase in SoA is visible, which may be seen as an agency boost (cf. post-error agency boost, Majchrowicz et al., 2021) – which, however, wears off if further attempts are still futile. This suggests that SoA may have a functional relevance in motivating agents to try harder and regain control. Together, this work sheds new light on the adaptive quality of human agency under varying levels of (un)controllability.

Voices from within: Conditioning-induced perception of errors in one's own vocalization

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Concurrent Session: Sense of Agency and Volition, Friday July 5th, Ito Hall, Ito International Research Center, 2:00PM-4:00PM

Most of the research into the neuro-cognitive mechanisms of conscious perception has focused on purely external stimuli. Here, we turn attention inwards and study how individuals consciously perceive errors in their own vocalization. During vocalization, the brain monitors for errors by comparing incoming auditory stimulation with top-down expectations from the motor commands (i.e., efference copies). Mismatch between expected and produced vocalization results in largely automatic corrections to speech motor commands. However, the role of conscious perception in speech feedback motor control remains understudied. We tested if hallucination-like percepts of vocalization errors can be induced by conditioning, and if these false-percepts would lead to corrections to speech motor commands. Auditory-verbal hallucinations are common in patients, but they can also be induced in healthy individuals by instilling a belief that an auditory stimulus co-occurs with a visual stimulus. Given that hallucinations are typically explained using over-precise top-down sensory expectations, or aberrant monitoring of what sensory stimulation is self-caused, self-produced vocalization offers an excellent model for studying the phenomenon. We asked participants (N=60, mean age 23-years) to vocalize the vowel /u/ for about four seconds while they heard their own voice through headphones. During the vocalization, we unexpectedly perturbed the auditory feedback of the participants' vocalization with a brief (200 ms) small upward pitch-shift and asked participants to report if they detected the pitch-shift. During the early stages of the experiment, a visual conditioning stimulus strongly predicted the presentation of the pitch-shift. As the experiment went on, the visual stimulus was more often presented alone without the accompanying pitch-shift. The results showed that the proportion of falsely reported percepts of the pitch-shift increased during the experiment (mean increase in false-alarm rate from 5% to 15%), suggesting successful induction of hallucinated pitch errors during vocalization. However, when participants reported false-percepts of the pitch-shift, the pitch of their *own* voice was more unstable at the onset of the visual conditioning stimulus when compared to the correct-rejection condition. This suggests that instead of hallucinations, through conditioning the participants learned to detect small errors in the pitch of their own vocalization. These results suggest conditioned expectations may enhance perceptual sensitivity to self-produced actions. The experimental paradigm introduced here offers a promising new avenue for exploring conditioning-induced percepts and conscious perception at large.

The Readiness Potential Revisited

Joachim Nicolodi (University of Cambridge)

Concurrent Session: Sense of Agency and Volition, Friday July 5th, Ito Hall, Ito International Research Center, 2:00PM-4:00PM

Libet's "classic" interpretation of the readiness potential (RP) was long thought to be the definitive scientific proof against our common-sense conception of free will, effectively showing that our actions are initiated unconsciously and not by our conscious volition. More recently, researchers proposed a new interpretation of the RP and concluded that it does not mark a causally efficacious neural event that leads to a movement but rather reflects ongoing stochastic fluctuations before a decision is made (Schurger et al., 2012). In brief, Schurger suggested that Libet made the mistake of only looking at the neural activity before the movement actually occurs. Typically, RPs are measured by looking backwards in time from all those moments where the participant moved. However, by time-locking EEG activity to movement-onset (so-called "biased sampling"), researchers systematically overlooked the possibility that RPs could also be found when voluntary actions don't happen. With the stochastic decision model (SDM) as new framework to think about the RP, both Schurger and Roskies – the only philosopher who has commented on this issue – argue that Libet-style studies support our common-sense notion of free will rather than undermining it. This is because the neural decision to move does not happen at the onset of the RP as proposed by Libet, but when the cortical activity crosses a certain threshold. This threshold-crossing is closer to the actual movement-onset and also seems to coincide with the conscious awareness to move. Consciousness seems again to play a pivotal role in voluntary action, just as common sense would suggest (Roskies, 2021). This theory has not yet received the philosophical consideration it deserves. In this paper, I aim to fill this gap in the literature by arguing against the common-sense interpretation of the RP. In the first part of the paper, I provide background information on the debate and deal in more detail with Libet's and Schurger's studies, as well as Roskies' take on the SDM. In the second part, I posit three problems for the common-sense interpretation of the RP: the problem of randomness, the problem of epiphenomenalism, and the mereological fallacy. The problem of randomness suggests that even in elaborate, evidence-based decisions, random noise is the decisive factor, not the participant's conscious control. This becomes evident once we take a closer look at the original experiment conducted by Schurger in 2012. The problem of epiphenomenalism posits that, in order to restore consciousness's causal role in decision-making, Schurger and Roskies need to prove that the brain state making the decision (i.e., leading to the threshold-crossing) is identical to the brain state instantiating consciousness. However, the data tells us is that the two states only approximately coincide, which is insufficient to support their claim. Lastly, the mereological fallacy suggests that part of the argument's strength stems from Schurger's and Roskies' unwarranted use of common-sense terminology to describe the underlying neuronal processes. I also consider and contest the strongest objections to each of these problems, concluding that they provide compelling reasons to reject Schurger's and Roskies' position.

Sense of agency during Human AI collaboration: the role of explanation

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Concurrent Session: Sense of Agency and Volition, Friday July 5th, Ito Hall, Ito International Research Center, 2:00PM-4:00PM

Situations involving collaboration between human operators and intelligent systems are becoming increasingly common. Recent work has suggested that people's sense of agency, i.e. the experience of control over their actions and their effects, may develop abnormally when interacting with an artificial agent. An altered sense of agency can have profound moral and legal implications, as a sense of agency is considered a prerequisite for the attribution of individual responsibility. Yet little is known about how to support the development of a human operator's sense of agency when interacting with an artificial agent, and how we can empower humans to cooperate with such systems.

In this work, we propose to mitigate this effect by making AI systems more intelligible to human operators. Based on the literature on joint action and the key role of sharing agents' intentions for coordination, we hypothesized that the readability of system intentions is a key element of their predictability and, by extension, of the human operator's abilities to cooperate with them. In same time, communication system intention could impact the human partner experience of control but also trust in and acceptability of the artificial partner. To test these hypotheses, we adapted a human-machine collaboration experiment based on the virtual cooking game Overcooked. In this game, participants have to coordinate with an artificial partner in order to complete a number of recipes as quickly as possible. The effect of the system's 'explanations' was tested by giving the human player access or not to the virtual agent's intentions. In a first experiment, we evaluated the impact of this explicability of the virtual partner on the development of the operators' sense of agency using a questionnaire at the end of each game.

The results showed that 1/ the development of the sense of agency is based on objective behavioral cues such as the role of the operator, the fluidity of the interaction with the virtual agent and the performance in the task, 2/ explanations based on intention increase the sensitivity of human operators to objective cues that inform them about their actual control. These results suggest that the development of operators' sense of control depends on cues present in the interaction and is not purely reconstructed a posteriori and that communication between the partners facilitates access to these cues. In a second experiment, we evaluated the impact of this explicability on participant's attitude toward the artificial partner: acceptability, trust and willingness to cooperate. We observed that intention communication shift participants' behavior towards cooperation with the artificial partner, but also increase trust and acceptability of this partner.

With this work, we demonstrate the importance of communication from artificial agents to their human partner when it comes to develop collaborative systems and support the development of a control experience based on objective cues. Given the place of artificial agent in the next future and the importance of the sense of agency in terms of responsibility, these results can guide the way we perceive and design future artificial partners.

Re-engineering the concept of decision for the neuroscience of volition

Paulius Rimkevicius (Kaunas University of Technology)

Concurrent Session: Sense of Agency and Volition, Friday July 5th, Ito Hall, Ito International Research Center, 2:00PM-4:00PM

In philosophy, and in related disciplines, there is an ongoing debate on whether there is such a thing as a conscious decision. If we define 'conscious' as accessible to the subject directly, not only through inference, and 'decision' as the mental event that settles the question what to do, the question is whether the mental event that settles the question what to do is ever conscious. Interestingly, there is mental event that everyone in the debate agrees is sometimes conscious and that at least closely resembles a decision, namely: an inner speech act of saying that you will perform an action, such as saying 'now' when you have to decide when to act. Given the disagreement on the existence of conscious decisions, the agreement on the existence of conscious inner speech acts, and their resemblance to decisions, it seems worthwhile to investigate just how closely those inner speech acts come to playing the role of a decision. Perhaps they are the closest real thing to a conscious decision, and perhaps we should re-engineer our concept of decision in order to accommodate this. Or perhaps they do not come close enough to playing that role and we should consider other options.

In this paper, I explore the idea of re-engineering the concept of decision, in this and in other ways, while focusing specifically on its usage in the neuroscience of volition. Lately, there has been a considerable amount of discussion in this field on how to define its central terms, such as "free will", "volition", "intention", and "decision". However, researchers working in this area have not yet been able to come into agreement on the kind of revision needed. Moreover, the discussion has so far proceeded without almost no methodological reflection on how one should revise concepts generally. I propose to contribute to the discussion by employing to this case the tools developed by philosophers engaged in projects of conceptual engineering. I will proceed by describing how the concept of decision is used by specialists in this and related fields, and by non-specialists, relying in part on evidence from our own recent empirical studies, and then suggest ways in which the concept could be revised, provide an evaluation of these revisionary proposals, and suggest how the revisions could be implemented, so that we could change the current usage in the field for the better.

Physical presence of listeners enhances the sense of agency over speech

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Concurrent Session: Sense of Agency and Volition, Friday July 5th, Ito Hall, Ito International Research Center, 2:00PM-4:00PM

Speaking is an action through which individuals articulate one's thoughts or feelings to others. Speech acts, embedded in communicative intention, may encourage speakers to feel a sense of agency or responsibility for one's statements. The sense of agency refers to the subjective experience that "I" am the one who is causing an action (Gallagher, 2000). In a previous study, we quantitatively assessed participants' sense of agency during their speech acts (Ohata et al., 2022). However, the impact of communicative intention on the sense of agency remains to be elucidated. In the current study, we address the hypothesis that the presence of listeners enhances a speaker's sense of agency over speech. Thirty-eight healthy volunteers participated in Experiment 1 and conducted an interval estimation task. In the task, participants vocalized one of five vowel sounds from the Japanese syllabary ("a," "i," "u," "e," or "o") to make into a microphone. Following a short interval (200 ms, 400 ms, or 600 ms), they heard their own spoken voice through headphones. Then, they reported the perceived interval between their speech and voice feedback. We assessed the compression of the perceived interval between the action and outcome as an implicit measure of the sense of agency, known as an intentional binding effect (Haggard et al., 2002). We manipulated communicative intention by introducing the remote presence of a listener. Participants (speakers) performed the interval estimation task by conveying a syllable word to a co-experimenter (listener) in an experimental setup designed to simulate an online meeting. Participants observed the face of a listener on a screen online in a presence condition, whereas they viewed an offline screen (i.e., black screen) in a non-presence condition. We found no significant difference in the compression of the perceived action-outcome interval regardless of the remote presence of listeners. Similarly, the remote presence did not significantly impact on the sense of agency even when participants' friends served as listeners in Experiment 2 (N = 38). In Experiment 3 (N = 43), we explored the effect of physical presence on the sense of agency. Participants faced a co-experimenter in person during the interval estimation task in the presence condition, whereas they engaged in the task alone in the non-presence condition. Consequently, participants reported a significantly shorter action-outcome interval in the presence condition than in the non-presence condition. These findings suggest that the physical but not online remote presence of listeners could endow speakers with a stronger sense of communication, thereby enhancing their sense of agency over their speech acts. The current study might offer valuable insights into how face-to-face physical interaction with others shapes our conscious experience of self-agency.

Fast sensory attenuation and slow sensory enhancement: A study on self-generated tactile stimuli using the SSSEP.

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Concurrent Session: Sense of Agency and Volition, Friday July 5th, Ito Hall, Ito International Research Center, 2:00PM-4:00PM

It is widely reported that self-generated touches usually feel weaker than those generated externally, a phenomenon known as sensory attenuation (Blakemore et al., 1998). In addition to subjective reports, studies utilizing event-related potentials have consistently demonstrated attenuated amplitude for self-generated stimuli, time-locked to the onset of these stimuli (Baess et al., 2009; Gentsch & Schütz-Bosbach, 2011; Horváth, 2015). However, it has been reported that the self-generated stimuli attract more attention than externally generated ones (Wen et al., 2018), because the former are usually more significant and more informative for humans in the environment. Are self-generated stimuli always attenuated, or are they, in fact, enhanced in our perceptual processing? This paradox remains largely unresolved.

The present study utilized the steady-state somatosensory evoked potentials (SSSEP) and applied analysis using sliding time windows to study the full time course of the perceptual processing of self-generated touch. In Experiment 1, a 2-second vibration at 71.43 Hz was delivered to participants' left index finger immediately after a self-paced key-press (i.e., the non-delayed condition), or after a random delay between 500-1000 ms (i.e., the delayed condition). Participants were asked to judge whether the intensity of the vibration was stronger or weaker compared to a subsequent standard vibration, which was always delivered 500 ms after the first vibration. The intensity of the second, standard stimulus was constant among all participants, while the amplitude of the first stimuli was chosen for each participant at the 50-percent discrimination threshold compared to the second, standard stimuli. The SSSEP for the first stimulus was calculated for each 1-second time window, which was slid every 100 ms, resulting in 11 time windows. The results showed that the amplitude of the SSSEP was significantly larger in the delayed condition than in the non-delayed condition in the first time window, aligning with the phenomenon of sensory attenuation. However, this significant difference disappeared by the second time window and quickly reversed from the third time window onwards, indicating that the perceptual processing was in fact enhanced for the non-delayed stimulus in most of the duration except for the first time window. The behavior results were consistent with the SSSEP findings. Participants perceived the non-delayed touch as stronger than the delayed touch, reflecting sensory enhancement. This novel finding was replicated in Experiment 2, which compared touches generated by self-paced key presses with passively received touches. Again, the SSSEP for self-generated touches was weaker than for passively received touches only in the first time window, and the difference rapidly reversed in subsequent time windows.

Taken together, our findings revealed that self-generated touches are attenuated for a very brief duration (about 100 ms) and are then, in fact, enhanced in our perceptual processes, constantly capturing our attention. The rapid sensory attenuation is likely to be associated with corollary discharge, which refers to the copies of motor signals sent to sensory regions, while the subsequent sensory enhancement indicates that self-generated stimuli are important for humans and are allocated more and longer-lasting cognitive resources.

Behavioural and Neural Correlates of Visual Illusion Sensitivity

Catriona A Osborn Moar (University of Sussex), Dominique Makowski (University of Sussex)

Concurrent Session: Neural Correlates, Friday July 5th, Gallery 1, Ito International Research Center, 2:00PM-4:00PM

We introduce the Illusion Game, a novel paradigm designed to reliably measure illusion sensitivity. This paradigm combines psychophysics design principles with advanced modelling techniques to index the objective impact of illusion strength and dissociate this from perceptual abilities. This approach addresses limitations of previous paradigms, in which metacognitive processes predominate.

In a first study (n=250; Makowski, 2023), we utilised Pyllusion, an open-source software, to generate stimuli for ten classic visual illusions with varying task difficulty and illusion strengths, in a reproducible manner. This study validated our paradigm and identified potential correlations between illusion sensitivity and a range of personality traits, both adaptive and maladaptive. A subsequent OSF preregistered study (osf.io/k4ntd; n=497; in preparation) aims to replicate and extend these initial findings to other dimensions, such as autistic and schizotypic traits. In particular, we assess the psychometric properties of a short version of the task, focussing on three classic visual illusions: Ebbinghaus, Müller-Lyer and Vertical-Horizontal, and incorporate a control task for perceptual discrimination and an assessment of test-retest reliability. A third study (n=103, in preparation) uses the Illusion Game in conjunction with physiological (heart rate and respiration) and EEG recordings, to further characterise the neurophysiological correlates of illusion perception and sensitivity.

We will present findings regarding the dispositional correlates of illusion sensitivity, particularly its association with “psychopathological”, i.e., maladaptive, personality traits, which align with alterations observed in some clinical groups (e.g., diminished sensitivity to illusions in people with schizophrenia; Adams et al., 2013; Notredame et al., 2014; King et al, 2017; Grzeczkowski et al., 2017). Despite inconsistent empirical support for the existence of a common factor underlying illusion sensitivity, our work suggests that methodological refinements can clarify this relationship. We then explore predictive coding as a theoretical framework for understanding illusion perception, where individual differences in sensitivity may reflect diversity in inferential processes. Lastly, we present preliminary findings for neurophysiological correlates within the paradigm, with a focus on the resting-state signal characteristics (in particular, complexity features such as entropy and fractal dimensionality) in relation to illusion sensitivity, as well as the event-related fluctuations that predict Illusion Game performance. This investigation contributes to our understanding of the neuropsychological correlates of illusion sensitivity and offers a replicable framework for future research in this domain.

A Burst-dependent Thalamocortical Model of Perceptual Awareness and Rivalry

Christopher J. Whyte (University of Sydney), Brandon R. Munn (University of Sydney), Eli J. Muller (University of Sydney), James M. Shine (University of Sydney)

Concurrent Session: Neural Correlates, Friday July 5th, Gallery 1, Ito International Research Center, 2:00PM-4:00PM

Investigations into the neural basis of conscious perception span multiple model organisms and levels of analysis. There is, however, a methodological divide between advances made at the microscopic scale in rodent models and those made at the meso- and macroscopic scale in human and non-human primate cognitive neuroscience. This divide constrains the neurobiological understanding of conscious perception to the scale of each specific measurement modality. Here, we use computational modelling to help bridge this divide. Inspired by recent work in a mouse model of threshold detection, we built a thalamocortical spiking neural network that reproduced the full suite of behavioural and neural findings reported in the mouse model. Namely, synchronous thalamic-mediated burst firing in thick-tufted layer 5 (ttL5) pyramidal neurons controls the threshold for perception. The non-stationary nature of burst firing makes largescale (i.e. mean-field) modelling challenging, we avoided this issue by orienting our modelling at the spiking level. Through a series of simulation experiments, we then interrogated the hypothesis that this same burst-firing mechanism may underlie visual awareness in the primate visual system. Specifically, using the same model with identical parameters, we simulated two key visual rivalry paradigms widely used in the cognitive neuroscience of consciousness; binocular rivalry and continuous flash suppression. We found that the same thalamus-mediated burst-dependent mechanism determined perceptual dominance and conformed to key psychophysical constraints (Levelt's laws). In addition, the novel layer-specific structure and thalamocortical connectivity backbone allowed us to generate a suite of novel predictions at cellular, mesoscale, and behavioural levels of analysis some of which have received tentative empirical support from recent experiments in high-field fMRI. Our model, therefore, provides a potential empirically tractable bridge between cellular-level mechanisms and conscious perception.

The central role of the thalamus in the state, content and character of consciousness

James M. Shine(The University of Sydney)

Concurrent Session: Neural Correlates, Friday July 5th, Gallery 1, Ito International Research Center, 2:00PM-4:00PM

The thalamus is a small, bilateral structure in the diencephalon that integrates signals from many areas of the central nervous. This critical anatomical position allows the thalamus to influence whole-brain activity, adaptive behavior and consciousness. Despite these links, traditional research paradigms have struggled to attribute specific functions to the thalamus and it has remained under-studied in the human neuroimaging literature. Recent advances in analytical techniques and increased accessibility to large, high-quality datasets have brought forth a series of studies and findings that (re)establish the thalamus as a core region of interest in human cognitive neuroscience and consciousness studies, which otherwise remain relatively cortico-centric. In my talk, I will argue that using whole-brain neuroimaging approaches to investigate the thalamus and its interaction with the rest of the brain is key for understanding systems-level control of information processing characteristic of consciousness. To this end, I will highlight the role of the thalamus in shaping a range of functional signatures, including evoked activity, inter-regional connectivity, network topology and neuronal variability, both at rest and during the performance of cognitive tasks. I will then summarise the results of recent cellular- and systems-level biophysical modelling projects from my group that highlight the central role of the thalamus in shaping and constraining brain states associated with conscious experience. I will conclude my talk by summarizing recent theoretical work that argues for specific micro-circuits connecting the thalamus and cerebral cortex that differentially support the state, content and character of conscious experience. Together, these studies highlight the crucial role of the thalamus in supporting the neural mechanisms of consciousness.

Non-conscious multi-sensory integration in the ventriloquist effect

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Concurrent Session: Neural Correlates, Friday July 5th, Gallery 1, Ito International Research Center, 2:00PM-4:00PM

The degree to which information from distinct sensory modalities can interact in the absence of conscious awareness remains controversial. According to the Global Neuronal Workspace Theory (GNWT), unconscious sensory information remains relatively confined to the sensory cortex and should not interact with other modalities until it is broadcast into the (conscious) global workspace comprising late (>300 ms) frontal-parietal activation. The ventriloquist effect refers to the misperception of a sound location towards that of a concurrent visual stimulus, such as perceiving the voice of a ventriloquist as coming from the moving dummy. Here, we used visual masking to render the location of a brief flash stimulus unconscious while participants performed a sound localization task. We found that, despite being at chance performance in discriminating the flash location, participants were nevertheless biased to localize sounds towards the unconscious flash locations. Decoding analyses of concurrently recorded EEG signals confirms that the non-conscious flash location information was present up until around 300 msec, but not after; confirming that the visual influence on sound perception likely occurred before conscious broadcast. Our findings suggest that consciousness is not required for the integration of signals originating in distinct sensory modalities and could prompt revision of certain features of the GNWT.

Functional MRI investigation of the brain networks subtending task-related versus task-free conscious auditory perception

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Concurrent Session: Neural Correlates, Friday July 5th, Gallery 1, Ito International Research Center, 2:00PM-4:00PM

The neural correlates of conscious access are subject to a vast debate among the scientific community and many different theories exist. Some argue that conscious perception of a stimulus requires the activation of a broad network including high-level areas such as prefrontal and parietal cortices, while others consider that these distributed activations are actually task-related and correspond to post-perceptual processes. In a recent EEG study conducted by Sergent and colleagues (Nat. Comm., 2021), participants were presented with auditory stimuli around perceptual threshold, and either had a task to perform on them (task-related condition) or not (task-free condition). Results showed that conscious perception in both conditions is associated with the all-or-none triggering of late activations following initial sensory processing, beyond 250 milliseconds. EEG source reconstruction suggests that, during task-related conscious processing, these late activations might rely on a "global workspace" involving auditory, parietal and prefrontal regions. During task-free sessions, conscious perception appears to still rely on some higher-level areas (such as parietal and prefrontal cortices) beyond sensory areas, but with a notable absence of activation in motor planification areas compared to the task-related condition; we tentatively call this network the "global playground".

Here we set out to characterize the specific networks involved in these postulated global workspace and global playground using the excellent spatial resolution of functional MRI. Our preliminary results reveal two similar networks sensitive to stimulus intensity around the perceptual threshold, in both task-related and task-free settings, in temporal, prefrontal, parietal areas and in the anterior insula. However, we find broader and stronger prefrontal and parietal activations in the task-related condition, and conversely stronger temporal activations in the task-free one. This is in agreement with what was suggested by the EEG source reconstruction. We further delve into the specific trial-by-trial dynamics associated with conscious perception within these two networks to reveal their similarities and singularities.

Hierarchical theories and the quest for the elusive correlate of consciousness

Michał Wierzchoń (Jagiellonian University, Consciousness Lab and Centre for Brain Research)

Concurrent Session: Neural Correlates, Friday July 5th, Gallery 1, Ito International Research Center, 2:00PM-4:00PM

Hierarchical theories of consciousness provide a compelling framework for understanding consciousness. While various approaches differ in details, they all agree that consciousness involves being aware of a specific first-order state (e.g., conscious vision requires awareness of seeing) and that conscious information is represented hierarchically. However, there is limited empirical evidence directly supporting this view. One of the reasons seems to be the fact that most of the studies so far were aimed at disentangling between higher- and lower-order levels, but not in a more general question of how hierarchy is reflected in the structure of subjective experience. Interestingly, even though philosophical literature often discusses the structure of experience, this work has not been sufficiently discussed and implemented in the context of development of the empirical theories of consciousness in general, and hierarchical theories in particular. This is because the theories are typically focused on "how" consciousness arises and not "why" it is structured in a given way. One reason for the lack of strong evidence is that most studies have focused on distinguishing between higher- and lower-order levels rather than on a more general question of how hierarchy is reflected in the structure of subjective experience. While philosophical literature frequently explores the structure of experience, this work has not been extensively integrated into the development of empirical consciousness theories, particularly hierarchical ones. The focus of these theories tends to be on the consciousness emergence rather than its structural organization. I will introduce a minimal model of this structural hierarchy, drawing on studies from various studies, including our won work investigating non-perceptual contributions to visual awareness. I will examine the structural characteristics of this minimal hierarchy and argue for why hierarchical structure should be reflected in information theory metrics such as complexity. Additionally, I will discuss recent advancements in information theory-based metrics and assess their ability to capture key features of hierarchical models.

Systematically comparing theories of consciousness—a primer and example: Neural EEG dynamics discriminates between the Global Neuronal Workspace, Integrated Information Theory, and the Temporospatial Theory of Consciousness

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Concurrent Session: Neural Correlates, Friday July 5th, Gallery 1, Ito International Research Center, 2:00PM-4:00PM

Consciousness science is marred by a foundational methodological crisis of disparate constructs and methodologies that make it challenging to systematically compare theories, which abound. We proposed a solution by introducing a novel inter-theory classification interface, the Measure Centrality Index (MCI) (Chis-Ciure et al., 2024, in revision). Recognizing a gradient distribution, the MCI assesses the degree of importance a specific empirical measure has for a given consciousness theory. The MCI framework proposes the concept of cross-theoretical empirical translations, enabling experiments that rigorously test a theory's measures in the framework of other theories. We run an adversarial-style study that exemplifies the abovementioned MCI strategies (Chis-Ciure et al., in progress). More specifically, we conceptually formulated some cross-theoretical predictions involving the Global Neuronal Workspace Theory (GNW) (Dehaene et al., 2011; Mashour et al., 2020), Integrated Information Theory (IIT) (Tononi et al., 2016; Albantakis et al., 2023), and the Temporospatial Theory of Consciousness (TTC) (Northoff & Huang, 2017; Northoff & Zilio, 2022). The study operated with an EEG resting state of consciousness paradigm, which is a novel setting for such contrastive comparisons that have so far focused on conscious contents (Cogitate Consortium et al., 2023; Melloni et al., 2023). We had three EEG datasets involving different state of consciousness conditions with 126 distinct subjects: minimally conscious state and unresponsive wakefulness, anesthesia (ketamine and sevoflurane), and sleep. The theoretical target of the study was how the consciousness level or state is tracked by measures of neural dynamics in the three theories; hence, we assessed theory-driven complexity motifs of neurodynamics. To this aim, we chose two measures of neural dynamics: Lempel-Ziv Complexity (LZC), which is primarily emphasized in IIT empirical literature but was also appropriated within GNW, and the Autocorrelation Window (ACW), which the TTC proposed. The mean LZC and ACW values reliably and significantly tracked the presence/absence of consciousness in all three datasets, providing some degree of confirmation for all theories. As this was expected given the confirmatory bias of the field (Yaron et al., 2022), we also quantified the degree of centrality these different measures have within the theoretical structure of GNW, IIT, and TTC. Furthermore, we used the MCI-based method of cross-theory extrapolation to distill more specific and preferably divergent predictions. Thus, we considered LZC in the context of TTC and ACW in GNW and IIT. Based on their theoretical principles, it seems reasonable to infer that GNW and IIT would predict longer mean ACW values in intact states of consciousness. This conflicts with TTC's prediction of a balance of shorter and longer timescales entailing medium rather than longer ACW values. The data analysis results favor TTC in this potential locus of contention.

In conclusion, while this study does not provide a substantial disconfirmation of any of the three theories—to the contrary—it highlights how the MCI methodological novelty opens new research pathways for empirically discriminating between theories while simultaneously showcasing the need for an encompassing meta-framework for multi-theory assessment (Northoff & Lamme, 2020).

Can Neuroscience help us determine the boundary between conscious and unconscious processing?

Yinzhu Yang (University of Cambridge)

Concurrent Session: Neural Correlates, Friday July 5th, Gallery 1, Ito International Research Center, 2:00PM-4:00PM

The neuroscientific investigation of consciousness has been full of disagreements and debates since its inception, with various theoretical frameworks competing with each other, including Global Workspace Theory (GWT), Higher-Order Theory (HOT), Information Integration Theory (IIT), Recurrent Processing Theory (RPT) and others. These theories hold different views on where consciousness is located and how consciousness is processed in the brain. One core reason for this lack of consensus lies in how we measure consciousness. A standard method to study consciousness is to compare two conditions: one when people are conscious of the stimuli, and another when they are not. We then see how their brains differ in these two conditions (Dehaene and Changeux, 2011). This is the so-called contrastive analysis. The problem, however, is that scientists and philosophers cannot agree upon the criteria between 'conscious condition' and 'unconscious condition'. This problem is what underlies many debates revolving around consciousness. This talk is motivated by trying to find a useful criterion between conscious and unconscious conditions, which is critical to many related debates. I analyze why such disagreements arise by pointing to serious problems with the mainstream methodology, and the criteria we use to determine the presence and absence of consciousness. Can neuroscience help us draw the boundary? I say barely, as the mainstream method——contrastive analysis——suffers from problems with both subjective and objective methods. The former falls prey to the 'illusion' problem and the latter struggles with the 'confounding' problem.
Why do we fall into this dilemma? I urge that we should question our assumptions first. I argue that the boundary between conscious and unconscious processes is porous and unfixed. We might never be able to derive a general rule that works in all cases. Given that there are good reasons to be less optimistic, I then reexamine our initial question and consider the possibility that we are asking the wrong one. I suggest that our conundrum may due to a more fundamental mistake with the current understanding of consciousness science: the very concept of consciousness itself might be based on a questionable taxonomy. I conclude by discussing potential ways out of this theoretical impasse, making space for two potential directions to proceed, namely eliminativism and especially pluralism. Now, can we still find useful criteria between conscious and unconscious processes? I answer this question with a tentative yes, but with the caveat that this question is only sensible in a context-dependent way.

Examining Hierarchical Neural Representations when Forming Mental Models of Self and Other Agents

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Concurrent Session: Body and Self 2, Friday July 5th, Seminar Room, Ito International Research Center, 2:00PM-4:00PM

Humans have an exceptional capacity to predict the complex set of emotions, beliefs, and motives of other individuals. This ability is in part due to personal experience with a mind. That is, having access to one's own set of emotions, beliefs and motives can be useful in determining the emotions, beliefs and motives of others. Previous work suggests shared computation in representing minds, with some areas dedicated to inferring abstract mental states irrespective of actor and others that track idiosyncratic aspects of particular minds. To identify the functional overlap in mental mind modeling, we created an attention monitoring paradigm that specifically required monitoring one's own mental state and the mental state of another actor. We contrasted these two 'mentalizing' conditions against two control tasks that involved self and other actors, but without explicitly requiring inference about a state of mind. Subjects performed a total of four tasks in an MRI scanner. In the Self Monitor task, we asked participants to meditate, instructing them to maintain attention on their breath and press a button if they observed their attention was no longer in the correct location. In the Self Count task, participants pressed a button at every fifth breath, focused on iteratively counting instead of metacognitively monitoring their own attention state. In the Other Monitor task, participants watched a video of a meditating actor and pressed a button when they believed the actor's attention had lapsed. In the Other Monitor task, to create an analogous control, participants were asked to count the number of breaths of the actor. We analyzed activity around the moment of a button press, specifically interested in areas that were similar for constructing models of minds compared to counting. As hypothesized, the Self Monitor and Other Monitor tasks evoked activity in similar brain areas overlapping the theory of mind network and Default Mode Network (DMN). The right TPJ and dmPFC were more active for both mentalizing tasks compared to the counting tasks; the posterior cingulate cortex was active when directing attention towards the self, but not when directing attention toward the mental state of another actor. To further investigate the specific representations in regions active for both mentalizing tasks, we conducted multi-voxel pattern analysis, finding patterns in the dmPFC and TPJ to reliably distinguish between mentalizing and control conditions. We then tested if representations contained information about specific actors, finding that the dmPFC contained information about mentalizing versus control conditions, irrespective of the actor type. In contrast, the rTPJ specifically delineated which kind of actor was the target of attention (i.e. self versus other). These results provide evidence for a hierarchical relationship in mentalization processes, with some regions, such as the TPJ, attributing mental processes to particular agents, and other regions, such as the dmPFC, applying general purpose computations related to social cognition. Additionally, our results indicate hubs of the DMN are less sensitive to internal versus external processing, instead providing further evidence that DMN may integrate previous models of the world with current attention states.

Investigating the relationship between metacognition and emerging self-awareness

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Concurrent Session: Body and Self 2, Friday July 5th, Seminar Room, Ito International Research Center, 2:00PM-4:00PM

The ability to adapt one's behavior not only by observing the consequences of one's actions but also by internally monitoring one's own performance is crucial for learning and optimal functioning. This capacity, broadly termed metacognition, gradually develops in humans during early childhood. Human infants have been shown to internally monitor the accuracy of their own decisions and to regulate their subsequent behaviour accordingly. These rudimentary metacognitive abilities have been recorded as early as 12 months age (indicated by EEG-recorded Error Related Negativity (ERN); Goupil & Kouider, 2016). However, it remains unknown whether infants consciously detect their errors and whether, or how, the mechanisms of metacognitive monitoring and control change during development, particularly with the emergence of self-awareness.

In a longitudinal project, investigating neuro-cognitive mechanisms of information seeking and learning, we study (N = 124) human infants at 3 age points: 12, 18, and 24 months. Using gaze-responsive eyetracking and concurrent EEG recordings, infants can interact with a display, using their gaze, and actively gather information and make decisions. The success and progression through the task depend on infants learning a rule (find cards with matching images) and adapting their information search to the changing difficulty of the task (similarity between images). We investigate infants' metacognitive monitoring, by examining their neural responses to the accuracy of their decisions (ERN); and infants' metacognitive control, by examining whether infants adapt their information search based on the difficulty of the task, and the accuracy of their decisions.

Behavioural data (eyetracking) collected at 12 months indicates that infants adapt their information search according to the difficulty of the task: increased similarity between images resulted in increased duration of exploration ($p = 0.028$); number of fixations ($p = 0.026$); and number of comparisons between images ($p = 0.002$). Moreover, concurrently recorded EEG data revealed an ERN effect in trials where infants selected an incorrect (compared to a correct) card ($p = 0.041$). Importantly, this negative deflection in EEG signal was observed prior to infants receiving visual feedback about the accuracy of their choice. This data suggests that already at 12 months, infants internally monitor the accuracy of their decisions (metacognitive monitoring) and adaptively gather information according to task demands (metacognitive control).

Data from the same task is currently being collected from the same infants at age 18 months, which is when self-representation typically emerges in humans. Gathering data at multiple time points enables the opportunity to investigate developmental changes and, crucially, examine differences in infants' indices of metacognitive monitoring and control on task, in relation to their emerging self-awareness. By administering the same task in addition to the mirror-self-recognition task at 18 months, we will be able to compare infants who exhibit evidence of self-awareness, to same-aged infants that do not show (mirror) self-recognition; and relate the results to the data collected with the same individuals at age 12 months. This developmental population offers the unique opportunity to directly investigate how self-awareness and metacognition interact in development.

Investigating the bodily self: a study on ketamine and self-other-distinction

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Concurrent Session: Body and Self 2, Friday July 5th, Seminar Room, Ito International Research Center, 2:00PM-4:00PM

A coherent sense of self is crucial for social functioning and mental health. The NMDA antagonist ketamine induces short-term dissociative experiences and can therefore be used to model an altered state of self-perception. This randomized double-blind placebo-controlled within-subject study investigated the mechanisms of ketamine's effect on the bodily sense of self in the context of affective touch. Participants received intravenous ketamine while performing self-touch and receiving touch by someone else during functional MRI – a previously established neural measure of tactile self-other-differentiation. Afterwards, tactile detection thresholds during self- and other-touch were assessed, as well as dissociative states, interoceptive awareness, and social touch attitudes. Compared to placebo, ketamine administration elicited dissociation and reduced neural activity associated with self-other-distinction in the right temporoparietal cortex. This reduction correlated with ketamine-induced reductions in interoceptive awareness. These results demonstrate that disrupting the self-experience through ketamine administration affects neural activity associated with self-other-differentiation in a region involved in touch perception and social cognition. This process may be driven by ketamine-induced effects on top-down signaling, rendering the processing of predictable self-generated and unpredictable other-generated touch more similar. These findings provide further evidence for the intricate relationship of the bodily self with the tactile sense.

Encoding others' attention as implied motion: Disentangling attention-motion and action expectation effects

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Concurrent Session: Social Perception, Friday July 5th, Seminar Room, Ito International Research Center, 2:00PM-4:00PM

When it comes to our ability to reconstruct other people's mental states (so called "theory of mind"), attention is a fundamental aspect. Understanding the attentional states of social agents helps us reconstruct their likely thoughts, intentions, and emotions, enabling predictions about others' behavior. Most previous work on understanding of others' attention has focused exclusively on perception of gaze direction. However, a model of attention must include more than simple 'gaze vectors' to allow the rich and dynamic predictive abilities that fall under theory of mind. We recently showed that viewing static images of agents attending to objects elicits behavioral motion aftereffects (Guterstam & Graziano, 2020a Prog Neurobiol), and motion-related fMRI activity patterns (Guterstam et al., 2020 PNAS), suggesting that the brain encodes others' attention as an implied motion traveling from an agent toward the attended object. An alternative explanation to these findings (offered in a commentary by Görner et al., 2020 PNAS) is that the observed motion signal may represent an expectation that the agent will perform an action directed towards the object. Although we find this alternative explanation a priori unlikely for various reasons (see our reply: Guterstam & Graziano, 2020b PNAS), we addressed it experimentally by contrasting the 'attention-motion' and 'action expectation' accounts in this behavioral study.

In the current study, we replaced the attended neutral object (a tree) used in the visual stimuli of our previous studies with something that is universally perceived as fearful/dangerous: a large spider. A vast body of research suggests that the perception of spiders is associated with automatic avoidance actions, such as pulling away a limb or moving away from the spider (e.g., Chen & Bargh, 1999 PSPB). Thus, in our paradigm, where participants (n=22) in each trial viewed an agent gazing at a spider (for 1.5 s) after which motion aftereffects were evaluated using a random dot motion task (adapted from Guterstam & Graziano, 2020a), we made the following predictions: if the action expectation account is true, we should observe a significant motion aftereffect in the spider-to-agent-direction (reflecting expected/simulated avoidance actions); but if the attention-motion account is true, we should observe a significant motion aftereffect in the agent-to-spider direction (reflecting the perception of the agent's attention as implied motion). We found a significant motion aftereffect in the agent-to-spider direction (mean difference in reaction times [dRT] = 23 ms, SE = 10.9, $t = 2.13$, $p = 0.04$), supporting the attention-motion account. On interleaved trials featuring a blindfolded agent, the motion aftereffect disappeared (mean dRT = 0 ms, SE = 12.7, $t = 0.0$, $p = 0.99$), replicating previous findings and excluding the possibility that the observed motion aftereffect results from the perception of the spider itself. These results contradict the notion that the covert motion signal observed in our previous studies is caused by an imagined action of the depicted agent. Instead, the simplest and best explanation to the pattern of results is that people implicitly code the gaze of an agent as a stream of motion emanating from the agent.

Social perspective-taking influences on metacognition

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Concurrent Session: Social Perception, Friday July 5th, Seminar Room, Ito International Research Center, 2:00PM-4:00PM

We often effortlessly take the perceptual perspective of others: we represent some aspect of the environment that others currently perceive. However, taking someone's perspective can interfere with one's perceptual processing: depending on where they are attending, another person's gaze can spontaneously facilitate or impair our ability to detect stimuli in a scene. But it is still unclear whether this type of social influence also extends to the cognitive evaluation of perceptual judgments. Is perceptual metacognition affected by social perspective-taking? In this study (N = 27), we investigated whether perspective-taking can influence the efficiency of metacognitive judgments about perceptual responses (i.e., being better or worse at distinguishing when one's perceptual response is correct or not). Participants performed a contrast detection task with a task-irrelevant avatar oriented either congruently or incongruently to the stimulus location. By "blindfolding" the avatar in half of the trials, we tested whether any congruency influence was due to taking the visual perspective of the avatar (being sensitive to what the avatar can or cannot see) or a domain-general orienting mechanism (being sensitive to low-level directional cues). Participants were more accurate and had better perceptual sensitivity with a congruent vs. an incongruent avatar regardless of the blindfold, suggesting a low-level directional cueing effect. However, their metacognitive judgments were more efficient only when the sighted avatar's perspective was congruent (vs. incongruent) with the stimulus location, that is, when participants believed that the avatar could also see the stimulus. These results suggest that perceptual metacognitive efficiency can be socially enhanced by tracking someone's perspective and sharing perception of the same objects with them.

Social perception of other people's covert attention

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Concurrent Session: Social Perception, Friday July 5th, Seminar Room, Ito International Research Center, 2:00PM-4:00PM

Covert attention is the act of orienting one's attention to a stimulus, without moving one's eyes. In the absence of other overt bodily or environmental cues indicating an attention shift, the reorienting of one's covert attention is considered, almost by definition, undetectable by outside observers. To the best of the authors' knowledge, social perception of others' covert attention is a largely unexplored subject, perhaps due to the aforementioned reasons. Here we tested the hypothesis that people implicitly perceive the direction of another person's covert visual attention, possibly by processing that person's involuntary miniature eye movements (Engbert & Kliegl 2003 Vis Res) or subtle bodily cues associated with reorienting covert attention.

In our study, two participants ("Reader" and "Task Performer") sat opposite facing each other. Behind the Reader's head, an ultra-wide monitor was positioned in full view of the Task Performer. In each 10-s trial, the Task Performer fixated on a central point just above the Reader's head while performing a covert, high-load visuo-spatial sustained attention task (Zimmer & Macaluso 2007 J Neuroscience) presented to the left or right. The Reader's task was to look (freely) at the Task Performer's face and figure out the direction of his/her covert attention (left or right), by making a forced choice at the end of each trial and rating their confidence on a 4-point scale (1=very unsure, 4=very confident). Participants (n=34) performed 50 trials in total. Task Performers showed a high level of performance (mean hit/false alarm rates=81.5%/9%), confirming that they sustained their covert attention at the intended location throughout the trial. Eye movements were monitored using a dual eye tracker setup (two Tobii Spectrum Pro, 1200Hz). All trials in which the Task Performer deviated from fixation or performed a saccade (on average 8.8% of the trials) were excluded from analysis.

The results showed that Readers were able to determine the direction of Task Performers' covert attention significantly better than chance (mean accuracy=53.6%, SE=1.7%, p=0.002, permutation testing with 10,000 iterations), suggesting that people perceive the attention of others even in the absence of overt gaze cues. This finding is compatible with previous work suggesting that reconstructing others' attention is a rich, partly implicit process that is about far more than noting where someone's eyes are pointing (Pesquita et al 2019 PNAS; Guterstam & Graziano 2020 Prog Neurobiol; Ziman et al 2023 PNAS). Although most Readers spontaneously reported they based their decisions on 'gut feeling', their performance scaled with increased confidence ratings (mean accuracy per confidence rating=51.4%, 53.9%, 55.1%, 59.1%), suggesting that the perception of another's covert attention involves at least some explicit component. Interestingly, Readers were quite good at rating their own performance in a post-experiment questionnaire (mean perceived performance=53.7%), while the Task Performers significantly overrated the Readers' performance (59.8%, p=0.022). These findings suggest that monitoring attention goes far beyond simply registering another's gaze direction. It involves predictive modeling based on subtle cues (to be further explored), which may contribute to humans' extraordinary social ability to predict the mental states and behavior of others.

The neurophenomenology of ketamine: a multimodal approach for a multifaced compound.

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Concurrent Session: Emotion, Friday July 5th, Conference Room, Ito International Research Center, 2:00PM-4:00PM

Ketamine, a compound known for its versatility in various applications including anesthesia, treatment for depression, misuse, and exploration of consciousness, remains enigmatic with regard to its mechanisms, particularly concerning its neurophenomenological effects and antidepressant properties in humans. This abstract presents two separate original research studies utilizing multimodal neuroimaging to investigate the acute and sub-acute effects of a single psychedelic-like dose of ketamine. In the first study, we examined the acute neurophenomenology of ketamine in patients with bipolar disorder undergoing ketamine therapy for treatment-resistant depression in a real-world hospital setting. Ketamine administration led to specific changes in EEG rhythmic activity, characterized by a decrease in low-frequency oscillations and an increase in high-frequency oscillations, consistent with existing literature. These changes were positively correlated with experiences of dissociation, particularly derealization. Additionally, ketamine altered the arrhythmic features of the EEG, increasing neural signal entropy as quantified by Lempel–Ziv Complexity (LZc). Using the novel estimator Complexity via State-space Entropy Rate (CSER) to isolate the contribution of each frequency to the changes in signal entropy, we found that ketamine increased complexity within the gamma frequency range while decreasing it in the alpha frequency range. Furthermore, ketamine resulted in a reduction of the power-law exponent (PLE), indicating a flattening of the fractal component of the power spectra. Notably, patients who exhibited a clinical response within one week of treatment showed less pronounced changes in EEG arrhythmic components (i.e., LZc, CSER, and PLE) compared to late responders. These findings hold significant implications for the evidence-based monitoring and evaluation of novel psychoactive antidepressants, like ketamine and classic psychedelics, as they diffuse into medical practice and are implemented in real-world clinical settings. In a separate study, we investigated the sub-acute neuroplastic changes induced by ketamine in healthy participants using PET and fMRI within 1 to 8 days post-administration. We did not observe a significant modulation of synaptic density, as assessed by the novel PET tracer [11C]-UCBJ following ketamine exposure. However, a trend towards an increase was noted, which correlated positively with acute experiences of dissociation and long-term improvements in mood and well-being. Collectively, our findings highlight the impact of individual and endophenotypic differences, including brain structural and functional architecture, on the dynamics of neural responses to psychoactive drugs such as ketamine, adding an additional layer to the extra-pharmacological factors of ‘set’ and ‘setting’.

Tell me what you feel: The use of altered states as discriminative stimuli may indicate conscious awareness in animals

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Concurrent Session: Emotion, Friday July 5th, Conference Room, Ito International Research Center, 2:00PM-4:00PM

Discriminative stimuli', DSs, are stimuli that predict the appropriateness of a learned action (or operant). To illustrate, for human drivers, traffic lights are DSs predicting whether or not braking is an appropriate action; while for toddlers undergoing 'potty training', bladder distension becomes an internal DS that now guides their choices of action. And laboratory animals trained in operant tasks (e.g. lever-pressing) can learn to use diverse internal and external stimuli as DSs. Since the 1950s, psychologists interested in Learning Theory, and behavioural pharmacologists interested in addiction, have thus trained thousands of animals to use altered states as DSs, with a particular focus on drug effects. For example, rats can be trained to turn right or left in a T-maze for food, depending on whether recently injected with ethanol or saline (their state of alcohol inebriation being the DS); and pigeons can be trained that which of three discs will yield food when pecked, depends on whether they were recently injected with saline, a stimulant, or an opiate. Since the 1970s, behavioural pharmacologists have treated such results as indicating animals' subjective experiences: the feelings that psychoactive compounds induce in them. However, today's consciousness researchers seem not to have connected with this intriguing (sometimes disturbing) body of work. We therefore review four key strands of evidence that when animals use altered states as DSs, this indicates the conscious awareness of those states. 1) Humans can only confidently use drugs as DSs if these drugs have subjectively felt effects (as evaluated from self-reported feelings of e.g. dizziness or euphoria); and animals can typically only use these same drugs as DSs. 2) Humans' abilities to use drugs as DSs are affected by relevant pre-existing subjective states; e.g. fatigue enhances abilities to use low doses of amphetamine as DSs (since these are otherwise hard to distinguish from saline). Animals seemingly behave similarly. Thus rats can more readily use aspirin as a DS if they have painful arthritis; and both humans and rats more readily use naloxone ('Narcan') as a DS if first pre-dosed with opiates. 3) Humans trained to use one drug as a DS, can then 'generalise' to others that subjectively feel similar (even if molecular structures diverge); and animals' generalisation responses are similar. For example, pigeons trained to peck one key when dosed with amphetamine, will peck it if given another stimulant even if chemically dissimilar (e.g. caffeine). 4) Animals generalize from drug DSs to non-drug-induced experiences with intuitively similar subjective effects. Thus rats trained to use the seemingly anxiety-inducing drug 'PTZ' as a DS, then pick the PTZ lever if electrically shocked: consistent with the DS being feelings of fear. Overall, such results seem hard to explain without conscious awareness. However, the belief that subjective experiences are essential for this learned behaviour needs testing more rigorously, to rule out unconscious processes. We will discuss the research required to test this hypothesis robustly, in the hope that using altered states as DSs ultimately proves useful for identifying conscious awareness (e.g. sentience) in animals.

Exploring the Role of Valence in Conscious Perception: Insights from Similarity Judgments and Deep Learning Models

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Concurrent Session: Emotion, Friday July 5th, Conference Room, Ito International Research Center, 2:00PM-4:00PM

Recent theories claim that valence plays an important role in conscious perception. Barrett & Bar (2009) argued that affective information helps process and understand visual scenes quicker in normal vision. Therefore, they say, affective evaluation is not a separate stage in visual processing but an integral part of it. In the same vein, Cleeremans and Tallon-Baudry (2022) argued that all this affective evaluation in visual perception is what makes the perception conscious and what makes consciousness functional. The function of consciousness, in their view, is to attach value to conscious experience. This way, conscious perception can be subjective, motivating, aesthetic, and uniquely phenomenal. Inspired by these theories, we explored the phenomenal space focusing on the role of valence. We tested how valence judgments are related to similarity judgments and whether they correlate with different stages of processing in deep neural networks (DNNs). In other words, we studied the relationship between subjective distances between objects in the phenomenal space, the objective perceptual distances between the same objects, and their valences. More specifically, we focused on micro-valence (Lebrecht et al., 2012), i.e. valence of presumably neutral everyday objects such as teapots, chairs, etc. If we can show that micro-valences, affect behavior, it will support Cleeremans & Tallon-Baudry's claim according to which all perception is valenced and that this perceptual valence is functionally significant. Forty-seven participants provided similarity judgments for 120 images of everyday objects (10 semantic categories) using the odd-one-out task (Hebart et al., 2020). Using the birthday task (Lebrecht, 2012), we also collected their affective judgments about the same objects. Both similarity and birthday tasks were administered on the base-category and subordinate levels, i.e. participants selected between 3 objects from different semantic categories or the same semantic category respectively. For the same 120 images, we extracted activations from different layers of DNNs trained to classify objects. Leveraging representation similarity analysis, we first compared perceptual and affective dissimilarities between stimuli. We found that affective processing was correlated with similarity processing, indicating that valence contributes to similarity judgments, especially when making judgments in the case of subordinate, i.e. same category, triplets. This result was confirmed by multidimensional scaling analyses that highlighted the role of valence in the similarity space. DNN analysis showed that perceptual features of the stimuli contributed to both valence and similarity processing. Most importantly, valence processing correlated with activations in the first DNN layers, indicating that low-level visual features take part in the computation of valence in everyday object perception. These results indicate that valence computation may be present already in early visual processing. They also show that valence is involved in similarity judgments, suggesting a link between affective experience and cognitive tasks, corroborating recent claims for the functional role of affective conscious experience (Cleeremans & Tallon-Baudry, 2022).

Threat from faces and bodies differentially modulates awareness in prominent near and far neglect patients

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Concurrent Session: Emotion, Friday July 5th, Conference Room, Ito International Research Center, 2:00PM-4:00PM

Introduction: The interplay between the recognition of fearful expressions and spatial context is pivotal for survival, influencing both physical and social behaviors. A bidirectional influence between emotion perception and spatial cognition has been reported in literature, as not only distance modulates emotion perception, but the emotional value modifies spatial representation as well. This study explores the role of threat proximity in modulating awareness through emotional encoding from different stimulus categories, a topic that has received limited attention in human research. Previous studies have predominantly focused on the prioritization of fearful expressions in attentional selection among patients with neglect, aiming to overcome attentional deficits. Our research goes further investigating how facial and bodily expressions of fear, differentiated by proximity to the observer, affect spatial representations and attentional processes in patients with near (peripersonal) of far (extrapersonal) hemispatial neglect.
Method: We recruited 26 subjects with hemispatial neglect (Behavioral Inattention Test < 126). A clinical evaluation through line bisection and star cancellation tasks at 60 cm (near) and 150 cm (far) distances was conducted to determine a composite score indexing the neglect's spatial prominence. The experimental phase involved line bisection and visual search tasks using emotional cues, assessing the efficacy of fearful faces and bodies in reducing neglect symptoms across different spatial contexts. Through a parcellated and a continuous multivariate lesion symptom mapping both in gray and white matter, we explored differences between the two groups (near vs far) and correlation between brain lesions and behavior.
Results: The composite score categorization resulted in 18 with a predominant Neglect for Near space and 9 for Far space. Findings from a Mixed ANOVA indicate that fearful faces significantly reduce bisection bias in the Near Group at peripersonal distances, while bodies are more effective in the Far Group at extrapersonal distances (distance*stimulus*group interaction $p = .047$). Similarly, detection of fearful targets in the visual search task was enhanced for faces at peripersonal distances in the Near Group, and for bodies at extrapersonal distances in the Far Group (distance*stimulus*group interaction $p = .026$). We identified key brain regions, including the fusiform gyrus and ventromedial areas, as crucial for distinguishing between near and far neglect.
Conclusion: Our study demonstrates that both faces and bodies effectively convey fear and attract attention, potentially compensating for spatial awareness deficits in left space neglect. Faces, however, are particularly impactful at close range, while bodies gain prominence at greater distances. Moreover, lesion symptom mapping allowed us to understand which areas are underline the near/far clinical dissociation. These findings contribute to underscore the malleability of space representation and the complex interplay with emotions and biological categories.

Decoding approach-avoidance state from endogenous activity in emotion-processing brain regions

Taiki Oka (Advanced Telecommunications Research Institute International), Akihiro Sasaki (KDDI Research, Inc.), Nao Kobayashi (KDDI Research, Inc.), Aurelio Cortese (Advanced Telecommunications Research Institute International)

Concurrent Session: Emotion, Friday July 5th, Conference Room, Ito International Research Center, 2:00PM-4:00PM

Adjusting the balance between unconscious approach and avoidance behaviors is crucial when responding to external emotional events in ambiguous situations. Imbalances in such approach-avoidance behaviors, often observed in psychiatric patients, are essential factors in the development of disorders like social anxiety disorder (SAD). However, recent findings suggest that approach and avoidance tendencies are not static but dynamic, fluctuating from moment to moment based on endogenous neural activity. Despite its clinical importance, the neural bases of temporal dynamics of approach-avoidance behaviors are not well investigated. Here, we attempted to clarify which brain regions are essential for temporal approach-avoidance states in SAD using a cognitive task that measures implicit approach-avoidance behaviours. We used an Approach-Avoidance Task (AAT) to assess participants' approach-avoidance behaviours based on reaction times (RTs) while their brain activity was measured with fMRI. Participants pulled or pushed a joystick in response to the frame color of visual stimuli, which were either negative emotional (disgust) faces or standard neutral faces. We defined the approach-avoidance state as the differences between RTs of congruent/incongruent (pull/push in negative gaming stimuli) trials, and the baseline was defined as the average of each direction when responding to negative emotional stimuli. We then applied multivariate pattern analysis (MVPA) to decode the approach and avoidance state in a set of pre-defined regions of interest (ROI): the anterior prefrontal cortex (aPFC), dorsolateral prefrontal cortex (dlPFC), ventromedial prefrontal cortex (vmPFC), amygdala, hippocampus, and insula. Moreover, we also used two combined regions to examine the effect of the emotional-related areas: the vmPFC-amygdala region and the amygdala-insula region. We used fMRI signals immediately before the stimuli onset as endogenous brain activity for decoding. Although decoding accuracy was above chance in most ROIs, only the amygdala-insula showed a clear difference from a control result based on neutral conditions. Our multivariate decoding results thus suggest that brain regions related to emotion and interoception might be a crucial neural substrate of approach-avoidance states. The results are consistent with previous findings that insula and amygdala activity support emotion-guided attention in the preparatory epoch before responding to stimuli. Finally, we introduce a novel experimental investigation of a decoded neurofeedback paradigm targeting metacognition for the internal state of approach-avoidance balance. Metacognition of approach and avoidance has recently been highlighted as a core of self-regulation dysfunction related to emotional disorders. Decoded metacognitive training delivers computerized, personalized, real-time feedback regarding individual states calculated in a data-driven manner based on real-time brain states using online MVPA based on the above amygdala-insula combined region. This method could be applied to elucidate and train metacognitive dysfunctions in clinical populations.

Beyond Sight: Probing the Neural Signature of Affective Blindsight with MEG

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Concurrent Session: Emotion, Friday July 5th, Conference Room, Ito International Research Center, 2:00PM-4:00PM

Background This study investigates the unique case of patient SJ who exhibited blindsight for emotional information following the complete resection of their right V1. Affective blindsight, traditionally defined in the context of emotional faces, here extends to complex affective scenes, challenging the idea that high-level processing requires conscious visual perception. Here, we used magnetoencephalography (MEG), machine learning (ML), linear regression and mediation analyses, to probe the intricate neural mechanisms that mediate affective blindsight. Methods We measured performance and reaction times (RTs) to a three-forced choice discrimination task involving affective complex scenes. Correct and incorrect responses were determined based on the International Affective Picture System classification. Data cleaning and preprocessing was followed by independent component analysis and source reconstruction (on both cortical and subcortical regions). Neural activity was computed for the intact (seen) and blind hemifield (unseen) across four distinct time windows from 0 to 800 ms and various brain regions, from the thalamus to the frontal medial lobe, extracting three types of features: evoked activity, power across multiple canonical frequency bands, and effective connectivity (granger causality: GC). In terms of data analytics, we used a Random Forest ML algorithm to classify stimuli based on visibility (seen vs unseen), spatial positioning (central vs periphery), accuracy (correct vs incorrect), and emotional valence (unpleasant vs pleasant vs neutral). In addition, we examined the feasibility of predicting RTs through linear regression and mediation models. Results With above chance level performance in their blind hemifield and RTs that varied similarly for seen and unseen pictures across affective conditions, our study suggests that patient SJ can process higher-order complex features without visual awareness. We observed differential latencies in evoked responses and changes in beta and gamma power suggesting that cognitive resources were differentially recruited for seen and unseen affective stimuli. Our supervised machine learning framework led to several interesting results: (1) The early time window (50-150ms) appeared as crucial for the initial differentiation of seen and unseen stimuli, while subsequent windows, particularly 350-800ms, were predominant for processing unseen stimuli. (2) The intact hemisphere was the dominant important feature compared to the lesioned hemisphere, underscoring the compensatory role of the intact hemisphere after a V1-lesion. Nonetheless, the right hemisphere was also important for unseen stimuli classification. (3) The thalamus was significantly implicated in seen-unseen classification, highlighting its role in sensory processing. The amygdala and superior temporal sulcus, showed varied involvement, with the intact V1 region notably recruited for unseen stimuli processing. (4) Beta and low gamma bands played an influential role across all classifications, affirming their significance in visual information processing. The high gamma band and subcortical GC were particularly relevant for unseen stimuli, indicating their importance in unconscious processing. Moreover, using linear regression and mediation analyses we predicted SJ's RTs for both seen and unseen stimuli with significant precision from the top features. Conclusion This case study provides novel insights using MEG into the role of alternate neural pathways, (incl. thalamus, amygdala, and extrastriate areas) in unconscious perception, and affective blindsight in particular.

Poster Presentations

Exploring the Depths of Spiritual Psychedelic Consciousness with Machine Learning

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Poster Session 1, Wednesday July 3rd, Ito International Research Center, 10:00AM-11:00AM

Mystical experiences (MEs) are key in consciousness research for their insights into altered perceptions of time, space, and self. Despite their importance, the nebulous nature of MEs and the lack of a standardized definition and robust measurement tools have hindered scientific study. Our research utilizes Artificial Intelligence and Machine Learning to analyze personal accounts of MEs from Reddit, specifically those induced by the psychedelic drug N,N-Dimethyltryptamine (DMT). We aimed to quantitatively explore the varied phenomenologies of DMT-induced MEs to identify and synthesize common themes, examining the impact of MEs on wellbeing. We hypothesized that individuals experiencing MEs during DMT use would show greater increases in positive emotional language post-use. We gathered 447,736 'trip reports' of first-hand experiences with psychedelics from Reddit. To filter through this large dataset and exclude unwanted entries (e.g. multidrug reports, no evidence of DMT consumption), we trained a machine learning model to classify each trip report on our set of inclusion/exclusion criteria. Specifically, we fine-tuned the Open AI GPT-3.5-turbo model on 300 manually classified DMT trips. The fine-tuned model achieved over 70% congruence with manual assessments, evidencing its reliability. This AI-generated classification helped us filter down the dataset to a final 2,299 DMT trip reports. To analyze mystical intensity, we applied the BART (Bidirectional and Auto-Regressive Transformer) Large MNLI (Multi-Genre Natural Language Inference) zero-shot classification, using "mysticality" as the class label. A Latent Dirichlet Allocation (LDA) then allowed the identification of common recurring themes in ME reports. To examine language changes over time, we gathered the Reddit posts and comments history from the authors of the DMT reports, identifying 410 relevant posts/comments made two weeks before or after their DMT experience. Using the 2D sentiment model (Dougherty & Clarke, 2022), we calculated sentiment scores for each entry. These scores were analyzed using mixed-effects models and t-tests to compare the ME and non-ME groups. The LDA analysis revealed three distinct recurring themes in DMT-induced ME narratives: Mystical Transcendence (33.5%), Aesthetic Perception (40.2%), and Relational Interpersonal (26.2%). Our analysis of group effects (ME vs. non-ME) on the evolution of sentiment scores revealed that the ME group was associated with a greater increase in emotional valence compared to the non-ME group ($p=0.000182$, $t=3.835$). No group-related significant effect was found for arousal ($p=0.750$, $t=-0.319$). This automated bottom-up methodology for the study of MEs significantly enhanced our understanding of their nuanced phenomenologies. It illustrates how the use of transformer-based language models can overcome typical research challenges in complex aspects of human consciousness. It highlights the potential of MEs to foster significant well-being shifts, underscoring how consciousness interacts with mental health. Our results support the view that the more radical the shift in consciousness, the stronger the improvements in well-being. Finally, the detection of specific altered states through language provides evidence for the relationship between language and consciousness. ----- Dougherty, R. F., Clarke, P., Atli, M., et al. (2023). Psilocybin therapy for treatment- resistant depression: Prediction of clinical outcome by natural language processing. Psychopharmacology. https://doi.org/10.1007/s00213-023-06432-5

Phenomenological Control Modulates Emotion Induction and Regulation in Health and Depression

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Poster Session 1, Wednesday July 3rd, Ito International Research Center, 10:00AM-11:00AM

Emotional dysregulation is usually investigated with standardised stimulus galleries consisting of static images. Negative images depict scenes of violence, disaster and injury. Positive images depict cute animals, babies, flowers and images of nature. Static images are most commonly used to analyse event-related potentials (ERP) in the electroencephalogram. In clinical settings, neuroimaging is often used in combination with such images for a more accurate diagnosis of dysconnectivity in disorders such as treatment-resistant depression. However, in our laboratory we have not been able to replicate many standard neuromarkers of emotion induction and regulation typically observed with standardised emotional stimuli (e.g. late positive potential; LPP). We conducted two studies to investigate this discrepancy. In the first study, we collected qualitative phenomenological data on the lived experience of standard emotion induction and regulation tasks. Participants reported that the pictures did not elicit a genuine emotional response. Rather, they had to upregulate their emotions during emotion induction in order to experience a reaction. During emotion regulation, however, they simply did nothing. This finding led us to hypothesise that the response to emotional stimuli is mediated by phenomenological control (i.e., a person's sensitivity to suggestions). In the second study, we recorded participants' electroencephalogram while they performed an emotion induction and emotion regulation tasks. The participants' level of phenomenological control was assessed using the Phenomenological Control Scale. We find that the level of emotional arousal correlates significantly with phenomenological control, especially when it comes to negatively valenced stimuli. We also observed statistically significant differences in LPP between the emotion induction and emotion regulation conditions. In particular, we observed activity associated with upregulation (i.e., higher mean amplitude in the ERP signal) in the emotion induction condition. Interestingly, these effects are attenuated in the patient group. Taken together, these findings suggest that standardised emotion induction and emotion regulation paradigms produce valid measurements only in highly specialized populations (e.g., patients with mood disorders, highly suggestible individuals). We discuss potential reasons for this relationship, such as the changing attitude towards image and media in the recent decades, as well as implications for research and clinical assessment in psychopathology of mood disorders.

Oscillating Bodily-self consciousness

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Poster Session 1, Wednesday July 3rd, Ito International Research Center, 10:00AM-11:00AM

Although bodily-self consciousness (i.e., the feeling that our body parts belong to us; Gallagher et al. 2000) is deeply rooted in our psyche, it can be challenged by multisensory illusions. For instance, during the Rubber Hand Illusion (RHI; Botvinik & Cohen, 1998), the synchronous stroking of a rubber visible hand and the real hidden one induces participants to feel touches at the sight location. Since our body is the only object in the world on whose surface we feel and concomitantly see touch, the RHI causes participants to believe that the fake hand is their own. A previous behavioral study suggested that such modulation of bodily-self consciousness relies on a sensory re-weighting mechanism. In particular, the brain decreases responses to somatosensory stimuli occurring on the real own hand and concurrently increases those to visual stimuli on the rubber hand (Rossi Sebastiano et a., 2021). Here, we addressed the neural mechanism underpinning this effect through electroencephalography. In Experiment 1, we recorded event-related potentials evoked by somatosensory stimuli delivered on the real hand (SEPs) and visual stimuli occurring on the rubber hand (VEPs), immediately after the RHI procedure in two conditions: synchronous (i.e., illusion-present condition) and asynchronous (i.e., control illusion-absent condition). We found a diametrical modulation of late-latency components with significantly decreased SEPs and increased VEPs in the illusion as compared to the control condition. While the central topography of the SEP effect is in line with the somatosensory nature of the stimulus, the central topography of the VEP effect deserves further investigation. We speculated that, once the rubber hand is embodied and touch is felt on it, the simple delivery of visual stimuli could trigger responses in channels that normally reflect somatosensory processing. In Experiment 2, we sought to investigate a possible mechanism explaining how the somatosensory system may start to respond to visual stimuli. Among brain oscillations, alpha-band rhythms (8-12 Hz) have been described as the natural frequency of the visual cortex, while beta-band ones (13-20 Hz) have been characterized as the natural frequency of the somatosensory cortex (Rosanova et al., 2009). Against this background, we anticipated that, during the RHI, the visual dominance over somatosensory input would result from a neural tuning of the somatosensory cortex on typically visual alpha-band oscillations. To address this issue, we analyzed absolute alpha-band power during synchronous (i.e., illusion-present condition) and asynchronous (i.e., control illusion-absent condition) RHI. Interestingly, we found increased power during the illusion as compared to the control condition over frontocentral channels, while no difference was found over occipital ones. We speculate that somatosensory regions, by adapting their activity to a visual-like frequency, could start to respond to visual stimuli, causing the feeling of touch at the sight location. Taken together, these results point out the malleability of bodily-self consciousness and reveal a possible mechanism underpinning the plasticity of such a representation.

To press or not to press: the outcome of movement decisions are more predictable when decisions are made in advance

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Poster Session 1, Wednesday July 3rd, Ito International Research Center, 10:00AM-11:00AM

Is pre-movement neural activity related to a pre-conscious commitment to move, or does it simply reflect a nonspecific readiness to move? The goal of this study is to investigate whether the outcome of a motor decision (whether or not to press a button) can be decoded when decisions are made spontaneously, compared to when decisions are made in advance. In a previous experiment we found that early EEG activity was not predictive of spontaneous decisions regarding which hand to use to press a button. By contrast, in this study we focused on the difference between action and non-action, which might yield a stronger neural signal. Hence, in the current paradigm, we tested decisions where the participant had to decide whether or not to press a button, at a pre-ordained time. The experiment had three conditions: an instructed condition, where the participant is told whether or not to press, an early decision condition, where the participant commits to a decision of their own at the start of the trial, and a spontaneous condition, where the participant must make their decision as close to the time of execution as possible. After recording EEG data from 17 participants doing this task, we used a machine learning classifier (CSP-LDA) to predict whether or not the participant moved in each trial. In the instructed and early decision condition, decoding accuracy rose above chance almost 1 second before movement. However, in the spontaneous decision condition, decoding accuracy remained at chance until the time of decision execution. Our results suggest that the brain activity present before a spontaneous motor act does not reflect a pre-conscious decision to initiate movement, but rather a general state of readiness to move.

Communicative context enhances emotional word processing with human speakers but not with robots

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Poster Session 1, Wednesday July 3rd, Ito International Research Center, 10:00AM-11:00AM

Emotional word processing is shaped by factors beyond mere linguistic input. Building on prior research, the present work focused on investigating the interplay of two relevant influences: communicative intent and agent type. In two behavioral studies (N1 = 36, N2 = 72), participants were exposed to short videos featuring different agents (humans, androids, and humanoid robots with a less anthropomorphic appearance) alongside the auditory presentation of single words of varying valence (negative, neutral, positive). The communicative intent was varied: in the communicative condition, the agent directly spoke the word to the participant; in the non-communicative condition, the audio played while the agent remained passive (eyes closed, no mouth movements). After each video, participants rated the valence and arousal of the presented word. Through a counterbalanced design, the auditory information remained consistent across conditions, allowing us to isolate the effects of social factors on word evaluation. We expected that the communicative context, compared to the non-communicative context, would elevate arousal ratings for words, particularly emotional ones, when spoken by human speakers. We examined whether this effect extended to robot speakers and whether the degree of anthropomorphism in robot appearance (more versus less human-like) influenced the outcomes. In line with previous research, the results from both studies revealed a consistent pattern: for human speakers, emotional words were more emotionally arousing in the communicative condition than in the non-communicative one. This effect was absent in both robot conditions. The results demonstrate differences in emotional word processing based on agent type: a communicative context enhances emotional processing with human speakers but not with robot speakers. This discrepancy may indicate a relatively lower perceived relevance of direct emotional speech from robots, possibly related to an overall lower attribution of intentionality to robot agents compared to humans. In a broader view, the results illustrate how the integration of auditory, visual, and knowledge-based information shapes the experience of emotional speech.

Modulating the proportion of false perceptions in a face detection task

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Poster Session 1, Wednesday July 3rd, Ito International Research Center, 10:00AM-11:00AM

False perceptions (hallucinatory-like perceptual experiences) constitute an interesting framework to study the intricate mechanisms underlying perceptual experience. Assuming that perceptual experience depends on the accumulation of noisy sensory evidence over time reaching a threshold, false perceptions may occur when noise is accumulated up to a perceptual threshold even though no stimulus was presented. In two behavioral studies, we use this putative computational mechanism to derive experimental manipulations to generate false perceptions of faces The first study focused on one model parameter called leakage reflecting that accumulated evidence is driven back to zero in the absence of sensory evidence. Participants were presented with a stream of visual noise frames, some containing faces of different durations at an intensity corresponding to participants' detection threshold. To optimally detect these faces, participants should adjust their integration strategy according to the stimulus duration. We hypothesized that manipulating the proportion of long versus short faces would affect stimulus detectability, offering valuable insights into the impact of leakage on false perceptions. Specifically, we hypothesize that a higher proportion of long stimuli, leading to decreased leakage (and therefore increased integration times) will i) raise the proportion of trials for which a face was detected although none was presented (i.e. false alarms) and ii) lead to overall longer perceived durations. Preliminary results confirm both our hypotheses. In the second study, we investigate the influence of prior expectations on the starting point of evidence accumulation as an enabling factor for false perceptions. To this end, we used a similar face detection paradigm but we presented a cue preceding each trial that predicted the presence or absence of a stimulus with 80% validity. We anticipate that when cueing the presence of a face and not presenting one, prior expectations will increase the likelihood of false perceptions through a change in the baseline of accumulated evidence. By integrating experimental designs grounded in a leaky evidence accumulation process, our results advance our understanding of the mechanisms underpinning false perceptions. A better understanding of this mechanism could help in understanding hallucinations in clinical settings.

Large-Scale Database of Vividness Judgments for Natural Scenes: Insights into Visual Mental Imagery

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Poster Session 1, Wednesday July 3rd, Ito International Research Center, 10:00AM-11:00AM

Assessing the content of our minds is challenging. We still lack a comprehensive understanding of what makes an image easy to imagine. Prior investigations have mostly relied on limited samples or non-representative stimuli. Drawing inspiration from a previous experiment on memorability (Khosla et al., 2015), we aimed to create a large-scale database featuring over 219,000 vividness judgments associated with natural scenes to directly investigate the relationship between image characteristics and mental imagery. In each trial of the task, participants sequentially viewed two NSD images and were then randomly instructed to imagine one of the images (cued target image) for 4 s. Next, participants rated the level of vividness evoked by the image on a continuous scale from 0 to 100. The participants were then instructed to identify the target images from the two original images. Our preliminary results, based on 719 participants recruited through Prolific, revealed strong performance on the task, with an average accuracy rate of 95.83% correct target identification. Additionally, we found substantial variability in both interimage ($M = 0.65 \pm 0.25$) and interindividual ($M = 0.66 \pm 0.17$) average vividness scores. Along with our experimental task, the database also includes visual imagery ability assessments using the Vividness of Visual Imagery Questionnaire (Marks, 1973), allowing for comparisons between trial-by-trial self-reports and psychometric measures of vividness. Overall, this large-scale dataset of vividness ratings will provide invaluable insights into visual imagery and enable the development of predictive models of subjective imagery experiences.

The Heavy-Tailed Valence Hypothesis: Quantifying the human capacity for experiencing pleasure and pain

Chris Percy (University of Washington), Andrés Gómez-Emilsson (Qualia Research Institute, San Francisco, United States)

Poster Session 1, Wednesday July 3rd, Ito International Research Center, 10:00AM-11:00AM

Introduction: The "Heavy-Tailed Valence" (HTV) hypothesis holds that the accessible human capacity for pleasure and pain spans a minimum of two orders of magnitude. We develop a novel method for quantifying this capacity, present the results of a pilot survey, and interpret various stylized facts with respect to the hypothesis. The hypothesis runs counter to standard current approaches for analysing pleasure and pain from a wellbeing policy perspective. Standard techniques, such as ranking happiness on an integer scale from 0-10, implicitly assume that capacity for experience spans around a single order of magnitude, i.e. that our most intense experiences can only be at most ten times more intense than our mildest experiences.
Methods: We specify five testable predictions of the HTV hypothesis, as compared to a null hypothesis of a "constrained valence" psychology as assumed by existing techniques. A pilot survey of adults aged 21-64 (n = 97) then tested two predictions, asking respondents to comment on the most painful and most pleasurable experiences they can recall, alongside the second most painful and pleasurable experiences.
Results: The results find tentative, indirect support for the hypothesis. For instance, over half of respondents said that their most intense experiences were at least two times more intense than the second most intense. As such, it would only take six steps of the same magnitude between the most mild and the most extreme experiences to identify two orders of magnitude. Simulations also demonstrate that the reported data fit better to underlying heavy-tailed distributions of valenced experiences rather than narrow-tailed distributions.
Discussion: A synthesis of these results with the literature suggests a "kinked" scale, such that a wide range of felt experience is compressed in reports at the high end of intensity scales, even if reports at lower intensities behave more cardinally. We integrate the findings in the context of three stylized facts that support HTV (e.g. heavy tailed distributions in neurological function). We also present consistent interpretations in the context of six stylized facts seemingly against HTV (e.g. action potential phases; hedonic adjustment). The evidence so far remains indirect, but with enough room for error that HTV has some base credibility, sufficient to motivate more robust testing, especially as methodological choices were made in the survey analysis to disfavor the HTV.
Relevance: If HTV better reflects the psychology of most people, there are consequences for policy design and consciousness research. For policy design, we provide guidelines for checking the robustness of existing conclusions to HTV and urge greater ambition at the extremes of experience. Even in high average income countries, HTV suggests we remain far further below our wellbeing potential than a surface reading of the data might suggest. For consciousness research, the work points to methods for quantifying the extent of qualia space. The findings suggest that everyday intuitions may significantly underestimate our full capacity for experience, pointing to the need for deliberate, diverse, and quantitative phenomenological approaches to generate explananda for consciousness research.

Breathwork-Induced Psychedelic Experiences Modulate Neural Dynamics

Evan Lewis-Healey (University of Washington)

Poster Session 1, Wednesday July 3rd, Ito International Research Center, 10:00AM-11:00AM

Breathwork is a school of practices that entail voluntary modulations of respiration, such as depth and frequency, to induce an altered state of consciousness (ASC). Historically, experiences cultivated through breathwork have been compared to psychedelic experiences, with a recent study supporting this notion (Bahi et al., 2023). However, it is unclear whether the neural effects of breathwork are similar to psychedelics, and if these relate to the subjective experiences themselves. Within this study, we used a neurophenomenological approach by combining a quantitative phenomenological methodology that preserves the temporal dynamics of subjective experience (Temporal Experience Tracing), with low-density portable EEG devices for every session. Fourteen novice participants completed a series of up to 28 breathwork sessions - of 20, 40 or 60 minutes - in 28 days, yielding a neurophenomenological dataset of 301 breathwork sessions. Using both hypothesis-driven and data-driven approaches, we found that ‘psychedelic-like’ experiences that occurred within the breathwork sessions were associated with increased neural Lempel-Ziv complexity. Further exploratory analyses showed that the aperiodic exponent of the power spectral density (PSD) - but not oscillatory alpha power - was also associated with these psychedelic-like phenomenological substates. To conclude, we demonstrate the strength of this neurophenomenological framework, maximising the concurrent data acquisition of brain activity and phenomenological dynamics in multiple experiential dimensions. Non-linear aspects of brain dynamics, like complexity and the aperiodic exponent of the PSD, neurally map both a data-driven complex composite of positive experiences, and hypothesis-driven aspects of positive psychedelic-like experience states such as high bliss.

Investigating the Neural Correlates of Social Awareness

Finda DwiPutri (University of Washington)

Poster Session 1, Wednesday July 3rd, Ito International Research Center, 10:00AM-11:00AM

The embodied cognition theory implies that a mental phenomenon relies on the interaction dynamics involving the brain, whole body functions, as well as the environment – this includes social interaction between individuals. This dynamic interaction allows humans to have the ability to create shared experiences, i.e. the ability to be aware of others' emotional states or intentions and social cues and to create a shared experience with others as a result. This study proposed the utilization of the Perceptual Crossing (PC) paradigm as a method to explore dyadic social behaviour during a shared experience. PC enables perceptual interaction in a minimalist paradigm that is facilitated by a human-computer interface that employs a continuous sensorimotor feedback loop. PC has been previously applied to study the role of sensorimotor interaction in the social abilities of different populations, i.e. adults, adolescents, and adults with autism. Despite this potential, the information regarding the neural correlates during PC remains unexplored and the participants' subjective experience, such as social awareness level, is rarely reported. The current study performed EEG hyperscanning during PC experiment in pairs of participants while also measuring the behavioural pattern and subjective experience, including the perceptual awareness scores. The goals of this study are to identify distinct brain signatures that occur during PC and to eventually correlate those signatures with behavioural measures. Moreover, it was previously reported in a past PC study, that mutual recognition predicts participants' subjective reports of clearer social awareness, which the current study successfully replicated. It is expected that this study will contribute to providing new insights into the field of embodied cognition, specifically its relation to human social awareness.

Expectations about precision in the human brain

Helen Olawole-Scott (University of Washington), Sam Gilbert (Institute of Cognitive Neuroscience, University College of London), Daniel Yon (Goldsmiths, University of London; Birkbeck, University of London)

Poster Session 1, Wednesday July 3rd, Ito International Research Center, 10:00AM-11:00AM

Our previous work has found that expectations about precision alter metacognition and perceptual awareness – with participants feeling more confident and stimuli appearing more vivid when strong sensory signals are expected, without concomitant changes in perceptual performance (Olawole-Scott & Yon, 2023). These results support an influential but untested tenant of Bayesian models of cognition: suggesting that agents do not only 'read out' the reliability of information arriving at their senses, but also take into account prior knowledge about how reliable or 'precise' different sources of information are likely to be. In this project, we extended this work – investigating how expectations about precision alter representations of evidence reliability in the human brain. The study itself spanned two days. On the first day, outside the scanner, participants were familiarised with the task: rating the clarity of moving dot clouds that could be either clear or ambiguous. Crucially, probabilistic cues allowed observers to form expectations about the strength of motions signals on each trial. Seventy-five percent of trials were 'expected' trials, (e.g., expect clear motion, perceive clear motion) and 25% were 'unexpected' trials (e.g., expect clear motion, perceive ambiguous motion). On the second day, participants completed the same task while we recorded their brain activity with 3T MRI. We used a whole brain searchlight decoding approach to identify regions that distinguish 'clear' from 'ambiguous' sensory signals, revealing candidate sites that could act as neural representations of perceptual precision. We then asked how the quality of these representations is changed by expectations. These results reveal sites across the neural processing hierarchy that encode the precision and clarity of the sensory world, and pinpoint where and how these representations are changed by expectations about precision.

Evaluation in early visual processing – evidence from deep neural networks

Ivan Ivanchei (University of Washington), Inès Mentec (Université libre de Bruxelles), Axel Cleeremans (Université libre de Bruxelles)

Poster Session 1, Wednesday July 3rd, Ito International Research Center, 10:00AM-11:00AM

Recent theories suggested that evaluation can be central to conscious perception (e.g. Barrett & Bar, 2009). The most radical suggestion is that all consciously perceived objects are colored by valence (Cleeremans & Tallon-Baudry, 2022). The question arises whether evaluation is an integral part of perception or a post-perceptual process. To answer this question, we studied how people perceive pictures of everyday objects considered emotionally neutral, e.g. teapots, watches, etc. Participants were presented with triplets of objects and selected one item from each triplet to keep it as a birthday present. Using these data, we created representation dissimilarity matrices (RDMs) containing distances in valence between objects. Using deep neural networks trained to categorize objects, we created another set of RDMs containing distances between activations in neural networks when presented with the same stimuli. We then correlated these valence and neural-network RDMs. We examined various layers of the neural networks to identify when differences in activations start predicting valence variances. These layers presumably correspond to levels of visual processing in the brain (Kriegeskorte, 2015). Previously (Mentec, Ivanchei & Cleeremans, in preparation), we found that some differences in valence were predicted by differences in the first neural-network layer. Given that it represents very basic perceptual features (e.g. bars, contrasts), we concluded that evaluation could happen very early in visual processing. In the present study, we replicated and extended this finding, exploring this effect in different conditions. In Experiment 1 (N = 46), we replicated our previous study and obtained the same result: differences in activations on the first neural-network layer predicted differences in valence. Interestingly, other early convolutional layers did not predict it. Only late convolutional and the last, fully connected (i.e. semantic), layers predicted differences in valence. In Experiment 2 (N= 46), we presented stimuli for shorter durations (800 ms instead of 2000 ms), to check whether participants would rely even more on the early visual features. This prediction was not confirmed: participants responded more randomly, probably disengaging from the task due to strict presentation conditions. In Experiment 3 (N = 45), participants were instructed to make their preference judgments based on the objects' utility. We expected that participants would rely only on higher-order features in this condition. This hypothesis was confirmed – early-layer activations did not predict differences in valence anymore. In Experiment 4 (N = 46), participants were instructed to make their preference judgments based on the aesthetics of the perceived objects. In this condition, participants again demonstrated the influence of the early visual features. Collectively, these experiments show that differences in the evaluation of objects can be predicted by the differences in low-level perceptual features detected very early in visual processing. This suggests that evaluation can happen in parallel with object perception. Our study is one of the first to show links between neural-network activations and the evaluation of emotionally neutral objects. Because of that, we can generalize our findings, supporting the claim that all conscious perception is valenced.

Reverse Engineering Agentive Control in Biological Neural Systems

Jingyue Xu (University of Washington)

Poster Session 1, Wednesday July 3rd, Ito International Research Center, 10:00AM-11:00AM

Sensorimotor enactivism posits that perceptual experience is constituted by the dynamic coupling of the sensorimotor system and its environment, which comprises the system's actions on the environment. When an agent is confronted with the Selection Problem of actions, implementing agentive control is the process of finding a solution to this problem. How do our brains endogenously generate voluntary action control over our bodies and mental faculties? This presentation brings forth a new theoretical perspective, interfacing neuroscience, control theory, and philosophy of mind, by taking a system-level approach to modeling the brain's control of its internal processes. In a feedback control system, a controller is implemented to define a closed-loop map and subsequently a solution given its current state. The enactive brain can be similarly viewed as an online control system operating with a "pre-defined" controller design that at least yields local stability and robustness (namely, the agentive state does not dissolve in an arbitrarily near future). Therefore, to characterize the source of agentive control is to reverse engineer the internal controller design, which does not necessarily have a physical mapping, in the brain. To do this, I will deploy a data-driven version of System Level Synthesis (SLS), which is a novel system-level parameterization of linear systems in control theory. SLS is compatible with systems that are large-scale, localized, and endowed with internal communication delays, all of which are problems that theoretical neuroscientists are constantly faced with. Data-driven SLS offers a unique approach to learning the controller in the brain using physiological data as state/input signals without requiring an explicit identification of the system model of the brain. Given the near-ubiquitous layered architecture of the brain across the animal kingdom, one can approximate the source and structure of agency in various networks/ sub-systems of neurons by appropriately constraining the agentive state of the subject, and thereafter characterize the performance of the brain controller in terms of its closed-loop behavior.

Unveiling the Hidden Guide: Perceptual and Semantic Fluency Enhance Intuitive Judgments of Coherence in RAT Items

Joanna Sweklej (University of Washington), Robert Balas (Institute of Psychology Polish Academy of Sciences)

Poster Session 1, Wednesday July 3rd, Ito International Research Center, 10:00AM-11:00AM

Extensive research on RAT items (three words with a common associate) demonstrates participants' ability to accurately detect their semantic coherence without knowing the solutions. Building on this, we conducted three studies (Ns = 123, 154, and 100, respectively) to investigate how perceptual and semantic fluency influence intuitive coherence judgments. Studies 1 and 2: These studies manipulated fluency through priming. Study 1 employed semantic priming: participants were exposed to words related to the solution before encountering the RAT item. Study 2 used perceptual priming, presenting words with similar or dissimilar fonts to the RAT words. In both studies, participants judged the coherence of RAT items with solutions varying in affective valence (positive, neutral, negative), evaluated their certainty, proposed solutions, and rated their confidence. Study 3: This study focused on detecting incoherence. Participants encountered RAT items with an added, unrelated word and underwent semantic priming. They were tasked with identifying the non-fitting word, judging their certainty, proposing solutions, and rating their confidence. Results: All three studies revealed that both perceptual and semantic priming significantly increased the accuracy of coherence judgments. In Studies 1 and 2, this effect interacted with solution valence: increased fluency amplified the influence of positive solutions and mitigated the effects of negative ones. Study 3 showed similar fluency-driven enhancements in detecting incoherence. Discussion: These findings suggest that fluency plays a crucial role in intuitive judgments of semantic coherence. Processing fluency leads to a positive affective response that biases judgments towards coherence, especially if the solution evokes positive emotions. Conversely, disfluent processing generates negative affect, potentially hindering coherence judgments, particularly with negative solutions. This mechanism extends beyond explicit solutions knowledge, as evidenced in Study 3. Implications: Our research confirms a link between fluency, affect, and intuitive judgments. This has broader implications for understanding how low-level processing influences higher-order cognitive functions, potentially impacting areas like social perception and decision-making. Future research could explore the neural mechanisms underlying these effects and investigate their influence in real-world contexts.

Unraveling the Representational Geometry of Unconscious and Conscious Colors with Metacontrast Masking

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Poster Session 2, Wednesday July 3rd, Ito International Research Center, 4:00PM-5:00PM

Previous investigations on the Neural Correlates of Consciousness (NCC) have predominantly relied on the application of the contrastive method, which involves subtracting brain activity in conscious versus unconscious perception. However, its ‘all or none’ nature has fallen short in capturing the intricacies of phenomenology and reconciling conflicting experimental results. On the other hand, the structuralist approach directly tackles phenomenology and constrains the range of putative NCC by proposing a correspondence between the representational geometry, or structure (collection of relationships), of percepts and brain activity. Recent advances have been made in constructing structures across perceptual modalities and relating them to neural activity. However, a systematic evaluation of the putative differences between conscious and unconscious structures, possibly useful for further constraining the NCC, has yet to be undertaken. The aim of this study is to validate metacontrast masking as a surrogate for similarity ratings and determine if the resulting color spaces vary with the level of awareness. The interstimulus interval (ISI) between prime and mask is varied to render the prime conscious and unconscious, while reaction times for identifying the colored mask serve as the parameter for structure building. We evaluate the fit of the generated structures under different conditions to established color maps, such as the opponent color and CIE color spaces, which are supposed to represent activity patterns in different levels of the visual hierarchy. Preliminary pilot results indicate that the conscious color structure obtained through metacontrast masking resembles the structure derived from subjective similarity judgments. Conversely, the unconscious color structure assessed via metacontrast masking appears to be less aligned with the hue circle, potentially reflecting color spaces associated with activity patterns encountered in lower stages in the visual system. These findings underscore the potency of the structuralist approach as a robust predictor for a gamut of behavioral, psychophysical, and neural phenomena. Furthermore, they carry implications for elucidating the mechanism of metacontrast masking in the visual cortex and further refining the neural correlates of color consciousness. Finally, we establish a psychophysical method for contrasting structures across the spectrum of conscious and unconscious perceptual states, which possibly map to processing stages across the visual hierarchy.

Deep Meditation Induction by Focused Ultrasound Neuromodulation and the Modulatory Effects of Prior-Experience

Joshua A.Cain (University of Washington), Sasha Bystritsky (Institute for Advanced Consciousness Studies (IACS)), Ninette Simonian (Institute for Advanced Consciousness Studies (IACS)), Tracy Brandmeyer (Institute for Advanced Consciousness Studies (IACS)), Mathew Sacchet (Harvard University), Nicco Reggente (Institute for Advanced Consciousness Studies (IACS))

Poster Session 1, Wednesday July 3rd, Ito International Research Center, 10:00AM-11:00AM

Rigorous empirical studies are increasingly demonstrating the benefits of meditation—both psychological and physical—for health and well-being. Concurrently, cognitive neuroscience is providing an ever-clearer, albeit incomplete, understanding of the functional architecture underlying the altered state(s) induced by meditation. These developments 1) Compel superior methods for assisting the attainment of meditative states (i.e., "meditative aids"), and 2) Enable methods that promote the brain states underlying them. Aspiring practitioners experience considerable difficulty maintaining the consistent, years-long practice (i.e., "meditative development") required to fully realize meditation's benefits, even while using extant aids (e.g., mobile applications, neurofeedback)—a greater struggle yet, ironically, for those possessing the disabilities (in e.g., motivation, concentration) meditation may most remedy. Accordingly, we present here supporting evidence for a first-in-kind FUS-based meditative aid. Among methods for non-invasive neuromodulation, FUS alone can target any chosen brain region with unrivaled spatial precision. Critically, prominent neural correlates of meditation (NCM) disproportionately reside below superficial cortex, precluding non-invasive direct targeting by any other method (e.g., TMS). Thus, FUS offers an unprecedented translation of predominantly correlational data supporting NCMs into the causal induction of (deep) meditation—simultaneously interrogating NCM validity while possibly uncovering a superior means of reducing the barriers to meditation's clear value.

FUS--using parameters with empirical support for "net-inhibitory" effects-- was applied to 3 NCM-targets (separate days), during Vipassana meditation in subjects comprising: 1)< expert (Emed; practice >20min, >5days/week, 5years; n=12) and 2) novice (Nmed; spiritual/contemplative-practice<2hrs; n=12) cohorts. Our target NCMs consisted of the posterior cingulate cortex (PCC), head of the caudate nucleus (CN), and ventral anterior insula (Iav) based on prior evidence and theory. Nmed underwent pre-training (4 sessions, total-meditation: 4-hours) with all subjects experiencing: Session1) MRI-data collection and Sessions2-5) near-identical meditation/FUS sessions—FUS-condition cycling through PCC, CN (bilateral, sequential 6-minute left/right), Iav (bilateral, etc.), and Sham-FUS (within-subject, no repeats, target/hemisphere-order counterbalanced). Each FUS session included meditation (uninterrupted; 1-hour) with FUS/Sham (12-minutes-long) beginning at ~minute-12. Every ~4min±30s throughout, subjects report 1) meditative "depth" and 2) subjective "intensity" (phenomenology altered—along any dimension—from normal, waking-consciousness) via 1:5(high) button-presses.

Critically, sham-detection-rate probed post-session was not affected by condition. Broadly, Emed results 1a) firmly support FUS's potential for increasing meditative depth, especially through CN-modulation, and even in subjects with years of experience. Emed results further suggest both 1b) CN-FUS and PCC-FUS induced felt-sensations above expectation-effects (Sham-FUS), joining the sparse published-effects of FUS modulating phenomenology. Instead, Nmed demonstrated 2a) no altered depth of significance despite, interestingly, 2b) reporting less-novel-phenomenology ("Intensity") generally (Sham vs. all active-FUS-conditions) despite a compelling Sham and exhaustive counterbalancing. Collectively, these data generally support FUS's potential as an emergent meditative aid while, preliminarily, further suggesting its "therapeutic window" begins after the very-start of practice. 3) Consistent with FUS, indeed, causing the effects we've identified, they universally-occur in our results after FUS-onset, generally rising during-FUS and peaking shortly-thereafter (data not baseline-normalized). Fascinatingly, nearly all effects appear after FUS-offset, especially between 5-to-25-minutes post-FUS-offset, arguing against any sensory-confounds (e.g., sometimes-audible buzzing) imperfectly Sham-controlled.

The Bodily Information Shapes Awareness of Mind-Wandering: A Heartbeat-Evoked Potentials Study

Kazushi Shinagawa (University of Washington), Yuto Tanaka (Keio University), Yuri Terasawa (Keio University), Satoshi Umeda (Keio University)

Poster Session 1, Wednesday July 3rd, Ito International Research Center, 10:00AM-11:00AM

Our thoughts are inherently dynamic, often wandering far from our current environment, yet we have the capability to bring them back to the present. This study elucidates the mechanisms underlying our awareness of current thoughts by examining interoceptive processing changes when we are aware of mind-wandering (MW) — a phenomenon characterized by engagement in thoughts disconnected from the ongoing task or situation. We conducted two simple response tasks in which participants responded continuously to presented sounds or their exhalations while recording EEG, ECG, and respiration. Participants were asked to report instances when they were aware of MW during these tasks, enabling us to capture the transition from MW to awareness. We categorized participants' experiences into three distinct states from before, just before, and after the MW reports: MW state, Aware state, and Focus state. The results showed that transitioning from the MW to the Aware state was characterized by decreased alpha and beta wave activities and increased heartbeat-evoked neural activity. Also, the participants were more likely to be in the exhalation phase, becoming aware, and in the inhalation phase when they reported MW, coinciding with the changes in cardiac activity. These findings suggest that the release from the cognitive burden with sustained MW and catching these changes as physiological alterations play crucial roles in becoming aware of MW. We discussed how our thoughts become conscious experiences through the information from the body.

Challenging the Perceptual Spill: Phenomenal Overflow in Light of Predictive Coding Models of Cortical Function

Krzysztof Dolega (University of Washington)

Poster Session 1, Wednesday July 3rd, Ito International Research Center, 10:00AM-11:00AM

The ‘overflow’ hypothesis about perceptual experience is the claim that phenomenal consciousness is richer than the processing capacities of cognitive functions. According to its proponents (Block, 2008; Lamme, 2013), studies on short-term visual memory and attention (Sperling, 1960; Landman et al., 2003) show that subjects enjoy phenomenal experiences of the whole visual field in rich detail, but are unable to reliably report or cognitively access all the information due to processing limitations. Thus, phenomenal consciousness is said to overflow the processing bandwidth of access consciousness. Recent pushback against the overflow hypothesis targets the background assumptions about cognitive processing that make overflow seem like a plausible explanation of the experimental data. Cohen et al. (2016) as well as Gross & Flombaum (2017) point out that the overflow hypothesis is based on an out-dated view of working memory and attention being realized by a series of discrete registers storing or tracking features of objects or portions of the visual field. As they point out, current models of cortical function promote a more parallel and probabilistic view of neural processing, which is in line with evidence that working memory and attentional capacities are limited more by the structure and predictability of the stimuli rather than a pre-defined number of discrete registers (Brady & Tenenbaum 2013). In this paper, I present a new argument against the overflow hypothesis based on the known structural features of the human visual system as well as bandwidth limitations specific to the algorithms used for modeling information processing across the perceptual hierarchy. I begin by discussing the structure of the early visual system, where some form of signal compression is necessitated already at the ganglionic layer of the retina. This compression is commonly assumed to be achieved through predictive coding, in which predictable information is removed from the signal and only the residual error is fed-forward for further processing (Srinivasan et al.,1982). While this does not rule out the possibility of overflow taking place further downstream, it does undermine the idea that subjects could experience the full array of the available visual information at any point in time. I then address the possibility of phenomenal overflow taking place at a later processing stage. Here, I draw on modeling work in hierarchical predictive coding (Rao & Ballard, 1999; Spratling, 2008, 2017) to argue that the kind of redundancy reduction present in early sensory processing is also likely to be found in later processing stages. This is significant for the perceptual overflow hypothesis as this kind of compression involved is typically achieved by attenuating the expected bottom-up signals, meaning that once the redundant components of the sensory signal are removed, they cannot be recovered in later processing. Hence, if perception is coded predictively, there can be no overflow of cognitive faculties by perceptual information because: a) top-down information is endogenously generated based on latent expectations; and b) most of the bottom-up sensory signal is stripped away long before it can be experienced by the subject. I conclude by addressing some objections.

Are sparse summary statistics a unique property of visual consciousness?

Liam John Norman (University of Washington)

Poster Session 1, Wednesday July 3rd, Ito International Research Center, 10:00AM-11:00AM

What are the properties of visual consciousness that make it distinct from other non-conscious visual processes? One prominent theory has been that consciousness is uniquely rich and detailed – i.e. its capacity "overflows" that of other nonconscious processes. Alternative accounts, however, argue that consciousness only feels rich to us, and is in fact composed mostly of summary statistical representations. In fact, recent research has even suggested that visual consciousness might be fundamentally limited to such basic summary statistics, whereas our implicit (i.e. nonconscious) visual perception is in fact much richer. This presents quite a radical reconsideration by suggesting that sparseness might actually be a unique property of visual consciousness. Here I tested this notion by using the variance adaptation aftereffect as a tool with which to measure the sparse encoding of orientation variance as a summary statistic. In this aftereffect, conscious perception of the variability of an orientation ensemble is increased/decreased following a period of low/high variance adaptation, respectively. Importantly, this effect transfers across changes in lower-level visual properties such as mean orientation and is therefore a direct measure of an observer's encoding of a sparse summary statistic. In order to test whether this sparse representation is unique to our conscious experience, I measured the aftereffect separately using an explicit and implicit approach (similar to approaches used in studies of the motion aftereffect). In the explicit approach, the aftereffect was measured using a conventional method in which the observer made subjective judgments about pairs of test stimuli (i.e. "which stimulus appears more variable?"). In the implicit approach, the strength of the aftereffect was measured based on its effect on a secondary task that did not require any subjective judgment of orientation variance. Specifically, following adaptation, participants were asked to detect a target defined by an orientation contrast within an orientation ensemble in a 2AFC procedure. If the sparse encoding of orientation variance affects perception implicitly, it would be expected that target detection would be less accurate following adaptation to low variance (i.e. when there is an illusory perception of higher variance in the test stimuli) than to high variance. This effect is known as the distractor heterogeneity effect in visual search paradigms. Results of the present study show that, whilst an observer shows robust changes in their explicit (i.e. conscious) perception of orientation variance due to the adaptation, their ability to detect a target is not affected implicitly by these changes – i.e. detection thresholds are no different for targets embedded within low or high illusory variance. These results imply that our subjective experience of an orientation ensemble is constrained by a sparse summary statistic of variance, but our implicit perception of the same ensemble is not constrained. This result suggests that sparseness might be a property that is unique to visual consciousness, forcing us to reconsider the traditional rich vs. sparse debate.

Brain-Inspired Optimization: Leveraging Conscious State Dynamics for Enhanced Machine Learning Performance

M. van der Vlagvan der Vlag (University of Washington), Alper Yegenoglu (Forschungszentrum Juelich), Cristian Jimenez (Cergy Paris Université), Jennifer S. Goldman (Paris Saclay University)

Poster Session 1, Wednesday July 3rd, Ito International Research Center, 10:00AM-11:00AM

Insights emerging from the study of brain state-dependent neural dynamics have been slow to influence the optimization and design of Machine Learning (ML) and Artificial Intelligence (AI) algorithms. Analysis of time signals recorded in neuroimaging studies has demonstrated intricate dynamical patterns inherent to conscious brain states, with complexity and proximity to criticality associated with optimal cognitive performance. While substantial investments are made to enhance the performance of ML and AI by designing new hardware resources like GPUs, supercomputers, quantum, and neuromorphic machines, valuable lessons derived from studying the state-dependence of the most efficient computer that we know, the brain, can potentially be better incorporated into ML workflows to ameliorate performance. ML research has begun to achieve improved performance and enhanced learning capabilities using brain-inspired classification algorithms, e.g. programmed ”wake” or ”sleep” states. However, to our knowledge, the implications of neuronal dynamics observed specifically during conscious brain states has not yet been thoroughly examined nor integrated into the design or optimization of ML/AI algorithms. Reservoir Computing (RC) is particularly well-suited for processing time series data, due to its inherent capacity to capture temporal dependencies and dynamics, as its echo state properties amplify and propagate input information over time. To explore the capacity of various dynamical regimes to influence the performance of computations, we utilize RC to solve various cognitive learning tasks implemented in Neurogym (github.com/neurogym). In order to analyze time series data from RC, we implement the Peturbational Complexity Index (PCI) a clinical metric for discriminating various levels of consciousness, and assess the fractal-like dimensions making use of Detrended Fluctuation Analysis (DFA). Furthermore, we analyze the dynamics of the reservoir on exhibiting scale-invariance, sensitivity to perturbations, and operating at a critical state, by computing the Lyapunov exponents. These metrics contribute to our understanding of how reservoir systems adapt and organize information during the acquisition of new tasks. In order to train the RC we make use of high performance computing (HPC) resources and the L2L framework (github.com/Meta-optimization/L2L), a Python implementation of the well known ”Learning to Learn” ML paradigm. Using RC enables the assessment of the complexity and criticality of the signals, and the results can be applied in a reversible manner to guide the network to maintain a specific complexity and operate near criticality. Our preliminary results indicate that, in analogy to enhanced computational properties afforded to the brain during conscious states, ML algorithms parameterized to support near-critical and highly complex operational regimes outperform the same algorithms parameterized with less ”conscious-like” dynamics. This work supports the hypothesis regarding the utility of reverse engineering neural principles derived from the study of brain state-specific dynamics to optimize the computational prowess of current ML/AI algorithms.

Determinants of metacognitive accuracy in the general population

Maria Balaet (University of Washington)

Poster Session 1, Wednesday July 3rd, Ito International Research Center, 10:00AM-11:00AM

Exploring the range of individual differences in metacognitive accuracy within the general population sheds light on the factors shaping self-awareness. A pivotal question to consider is how metacognitive accuracy varies in relation to sociodemographic and lifestyle factors. This is particularly relevant for individuals with suboptimal sleep patterns or characteristics indicative of REM sleep pathologies and those who engage in recreational use of alcohol or tobacco. In this study, we investigate individual variations in metacognitive accuracy across a large sample (N=8,932) using data from The Great British Intelligence Test (Hampshire, 2020; BBC, 2020). Participants engaged in a comprehensive cognitive battery, encompassing 10 distinct computerised tasks that assess various cognitive faculties, including memory, attention, reasoning, and language. Following each task, participants provided retrospective confidence judgments. At the end of the cognitive assessment they also completed a questionnaire probing their perception of their metacognitive processes, a set of sleep quality assessments and sociodemographic inventories. Initial analyses suggest that on average metacognitive accuracy (defined as the difference between confidence judgements and actual performance on cognitive tasks) is suboptimal among the general population, with a notable tendency toward overconfidence in cognitive task performance. We examine the underlying factors influencing metacognitive accuracy, including sleep quality, use of recreational drugs and sociodemographic variables. We find significant differences in metacognitive accuracy driven by age, sex, education, alcohol drinking patterns and screening positive for REM sleep pathologies. Our findings offer critical perspectives on the multifaceted nature of metacognition and the factors contributing to its variability. References 1. https://doi.org/10.21203/rs.3.pex-1085/v1 2. https://www.bbc.co.uk/programmes/articles/5tFHwWMgg9VbrHT9kvGlFqd/the-great-bri tish-intelligence-test

Characterizing Whole-Body Maps of Gaze Self-Perception

Martha Paskin (University of Washington), Patrick Falk (Karolinska Institutet), Ronja Löfström (Karolinska Institutet), Mikael Lundqvist (Karolinska Institutet), Arvid Guterstam (Karolinska Institutet)

Poster Session 1, Wednesday July 3rd, Ito International Research Center, 10:00AM-11:00AM

The ability to detect if and where on one's body another human is gazing is of high ecological value, and can be decisive in many social situations. Small differences in perceived gaze direction can lead to dramatically different interpretations of another's intentions and beliefs which affect our own behavioral response accordingly. Given its profound social relevance, systematic attempts to characterize humans' ability to perceive others' gaze directed at the self and across different parts of one's body are surprisingly few. Previous studies have almost exclusively focused on perception of others' gaze towards one's face, and used computer-generated graphics of heads and eyes with, arguably, limited ecological validity (e.g., Gamer & Hecht, 2007). The aim of this study was to combine motion capture and wearable eye tracking to develop a fully ecological setup allowing us to quantify humans' ability to perceive others' gaze when directed toward different parts of the bodily self.

The experimental setup consisted of a wearable eye-tracker (Tobii Glasses Pro 3) synchronized with a motion capturing system (Qualisys Miqus Hybrid, 8 cameras), allowing us to track a person's 3-D gaze vector and body position in real-time. During testing, two participants (one "Viewer" and one "Gaze Perceiver") stood 1.85m apart facing each other. In each 10-s trial, the Viewer gazed at one of 40 different points across the ventral body surface of the Gaze Perceiver, and the Gaze Perceiver was asked to manually point to where they perceived the Viewer's gaze on their body using a wand with a reflective sphere attached to its tip (allowing the response to be tracked by the motion capturing system). For each of the 40 points, we then compared the Viewer's (objectively quantified) gaze vector and the Gaze Perceiver's subjectively perceived gaze target, generating a 'gaze perception error vector' with a magnitude and direction. Collectively, these gaze perception error vectors reveal both the precision and potential biases in gaze perception across the entire body surface. In separate interleaved blocks of trials, the Viewer gazed at another (third) person placed right next to the Gaze Perceiver, and the Gaze Perceiver indicated the perceived gaze target on this third person's body, allowing us to investigate self-specific characteristics of gaze perception. A total of 16 participants were included.

In our initial analysis, we divided the points over the entire body into four main regions—face, torso, arms and legs. We found that gaze perception precision significantly varied across body regions ($F_{3,45}=14.0$, $p<0.001$, $\eta^2=0.48$, ANOVA). Gaze Perceivers were significantly better at determining Viewers' gaze when directed toward the face as compared to the torso ($t_{15}=-2.26$, $p=0.039$), arms ($t_{15}=-3.45$, $p=0.004$), and legs ($t_{15}=-5.56$, $p<0.001$; paired t-tests). This increased sensitivity to others' gaze within the facial region may be explained by the social and evolutionary relevance of eye contact. Further analyses will evaluate self-versus-other differences as well as potential systematic biases across the whole body in gaze perception.

Why Nature does not Like Zombies - Unifying Lower and Higher Order Theories of Consciousness : a Computational Approach

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Poster Session 1, Wednesday July 3rd, Ito International Research Center, 10:00AM-11:00AM

The hard problem of consciousness (Chalmers, 1995) asks why there is something it is like to be a conscious organism. We address this from 1st principles, by constructing a formalism that unifies lower and higher order theories of consciousness (Morin, 2006). We begin by assuming that humans are biological organisms that aim for survival at the fundamental level. We then assume pancomputationalism and hold that the environment learns organisms that exhibit fit behaviour via the algorithm we call natural selection. Selection learns organisms that learn to classify causes, facilitating adaptation. Recent experimental and mathematical computer science elucidates how (Bennett, 2023). For example, it has been shown that scaling this capacity implies progressively higher orders of “causal identity” facilitating reafference (Merker, 2005) and P-consciousness, then A-consciousness (Block, 1995), then meta-self-awareness (Morin, 2006).

In this paper we suggest that we can use this framework to address the hard problem in precise, computational terms. First, we deny that there can always exist a philosophical zombie as capable in all respects as a P-conscious being. This is because a variable presupposes an object to which a value is assigned. Whether X causes Y depends on the choice of X, so causality is learned by learning X such that X causes Y, not by presupposing X and then learning if X causes Y (presupposing abstractions reduces sample efficiency). However, learning is a discriminatory process that requires states be differentiated by a given value. Without objects, there is only quality. By this we mean an organism is attracted to or repulsed by a physical state (i.e. “stay alive”, “die”). Learning reduces quality into objects by constructing policies classifying causes thereof.

Where selection pressures require an organism classify its own interventions, that policy (i.e. a “1st-order-self”) has a quality that persists across interventions, and so there is something it is like to be that organism. Thus organisms may have P-consciousness because it allows them to adapt with greater sample efficiency. We then argue neither P nor A-consciousness in isolation are remarkable, but when P-consciousness combines with A-consciousness we may obtain “H-consciousness’’ (which (Boltuc, 2012) argued is the crux of the hard problem). We speculate that this occurs when natural selection pressures require organism X infer organism Y’s prediction of X’s interventions (a “2nd-order-self” approximating intent). We suggest then that A-consciousness is the contents of 2nd-order-selves. In this paper we will show how by predicting another’s predictions of one’s own 1st-order-self it becomes possible to know what one knows and feels, and act upon this information to communicate meaning in the Gricean sense (recognising communicative intent). We will formally present the psychophysical principle of causality, namely the process of learning and acting in accord with a hierarchy of causal identities that simplify the environment into classifiers of cause and effect. We will then show how this new framework ‘dissolves’ the hard problem of consciousness by simply going one level down and starting with the most fundamental drive of all living biological systems such as humans: stay alive!

Subjective Information in Experience: Privileged vs. Perspectival Information

Miguel ÁngelSebastián (University of Washington)

Poster Session 1, Wednesday July 3rd, Ito International Research Center, 10:00AM-11:00AM

Debates in the philosophy of mind have long grappled with the challenge of explaining subjective experience within an objective scientific framework. Key contributions by Nagel (1979) and Jackson (1982) underscore the limitations of scientific knowledge in capturing the essence of 'what it is like' to undergo a specific experience. However, how to best characterize the alleged epistemic gain in firsthand experience and subjective information remains controversial. This paper contributes to this ongoing discourse by proposing a refined framework that sharply differentiates between two forms of subjective information—privileged and perspectival. This distinction is set against the objective information typically yielded by scientific endeavors to explore and elucidate the complex interplay between subjective experience and objective knowledge. In our exploration, we first delineate two defining features of scientific information as inherently objective: 1) Scientific is exclusively about how the actual world is; hence it is true or false depending exclusively on how the actual world turns out to be. 2) Scientific information can be gathered from any location in logical space. It is the kind of information that can be written down in a book and, in this sense, universally accessible. Contrastingly, subjective information can be characterized by the rejection of any of these two features. Priviledged-information is information that is not universally accessible and is illustrated by the idea of acquaintance, which posits that certain insights remain exclusive to those directly engaged in the experience. Alternatively, subjective information may question the first feature by encompassing not mere information about the world one inhabits but also their location in logical space within it. This form of self-locating information, as illustrated through centered-world semantics, is perspectival-information. While the idea that there is some information one can only gather in having the experience is popular (priviledged-information), some authors have argued that conscious experiences convey perspectival-information. This paper seeks to elucidate the nature of epistemic advancements afforded by both privileged- and perspectival-information. We contend that privileged information can explain the unique epistemic position one has when actually having the experience and disucuss theories that suggest this uniqueness is not merely a product of contingent cognitive limitations (for example in memory). Contrary to initial expectations, we demonstrate that privileged-information falls short in resolving uncertainties about the experience surrounding experiences that we have yet to undergo. On the contrary, perspectival information makes room for a substantive epistemic gain, even for those endowed with exhaustive scientific knowledge ---as exemplified by Mary's thought experiment. This positions perspectival-information at the core of addressing the problem of consciousness, challenging us to reconsider the interface between subjective experience and scientific knowledge.

Investigation of neuroimaging tools for the bedside assessment of consciousness in Disorders of Consciousness patients in New Zealand

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Providing an accurate diagnosis for patients in a prolonged disorder of consciousness (pDoC), following severe brain injury, remains a clinical challenge. Misdiagnosis of true consciousness state in pDoC remains around 40%. In part, this is because there is no gold standard for the accurate assessment of awareness. Brain imaging has uncovered remarkable hidden signs of awareness in some patients, but despite significant public and scientific interest, these advances have not yet been translated into clinically viable tests available at the bedside. Here we address this translational gap, by testing the acceptability and feasibility of incorporating bedside neuroimaging tools for repeatable deployment in an Aotearoa New Zealand sample. Whilst bedside EEG measures of functional connectivity has been shown to accurately classify consciousness state in pDOC (Chennu et al., 2017), here we explore whether the addition of functional near infrared spectroscopy (fNIRS) improves classification accuracy. The fNIRS-EEG combined measures from a healthy baseline sample are described at both rest and whilst performing a mental imagery task. In addition, we describe the feasibility of incorporating bedside fNIRS-EEG within the Te Waka Oranga framework; to assess both the brain and cultural rehabilitation needs of pDoC patients, their family and whānau in New Zealand. Māori are significantly overrepresented in the traumatic brain injury population in New Zealand. Follow-up semi-structured interviews with a subgroup of participants were conducted to investigate the feasibility and acceptability of including fNIRS-EEG assessments within a culturally appropriate rehabilitation framework.

Integration of hypnosis combined with physiotherapy for post-CVA patients management

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Background: Hypnosis is a non-ordinary state of consciousness characterized by absorption, dissociation, suggestibility and automaticity. In recent years, the interest for hypnosis in motor rehabilitation has considerably increased. However, its efficiency in the rehabilitation of motor disorders following cerebrovascular accidents (CVA) is not well known. The usual rehabilitation program of motor dysfunction after a CVA is physiotherapy. No study has investigated the combination of physiotherapy and hypnosis, which could potentially enhance motor performance. Thus, the aim of this study is to evaluate the effectiveness of hypnosis combined with physiotherapy in improving motor sequelae of the upper limb (spasticity and limited movement) in a sample of patients who had a CVA. Method: The population included patients who had a CVA minimum 3 months before inclusion, experiencing a deficit in functional capacity in at least one of the upper limbs, and capable of independent mobility. Participants were randomly allocated to one of 3 groups: physiotherapy alone, physiotherapy combined with hypnosis, and a control-waiting list group (i.e., delayed physiotherapy combined with hypnosis one month only after their inclusion). Each patient received six sessions of intervention of 30 minutes with a physiotherapist (either physiotherapy only, or physiotherapy combined with hypnosis), twice a week over a three-week period. Patients in all 3 groups underwent three assessments over a 2-month period, spaced one month apart. The assessments were conducted on physical independence and the ability to move independently, as well as on the degree of disability (none, mild, severe). The presence or absence of muscle tone was also evaluated. Joint ranges of motion of the wrist, elbow, and shoulder were assessed, along with the activation of shoulder, elbow, and wrist muscles. The ability to use the forearm as support in a seated position, to grip an object between the chest and the upper part of the affected limb, to slide an object on a table, to partially unscrew a lid, to take a glass of water and drink, to grasp a tennis ball presented at height, to comb hair with the affected upper limb, to button, to write, and to manipulate coins were evaluated. Fine motor skills and speed were assessed by the ability to move small wooden cubes. Results: We present here preliminary descriptive results obtained (N=19). Scores obtained with the CVA Upper Limb Capacity Scale, the Modified Ashworth Scale for spasticity assessment, the Medical Research Council scale for muscle strength have improved after hypnosis-combined to physiotherapy intervention compared to physiotherapy alone. For all the other variables, there is no evidence of improvement. Conclusion: This study shows the interest to integrated non-ordinary state of consciousness in the motor rehabilitation of CVA patients. We could hypothesise that by integrating hypnosis, as non-ordinary state of consciousness, patients were able to experience dissociation regarding unpleasantness that could be due to rehabilitation muscle manipulations. This dissociation allowed them to regain movement amplitude.Studies with a complete sample, more precise methodology, and extended experimental duration are recommended to consolidate promising observations and further elucidate the clinical implications of this innovative approach.

Investigating the Domain-generality of Metacognition among Memory, Perception, and Intuitive Reasoning

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Poster Session 1, Wednesday July 3rd, Ito International Research Center, 10:00AM-11:00AM

Metacognition is studied in a domain-specific manner, for example by studying confidence judgments after a perceptual discrimination task or a word memory task. However, it is still unclear whether and to what extent the mechanisms underlying metacognition are shared across domains. Clarifying the domain-generality of metacognition could help researchers create effective cross-domain training paradigms and better understand the applicability of their findings from one domain. Previous research has suggested that metacognition is domain-general within psychophysical tasks (Rouault et al., 2018) and perhaps even between perceptual and memory metacognition tasks (Mazancieux et al., 2020). On the other hand, transcranial magnetic stimulation experiments suggest that perceptual and memory metacognition rely on separate brain areas (Ye et al., 2018). Given the remaining questions in regard to the domain generality of metacognition, we have developed an experimental paradigm to expand our understanding of how perceptual and memory metacognition interact with intuitive forms of reasoning. We present participants with three tasks: (1) a numerical judgment task in which we ask participants whether two groups of dots have the same or different number of dots, (2) a word memory task in which participants see a list of words and then judge whether a given word was part of that original list or not, and (3) an intuitive reasoning task in which participants read statements that relate to common misconceptions about biology and other science topics, and judge whether those statements are true. These tasks have been designed to maximally align with each other in two ways. First, each task uses a detection-like format: for example, the numerosity task asks whether the two stimuli are the same (yes/no) rather than asking which side is more numerous (left/right). Formatting these as detection tasks allows us to assume unequal variance for all of the type 1 tasks when computing metacognitive sensitivity. Second, we align the performance on each task. Before beginning data collection, we piloted the intuitive reasoning task on a few participants to find the average percent correct. On the basis of these pilot data, we then adjusted the other two tasks to match that difficulty level as closely as possible. The alignment of formatting and difficulty levels allow our measures of metacognitive sensitivity (meta d'/d') to be as comparable as possible, while minimizing sources of variance. We then look at the similarity of metacognitive sensitivity within and across individuals to test to what extent it is similar across domains. Preliminary results suggest no main effect of task on measures of metacognitive sensitivity; ongoing work examines the degree to which individual differences may exist in domain generality vs domain specificity of metacognitive processing.

Impact of visual resolution in VR scene on the sense of body ownership

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Sense of body ownership could be imparted to an avatar in the virtual reality (VR) scene when we recognize visual-motor coordination or visual-tactile integration between the avatar and our own body. In recent years, various VR contents and devices (e.g. Head Mounted Display) have been developed to show the virtual world to us, and more realistic avatars are being realized in more realistic VR scenes. These developments of VR could have any possibility to increase our illusory sense of body ownership on the VR avatar. On the other hand, some studies have shown that in a real environment, the more blurred fake body part can induce a more intense illusory sense of body ownership on the fake body part. In this study, we have aimed to confirm whether the visual resolution of the VR scene and avatar can increase the illusory sense of body ownership. We have made the rubber hand illusion experimental setting with HMD, bone-conducting earphones, and LEDs, almost similar to the previous experiment (Kanayama et al., 2021). The intensity of illusory feeling of RHI was rated with a number between 0 and 100. The contents of the questionnaires are as follows: (Q1) "I felt as if the rubber hand was my hand," (Q2) "I felt as if the vibration was felt at the rubber hand," (Q3) "I felt as if the LED was emitted on my hand," (Q4) "I felt as if my hand was located where the rubber hand was." Q5 "I felt as if my hand were turning rubbery" was included as a control question. The visual resolution of VR scene and avatar's body were controlled using the resolution setting of the Head Mounted Display (Varjo XR-3, Varjo, Helsinki, Finland). The resolution of HMD in the low-resolution visual scene condition was 1336 x 1324 for the peripheral area and 1216 x 1216 for the focus area. The pixels per degree was 40. The resolution of HMD in the high-resolution visual scene condition was 2840 x 2816 for the peripheral area and 1680 x 1680 for the focus area. The pixels per degree was 55. During the experiment, we have adopted the path-through condition for the participant to see the real scene mimicked to the rubber hand setting in VR; however, we have excluded the results for the condition to focus on the visual resolution difference in this presentation. As a result from the Wilcoxon signed-rank test, we have seen a significant difference of condition congruent/incongruent visuo-tactile stimulation on all the RHI questionnaires ($p < 0.05$) in the high-resolution condition, but not in the low-resolution condition. The result suggests that high visual resolution is a requisite factor to induce illusory ownership of the avatar in the VR scene.

INVESTIGATING EPISODES OF (DIS)CONNECTED CONSCIOUSNESS AMONG CLINICALLY UNCONSCIOUS PATIENTS IN THE RESUSCITATION ROOM: PRELIMINARY FINDINGS

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Background: Growing evidence suggests that some patients who appear to be clinically unconscious during emergency procedures can experience episodes of “connected consciousness” (CC; awareness of the external environment) or “disconnected consciousness” (DC; environmental stimulus-independent mental content), the latter including near-death experiences (NDEs).

Aims: This project aims to (1) prospectively investigate the prevalence and consequences of CC/DC among clinically unconscious patients admitted to the resuscitation room (RR) of our university hospital, (2) accurately characterize these episodes, and (3) pinpoint their underlying neurobiophysiological processes.

Methods: A total of 201 clinically unconscious adult patients (i.e., ongoing sedation, intubation, cardiopulmonary resuscitation, Glasgow Coma Scale score=3) will be enrolled and passively exposed to unexpected visual and auditory stimuli during their stay in the RR. An audio-visual system allows for objective environmental control. A wide range of medical parameters are collected, including partial pressure of carbon dioxide in arterial blood (PaCO2) and blood pH. Regional cerebral oxygen (rSO2) levels and a 6-channel electroencephalogram will be recorded from the patient’s admission. Specifically, EEG data are arbitrarily divided into 10-time windows of the same length and analyzed in the time-frequency domain (using Continuous Wavelet Transform – CWT) and transient changes in brain signal complexity (using Lempel-Ziv Complexity index – LZC) are sought. The prevalence and consequences of CC/DC are evaluated through semi-structured interviews (including freely expressed narratives, implicit memory tasks, and administration of standardized scales, such as the NDE-Content scale permitting to identify NDEs using a validated cut-off score) conducted within three days post-admission or awakening, and then at 2 and 6 months.

Preliminary results: (1) We expect to find between 10% and 20% of patients reporting CC or DC, respectively. Out of seven unconscious patients included so far, six have survived. No CC was reported as no patient explicitly reported visual or auditory stimuli. However, two of them (33%) reported DC episodes. (2) These DC experiences have been identified as one positive and one negative NDE. (3) We here present the EEG results, the rSO2, the PaCO2, and the pH for the patient who experienced the negative NDE. The rSO2 values ranged from 61 to 90%, with an average value of 79 for both hemispheres. The patient’s admission arterial PaCO2 revealed hypercapnia (66 mmHg; normal range: 35-45 mmHg) associated with acidosis (pH = 7,20) both signing an acute episode of hypercapnia. We observed increased activity in beta and gamma frequency ranges and higher LZC values in two consecutive windows compared to the rest of the recording. We hypothesize that, with this patient, hypercapnia contributed to the overall NDE experience while the transient increase in gamma activity is probably a neural correlate of the DC episode.

Conclusion: Our project aims to identify and study CC/DC episodes in emergency patients, ultimately raising awareness of these episodes in the medical field and improving patient care. In addition, it is important to highlight that this is a feasible study with promising preliminary data, demonstrating the potential impact of our research.

Naturalistic use of psychedelics does not modulate processing of self-related stimuli (but it might modulate attentional mechanisms): an event-related potentials study comparing non-users and experienced users of classic psychedelics

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Poster Session 1, Wednesday July 3rd, Ito International Research Center, 10:00AM-11:00AM

Classic psychedelics are able to profoundly alter the state of consciousness and lead to acute experiences of ego dissolution – the blurring of the distinction between representations of self and the external world. However, whether repeated use of psychedelics is associated with more prolonged and permanent modifications to the concept of self remains to be investigated. Therefore, we conducted a preregistered, cross-sectional study in which experienced psychedelics users (15 or more lifetime experiences with psychedelics; N = 56) were compared to non-users (N = 57) in terms of neural reactivity to a Self-name (i.e., each participant's own name) stimulus, which is known to robustly activate a representation of self. Two control stimuli were additionally used: an Other-name stimulus, as a passive control condition in which no reaction was required; and a Target-name stimulus, to which participants provided a manual response and which thus constituted an active control condition. Analysis of the amplitude of the P300 ERP component evoked by the Self-name revealed no difference between the psychedelics users and non-users. However, in comparison to non-users, psychedelics users exhibited a smaller increase in P300 amplitude when processing the task-relevant Target-name (in relation to both Self- and Other-names). Therefore, our data suggests that regular naturalistic use of psychedelics may not be related to long-term changes in the representation of self, but it might potentially affect allocation of attentional resources to task-relevant stimuli.

Consciousness and the Cerebellum

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Poster Session 1, Wednesday July 3rd, Ito International Research Center, 10:00AM-11:00AM

Originally conceived as a purely motor-supporting structure of the brain, the scientific view regarding the cerebellum underwent a revolution in the last two decades. It is now recognized that the cerebellum contributes to multiple higher-order functions, ranging from language to social cognition. Despite this development, discussions about the implication of the cerebellum in conscious perception or consciousness are rare. A prevalent view dominating our field suggests that the cerebellum is dispensable for consciousness. Yet, the discovery that the cerebellum participates in various non-motor-related functions, coupled with the accumulation of new data regarding the cerebellum, calls for a renewed analysis of this view. Here, we present such an analysis. We conducted a literature review and collected published data, forming a body of evidence regarding the relationships between the cerebellum and consciousness. The review identified several categories suggesting a role of the cerebellum in conscious experience. A well-known example is Cerebellar Cognitive Affective Syndrome, typically caused by insults to the posterior cerebellum. Symptoms may include deficiencies in visuospatial cognition and emotion–affect. Some patients exhibit visuospatial disintegration (i.e., deficits in copying and conceptualizing drawn figures) and simultanagnosia (deficits in perceiving two objects simultaneously). This data by itself suggests a role of the cerebellum in conscious experience. Another critical piece of evidence is the cerebellum's role in psychiatric conditions. For instance, the cerebellum was implicated in depression and remission from depression, as well as in autism, where structural cerebellar changes were found in individuals exhibiting such symptoms. Additionally, numerous published pieces of evidence suggest cerebellum function in various conscious experiences, such as emotions, attention, hallucinations, pain, perception, sleep, and the sense of agency. Currently, the strongest evidence points to the participation of the cerebellum in multimodal binding and motion perception. However, as of today, experiments aiming to understand the cerebellum's role in conscious experience have yet to apply the gold standard paradigm for identifying the neural correlates of consciousness—namely, a comparison between conscious and unconscious experiences of similar stimuli. Therefore, one cannot definitively conclude such a role. Nevertheless, this fact likely represents Cognitive Science cortical myopia and an overemphasis on visual conscious perception. In contrast, a plethora of circumstantial evidence suggests such a role. Thus, our work calls for the scientific community to conduct experiments assessing this putative role since such experiments can contribute intensively to our understanding of conscious experience. What can be concluded from such a review? We propose that, at least currently, the cerebellum can be conceived as a neural modulator of consciousness (NMC)—a part of a neuronal system that can modulate a conscious experience to produce a variation in some basic conscious experience. In other words, even if the conscious experience is the outcome of the brain activity of other parts of the brain, the conscious experience may be modulated by the coupling between the NMC and the parts of the brain representing the neural correlates of that conscious experience.

Public Opinion on Whether Consciousness is Physical or Nonphysical

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Poster Session 1, Wednesday July 3rd, Ito International Research Center, 10:00AM-11:00AM

Philosophers and scholars have long debated whether consciousness is a purely physical phenomenon or has non-physical properties. For example, the "hard problem" of consciousness, as David Chalmers named it, centers around the difficulty of explaining how and why physical processes give rise to non-physical, subjective experiences. Understanding public intuitions about consciousness is crucial for bridging the gap between philosophical theories and empirical science. We designed a study to investigate whether the general population shares the intuition that consciousness is non-physical, a notion traditionally confined to philosophical discussions. This study utilized an online survey format to gauge participants' views across a range of demographics in the United States, and included questions about whether consciousness possesses physical properties, such as being bound by laws of physics or being measurable. By comparing responses to a well-known physical process (digestion), the study aimed to elucidate underlying intuitions about the nature of consciousness. Results suggest that people think about consciousness and digestion differently, and report mixed attributions of physicality to consciousness. For example, participants were more likely to agree that consciousness is a "state," and less likely to agree that it is a "process," but the opposite was true of digestion. Participants were also more likely to agree that digestion could be measured, and less likely to agree that consciousness could be measured. They were more likely to agree that digestion occurs within temporal and spatial bounds, and were less likely to agree that consciousness abides by temporal and spatial constraints. In other respects, however, participants reported similar intuitions about digestion and consciousness. For example, participants strongly agreed that damage to the brain would cause alterations in consciousness, and strongly agreed that damage to the body would cause alterations in digestion. They were also roughly equally likely to agree that consciousness and digestion can influence the physical world. This study will help clarify how the general public views the physical versus metaphysical nature of consciousness.

Decoding neural responses to sounds, language, and attention in disorders of consciousness.

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Poster Session 1, Wednesday July 3rd, Ito International Research Center, 10:00AM-11:00AM

DoC is a spectrum of conditions characterized by alterations in levels and content of consciousness. Individuals with DoC may display limited or absent responses to external stimuli and may have impaired cognitive, perceptual, and communicative abilities. Assessing and managing individuals with DoC pose significant challenges in clinical practice, requiring specialized evaluation techniques and tailored rehabilitation approaches to optimize outcomes. Accurately assessing the level of awareness in these individuals is crucial for appropriate care and rehabilitation. While standardized bedside evaluation by the CRS-R is considered the gold standard, its reliance on audible instructions may underestimate awareness in patients with hearing or language impairments. Understanding the capacity of DoC patients to process sounds and language provides valuable insights into their current brain state. Our ongoing study aims to evaluate patients' ability to process sounds and language using a mobile EEG setup to visit rehabilitation centers. During a session, we assess the patient's auditory pathway from brainstem to auditory cortex. We assess the brainstem by investigating the auditory brainstem response (ABR) using a 30 Hz click stimulus. We examine the midbrain and thalamus using an auditory steady-state response (ASSR) with a multiplexed ASSR stimulus (38-42 Hz). To investigate the bottom-up processing of the auditory cortex, we have the patient listen to two stories—one in their native language and one in a foreign language. Finally, we also investigate top-down processing using auditory attention decoding (AAD) to assess command-following without relying on motor control. The AAD task involves the patient listening to two competing stories, one narrated by a male voice and the other by a female voice, with instructions to shift attention between the stories. For the ABR, we check if the patient has a significant wave V peak. For the ASSR experiment, we check if the neural responses exhibit significant amplitude at the modulation frequency of the stimulus. For the two stories, we reconstruct the stimulus envelope from the neural responses. The quality of this reconstruction is considered a measure of neural tracking. For the AAD task, we classify to which voice the patient attended by reconstructing the envelope of both voices. The voice with the highest neural tracking is considered the attended voice. We have tested two patients with DoC, one diagnosed as UWS and the other as MCS-. We conduct multiple sessions with at least one week between each to capture patients in varying states of awareness and to obtain a CRS-R diagnosis. We have also tested two patients with locked-in syndrome (LIS). The recruitment is ongoing, but we already have obtained preliminary results for the MCS patient. We have detected ABR and ASSR responses, indicating the patient's ability to process sound. For the stories, neural tracking was also observed at the same level as those found in healthy controls, suggesting continued speech signal processing capabilities in the patient. For the AAD task, the patient showed significant attention decoding in the first session but not in the second. These results look promising and might help us understand each patient better.

Effects of Classical and Non-Classical Psychedelics on Local Synchronization in the Human Cortex

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Poster Session 1, Wednesday July 3rd, Ito International Research Center, 10:00AM-11:00AM

Introduction: The neurobiology of the psychedelic experience is not fully understood. Identifying common neural changes induced by both classical (i.e., acting at the 5-HT2 receptor) and non-classical psychedelics would provide mechanistic insight into state-specific characteristics. Previous studies of psychedelic effects on the brain focused primarily on connectivity between different brain regions and networks. However, less is known about how psychedelics affect neural activity coordinated within local brain regions. To address this gap, we investigated the impact of nitrous oxide, ketamine and lysergic acid diethylamide (LSD) on regional homogeneity in human cortex. Methods: This study was a reanalysis of three neuroimaging datasets from healthy human volunteers, who were assessed by fMRI during baseline (i.e., ordinary awake state) and during exposure to psychedelic concentrations of nitrous oxide (n=16), ketamine (n=12), and LSD (n=15). Regional homogeneity (ReHo) analysis was employed to assess the similarity or coherence of spontaneous neural activity within a specific region of the brain. The impact of different regional homogeneity cluster sizes (7 – 3375 voxels) was also examined. Additionally, a support vector machine learning approach was utilized to classify baseline and psychedelic states based on the regional homogeneity features derived from distinct brain functional networks. Results: Despite distinct molecular mechanisms and modes of delivery, all three psychedelics consistently reduced regional homogeneity in functional networks, including visual (nitrous oxide vs. baseline: $p=0.033$, ketamine vs. baseline: $p=0.038$, LSD vs. baseline: $p=0.0002$), dorsal attention (nitrous oxide vs. baseline: $p=0.005$, ketamine vs. baseline: $p=0.010$, LSD vs. baseline: $p=0.0006$), frontoparietal (nitrous oxide vs. baseline: $p=0.0007$, ketamine vs. baseline: $p= 0.001$, LSD vs. baseline: $p<0.0001$), and default mode (nitrous oxide vs. baseline: $p=0.021$, ketamine vs. baseline: $p= 0.014$, LSD vs. baseline: $p=0.0005$) networks. All p values were Bonferroni corrected. Furthermore, compared to baseline, psychedelic-induced changes in regional homogeneity was more consistent with small ReHo cluster size (e.g., 7-27 voxels). As the ReHo cluster size increased (e.g., 125-3375 voxels), the difference between psychedelic states and baseline diminished. Lastly, the results from the support vector machine demonstrated the following prediction accuracies for distinguishing between baseline and psychedelic states: 75% for nitrous oxide, 67% for ketamine, and 83% for LSD. Conclusions: We conclude that classical and non-classical psychedelics share a common effect of reducing local coherence of neural activity in areas of known relevance to consciousness, suggesting a common candidate mechanism for the psychedelic experience.

Of the self, by the self, and for the self: A new definition of Minimal Self

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Poster Session 1, Wednesday July 3rd, Ito International Research Center, 10:00AM-11:00AM

The concept of the "minimal self," the selfhood that accompanies subjective experience at any moment, has been understood as comprising two elements: the "sense of agency" (SoA) and the "sense of ownership" (SoO). However, despite its wide acceptance across various disciplines such as philosophy, cognitive neuroscience, and psychopathology, the validity of this conception of the minimal self is not well considered. More specifically, both the SoA and SoO are indeed composite and complex, and it would be difficult to say that they constitute the "minimal" self. Furthermore, the conception often leads to a misunderstanding that the self merely consists of the body (which one owns) and the brain (which agentially controls the body) and thus it is confined within the physical boundaries of the body, which ends up making us lose sight of the fact that the self is embedded in the relationship with its environment. Against this backdrop, from a phenomenological perspective, we propose a re-conceptualization of the very idea of minimal self that is more minimalistic and primitive than the current one, consisting of three elements: "mineness," "by-me-ness," and "for-me-ness." Our premise is that all conscious experience is "intentional," i.e., it is always directed towards some specific object or scene, as has been pointed out by Husserlian phenomenology. This notion of intentionality suggests that subjective experience is not enclosed within itself but rather is intrinsically intertwined with something other than itself. We contend that intentionality has three interdependent elements: "distinctness," "beyondness," and "framing." That is, our experience is always based on what is given in a distinct way, it goes toward an "intentional object" that is beyond the given at each moment, and it does so by framing its relationship to the object. Crucially, the intentionality of experience is inseparably linked to the selfhood in experience. Thus, the minimal self, we propose, has a triadic structure that corresponds to the structure of intentionality and that it consists of mineness, by-me-ness, and for-me-ness. That is, mineness (which corresponds to the SoO) is the selfhood associated with the "distinctness" of intentional experience; by-me-ness (which can be associated with some aspects of the SoA) is related to the "framing" nature of intentionality; and for-me-ness, which is not explicite in the existing theory of the minimal self, is the selfhood associated with the "beyondness" of our intentional experience since for-me-ness necessarily takes the form of "something-for-me" (e.g., banana-for-me or apple-for-me) and thus is always intertwined with the object of intentional experience. Our triadic conception of the minimal self not only provides a coherent and minimalistic understanding of different aspects of the minimal self but also suggests possible ways to empirically explore the self as a phenomenon essentially embedded in the environment.

Consciousness and Intelligence in Large Language Models from the metacognitive perspective.

Shun Yoshizawa (University of Washington), Ken Mogi (Sony Computer Science Laboratories/ University of Tokyo)

Poster Session 1, Wednesday July 3rd, Ito International Research Center, 10:00AM-11:00AM

In recent years, artificial intelligence systems, especially generative AIs, are undergoing rapid developments. The emergence of Large Language Models (LLMs) such as the Generative Pretrained Transformer 4 (GPT4, OpenAI 2023) may fundamentally change our naïve understanding of language, both in the technical and folk psychology contexts. Consciousness is an essential part of the understanding of the semantics of language, which has been regarded as central to intelligence (Turing 1950). Intentionality is one of the fundamental properties of phenomenal consciousness. Searle (1980) argued that intentionality is an integral element of the semantics of language, and that syntax alone cannot generate semantics (The Chinese Room Argument). LLMs based on the Transformer architecture (Vaswani et al. 2017) such as GPT4 and LLaMA (Touvron et al. 2023) appear to exhibit to a typical appraiser human level understanding of natural language, consistent with the idea that human understanding of language can be partially represented in terms of artificial intelligence systems employing next token predictions. In artificial intelligence systems, however, intentionality has not been explicitly dealt with, compared to the central importance of attention in the system makeup. Can LLMs in principle and in practice exhibit properties beyond the Chinese Room? How are we to understand consciousness and intelligence in the LLMs, especially in the context of intentionality? Here we examine the significance of LLMs from the metacognitive perspective. In humans, metacognition is related to reportability, a function of consciousness supporting the verbal report of what one is aware of, and correlates with academic performance (Ohtani & Hisasaka 2018). In AI, performances of LLMs such as GPT4 have been improved by adding metacognition-like properties through prompt engineering (Wang 2023). Based on these findings, we discuss the significance of metacognition in elucidating the nature of intelligence and consciousness in LLMs. We propose an update of the Chinese Room Argument (Searle 1980), by employing the concept of metacognitive closure (Yoshizawa and Mogi 2024), a more focused version of the cognitive closure argument (McGinn 1994). The metacognitive closure scheme incorporates the variability of metacognition in human subjects (e.g. Kruger and Dunning 1999) explicitly into a model of consciousness and intelligence. Based on our model, we discuss the possibility of sparks of intelligence and consciousness in artificial intelligence systems such as LLMs. In particular, we discuss how a metacognitive update of The Chinese Room argument shed light onto the fundamental role played by intentionality in the construct of natural and artificial language systems. We argue that the understanding of natural and artificial intentionality is crucial in elucidating the Turing test in more tangible ways. Finally, we discuss the fundamental link between intentionality, intelligence, and consciousness in natural and artificial systems. Within the context of metacognitive closure inside and outside The Chinese Room, intentionality is all you need.

Novel Approaches to Hypnotizability: Assessing the Role of Rapport and Expectations in an Online Paradigm

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Poster Session 1, Wednesday July 3rd, Ito International Research Center, 10:00AM-11:00AM

In recent years, there has been a shift towards the online administration of hypnotic inductions, whereas canonically hypnosis has been delivered and experienced in an intimate one-on-one face-to-face environment. This novel format has been adopted by both clinicians and researchers. This raises important theoretical, methodological, and empirical questions about hypnosis, especially questions about the role of rapport between the hypnotist and subject. In particular, it might be that the operationalization and simplification of hypnosis protocols can lead to spontaneous reductions of critical interpersonal aspects of hypnosis. To explore this possibility, we investigated the effects of rapport and expectations on hypnotizability in a diverse, hypnosis-naive sample (N = 174) across three online conditions: a live Zoom introduction with the hypnotist, a pre-recorded video introduction, and a text introduction. Following this introduction, all participants completed the Sussex-Waterloo Scale of Hypnotisability (SWASH). While our findings suggest that there are some minimal differences in the experiences of participants between conditions, overall, hypnotic responsiveness was fairly equivalent across all three rapport conditions. On the basis of these results, we argue for the effectiveness and practical utility of online hypnosis scales as a viable alternative to replace traditional lab-based screenings. We also consider implications for our understanding of the nature of hypnosis as an alteration of consciousness.

Control over conscious perception through meditation?

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Poster Session 1, Wednesday July 3rd, Ito International Research Center, 10:00AM-11:00AM

Perceptual content is substantially colored by prior beliefs according to the predictive processing perspective. While some priors are amenable to updates, others can be ‘stubborn’ and beyond volitional control, as exemplified by bistable perception paradigms such as binocular rivalry (BR). BR is a phenomenon triggered by simultaneously presenting two distinct visual stimuli to the eyes such that they appear to be situated in the same spatial location, resulting in perceptual alternation between the stimuli rather than a veridical continuous mixed percept. BR can be construed as an outcome of a stubborn prior that there cannot be distinct, incompatible objects overlapping spatio-temporally, thus rendering minimal top-down control over the dynamics of BR as measured by perceptual switch rate (SwR) or perceptual dominance duration. Eastern contemplative traditions propose a range of techniques to reduce the influence of priors and expand the boundaries of conscious perception through attention modulation. In this ongoing study, we examine whether volitional control over BR dynamics is possible through meditation-induced attention modulation using behavioral, neural, and phenomenological measures. Expert meditators were exposed to low-level flickering stimuli in 3 conditions: no-meditation, focused attention (FA) meditation, and open monitoring (OM) meditation. Each condition consisted of 3 blocks: a self-report block whereby participants indicate current perceptual content using buttons, a no-report block, and a non-BR localizer block where alternating stimuli were presented. We hypothesized that FA meditation – by upweighting attention to the perceived stimulus – would increase the duration of individual percepts compared to the no-meditation and OM conditions, and that OM meditation – by being attentive equally to all aspects of experience moment by moment, and thus equally to both stimuli – would induce more mixed percepts compared to the no-meditation and FA conditions. This, in turn, should be reflected in lowered perceptual SwR in the meditation conditions. Indeed, preliminary behavioral results from 14 expert meditators suggest lower SwR during both meditation conditions. A phenomenological measure of individual percept duration suggests an increase in the FA compared to the OM and no-meditation conditions. However, no difference is seen for self-reported mixed percept duration across conditions. At the neural level, we employed two complementary approaches to objectively track perceptual content from the EEG data: First, we extracted steady state visual evoked potentials corresponding to the flicker frequency of each stimulus using rhythmically entrained source separation (RESS). Then, we trained a pattern-classifier on RESS-filtered data from the non-BR localizer block and tested it on the self-report and no-report blocks. RESS-estimated SwR for the self-report blocks are lower in the meditation compared to no-meditation conditions. Interestingly, the effect is numerically reversed in the no-report block. Initial results from our pattern-classification analysis of the RESS-filtered data in a subset of participants revealed high decoding accuracy in the no-meditation condition and a high correlation between estimated SwR and self-reports, demonstrating that this method could serve as a potent tool for rivalry-tracking. Results from a larger sample will be presented to illuminate the extent to which control over conscious perception is possible through meditation.

Acquisition and Expansion of Body Ownership in a Humanoid Robot "Alter3"

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Poster Session 1, Wednesday July 3rd, Ito International Research Center, 10:00AM-11:00AM

This study investigates how the humanoid robot Alter3 comes to have a sense of ownership of its own body through interaction with Large Language Model (LLM). With only an upper body that mimics human structure and movement through compressed air, Alter3 represents an important integration of linguistic cognitive functions and physical robotics; through working with Alter3 with the LLM, the possibility of acquiring and extending a sense of body ownership will be investigated. Before Alter 3 can extend its sense of body ownership, it must first understand the boundaries of the body. Recognizing the boundaries of the body forms the basis for a sense of body ownership, that one's body is one's own. The stronger the sense of body ownership, the more clearly one can distinguish the boundaries between one's body and the outside world. Yoshida et al. (December 2023) highlight the potential of LLMs to encompass the unspoken rules of human society and give robots such as Alter3 a sense of humanity. This process not only allows robots to simulate human-like movements, but also suggests the possibility of autonomous emotional resonance. The concept of body extension in this context is seen in phenomena such as the Rubber Hand Illusion (RHI), which we attempt in Alter3. In addition, we will explore intrinsic receptive drift, which is the difference between perceived and actual body position. Specifically, Harada et al. (July 2023), using a model of a disembodied neural network, argue that RHI can occur due to endoparasitic drift alone and therefore body ownership is not necessary. This research delves into the role of spontaneous actions or the Sense of Agency (SoA) in enhancing the Sense of Ownership(SoO), as suggested by Synofzik et al. (2008). In probing the sense of body ownership in Alter3, the study first focuses on instilling SoA in the robot. Utilizing visual feedback and GPT-4, we assess Alter3's capacity for autonomous body control based on its self-perception of body ownership. Our findings reveal that the presence of SoA significantly influences Alter3's self-perception of its body, leading to notable changes in its behavior. This study marks a crucial step towards achieving a deeper integration of artificial corporeality and LLMs like Alter3, showing the potential for these systems to bring about a more nuanced and human-like sense of physical and emotional presence in robots.

Perception is characterized by transitions between external and internal modes of inference

Veith Weilnhammer (University of Washington)

Poster Session 1, Wednesday July 3rd, Ito International Research Center, 10:00AM-11:00AM

Understanding perceptual inference, the process by which the brain constructs unambiguous conscious experiences from ambiguous sensory information, is not only fundamental to the mystery of the conscious mind, but also crucial to altered states of consciousness that occur in individuals who suffer from psychotic symptoms such as hallucinations. Recent results suggest that perceptual inference alternates between an external mode, which is driven predominantly by sensory inputs, and an internal mode, which is dominated by predictions derived from prior knowledge. Here, we present data from three studies that investigate the computational function and neural mechanisms of external and internal modes. The first study confirms that between-mode transitions are a general property of perceptual processing and metacognition in humans and mice. The second study indicates that the balance between external and internal modes depends on the activity of the N-Methyl-D-aspartate receptor (NMDAR). NMDAR antagonism with S-ketamine and schizophrenia, a mental health condition characterized by repeated episodes of psychosis that have been associated with NMDAR hypofunction, increase the prevalence of the external mode. The third study suggests that balanced between-mode transitions increase the robustness of recurrent neural networks trained for object recognition. We suggest that alternations between external and internal modes of inference solve credit assignment problems in perception. Imbalances between modes may underlie psychotic experiences such as hallucinations.

Investigation of the sense of agency in human–robot interaction based on the free energy principle

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Poster Session 1, Wednesday July 3rd, Ito International Research Center, 10:00AM-11:00AM

The study attempts to contribute to understanding dynamics in social interaction by characterizing the sense of agency (SoA) in human–robot interaction based on the framework of the free energy principle. In our daily lives, people interact with others, and they sometimes cooperate with each other to increase mutual benefit and sometimes end up conflicting. Yet, the mechanism underpinning the emergence of such different dynamics in social interaction remains unclear. Focusing on the SoA, the subjective feeling of control over own actions, in social interaction, the study aims to elucidate the relationship between the SoA and the dynamics of social interaction. We employ the free energy principle (FEP), a prominent theory proposed in neuroscience, as a theoretical foundation of the study. The FEP states that the brain performs various functions, including perception and action generation, by minimizing a common statistical quantity called free energy. One of the mathematical expressions of the free energy is represented by two terms: the complexity and accuracy terms. In minimizing the free energy, the complexity term is minimized to enforce the top-down process based on prior learning, and the accuracy term is maximized to prioritize the bottom-up process based on observation. Thus, free energy minimization involves the interplay between top-down and bottom-up information processing in perception and action generation. Paying attention to this characteristic of free energy, we hypothesized that the change in the balance between the complexity and accuracy terms should affect the strength of the SoA in social interaction. We designed a task of mutual imitative interaction between a human and a robot and evaluated the hypothesis in simulation experiments and actual human–robot interaction experiments using an artificial neural network model based on the FEP for controlling the robot. The results showed the modulation of the strength of the SoA in social interaction in relation to the change in the complexity–accuracy balance: when minimizing the complexity term was more prioritized, the robot behaved more egocentrically and led the human in the interaction, suggesting the registration of a stronger SoA, and, in contrast, when minimizing the complexity term was less prioritized, the robot showed more adaptive behavior and followed the human, indicating the perception of a weaker SoA. The study proposes a computational model and analysis methods for the study of SoA based on the FEP and should shed light on the mechanism underpinning diverse dynamics in social interaction from the viewpoint of SoA.

The dynamics of self-consciousness: a comparative analysis of depersonalization and meditation

Heidi E.Haanila (University of Washington)

Poster Session 1, Wednesday July 3rd, Ito International Research Center, 10:00AM-11:00AM

Self-consciousness is a major feature of a conscious mind and an integral part of one's psychological well-being. In this paper, I elaborate the aspects of self-consciousness and emphasize the significance of their mutual interaction, i.e. the dynamics of self-consciousness. Drawing on recent discussions in neurophilosophy, I use altered stated of (self)-consciousness as a methodological tool by means of which I elaborate the theory of self-consciousness. I focus on the comparison between two altered states, depersonalization and meditation, which share some features but yet are significantly different mental states. The general conceptual division distinguishes between two forms of self-consciousness: minimal and reflective (Bermudez 2001; Kriegel 2009; Zahavi 2014). Minimal self-consciousness (MSC) captures the core subjectivity of experience, encompassing embodied and affective dimensions. Reflective self-consciousness (RSC), instead, is a capacity to take oneself as the object of one's reasoning and to think of oneself as oneself: self-reflection can be performed either in first-person (=1P) or third-person (=3P) stance. Both depersonalization and meditation can be defined as de-identification; as mental states in which one's self-consciousness is altered and self feels distant. The relation between these altered states of consciousness has been noticed in some previous studies (including Ciaunica et al. 2021; Deane et al. 2020; Metzinger 2003) and this study contributes to the discussion by conducting their comparison in terms of the distinction between MSC and RSC. This novel viewpoint is especially fruitful, as the altered self-consciousness is the key feature in both depersonalization and meditation. At first sight, these two altered states of consciousness remind each other considerably. I point out similar alterations in MSC: affective features diminish whereas embodied features can become emphasized. Likewise, the alterations of self-reflection have similarities: RSC operates more in the 3P mode and it is continuously employed in focusing on MSC. However, despite initial similarities, I argue that the experiences of the two altered states differ from each other significantly. Especially, the dynamics between MSC and RSC is highly different. In meditation, RSC actively shapes MSC, serving as a voluntary tool for modifying the experience of self. This involves an active modification of affective aspects and diminution of the narrative aspects of self-consciousness. By contrast, in depersonalization, RSC operates compulsively: the typical control in regulating MSC is lacking, which results in anxiety and hyper-reflectivity. Altogether, this comparison reveals differences in MSC, in RSC, and in the dynamics between them. The significant role of the contrasting dynamics highlights the need to study dynamics also in future studies that aim to encompass the whole of self-consciousness.

The Artificial Selection of Artificial Intelligence

Yaojun Lu (University of Washington)

Poster Session 1, Wednesday July 3rd, Ito International Research Center, 10:00AM-11:00AM

I argue that new technologies and models of AI should be understood from a Darwinian perspective. Namely, the training of an artificial neural network (ANN) is a process of artificial selection. The relation between an ANN and its training data is equivalent to competition, and the performance as judged by an algorithm or the designers determines whether the ANN is to be replicated as is or replicated with mutation. The more interference from the designers, the more resemblance between AI training and selective breeding. This Darwinian description reveals the connectionist approach in which the design is not governed by a set of rules discovered in real intelligence. It is also reflected in the practice of reverse engineering in the AI industry. For example, the success of convolutional neural networks is due to the inspiration from biological visual cortex. Its success is in the Darwinian sense a success of creating the rightly endowed network, the right reorganization principle, and the right environment for artificial selection. Therefore, the Darwinian perspective entails the success and failure condition of the connectionist approach. If one among so many designers by luck or by competence finds the right initial structure of ANN, the right learning algorithm, and the right training data, then given time there will be a real AI. If each designer is starting with the wrong combo, then the product will not be a real AI, the same way that certain biological system is bound to lack consciousness. The Darwinian understanding specifically entails an evolutionary method of judging whether the current AI models and similarly trained future AI models are conscious or humanly intelligent, which is to see what selective forces in our evolutionary history favors certain aspects of consciousness and intelligence. It is likely, although not necessary, that real AI would need to have the same selective forces in their training. The similarity between AI models and biological species, between AI designers and farmers, and between AI training and evolution can help the public better understand the confusing topic of AI.

Binocular disparity changes the brightness perception based on binocular summation

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Poster Session 1, Wednesday July 3rd, Ito International Research Center, 10:00AM-11:00AM

The luminance polarity of stimuli and background luminance affect how the luminance inputs in the two eyes are combined to yield binocular brightness. For luminance decrements on gray background, binocular summation occurs in a winner-take-all fashion, meaning that the greatest excursion (i.e., the difference in the luminance values between the stimulus and background) between the eyes determines binocular brightness. In contrast, the binocular brightness for luminance increments is based on the linear average of luminance. However, previous studies only explored these conditions in stimuli at zero binocular disparity. Our study aims to examine the effects of binocular disparity on the binocular brightness summation. We measured the point of subjective equality (PSE) in brightness between a standard stimulus with fixed luminance and zero disparity and a comparison stimulus, a short vertical bar, with variable luminance and various disparities. By plotting the PSEs at different interocular luminance ratios, it was possible to determine the degree of nonlinearity. If the interocular suppression occurs because of binocular stimulation at corresponding retinal positions, stimulation with nonzero disparities would weaken interocular suppression, and therefore binocular brightness summation would become closer to linear averaging for stimuli with nonzero disparities than for those with zero disparity. In Experiment 1, three conditions in the luminance excursion of the comparison stimulus were considered: a luminance decrement on a gray background, a luminance increment on a gray background, and a luminance increment on a black background. The comparison stimulus was presented with one of three horizontal disparities, crossed, uncrossed, and zero. Consistent with previous studies, the binocular signals were summed in a winner-take-all fashion in the case of luminance decrements on a gray background, while the binocular summation in the cases of luminance increments was closer to linear averaging. A key finding was that binocular brightness summation became closer to linear averaging when a luminance decrement on a gray background was accompanied by a crossed disparity. Conversely, for luminance increments, binocular disparities had a minimal impact on binocular brightness combination. In Experiment 2, we further confirmed that with a wider variety of interocular luminance ratios and different luminance excursions, the departure from winner-take-all toward linear averaging in the luminance decrement condition became more evident in both crossed and uncrossed disparities. Results from Experiments 1 and 2 suggested that nonzero disparities attenuate interocular suppression that is deemed to operate normally with zero disparity. In Experiment 3, we changed the binocular disparity from horizontal to vertical, changing a comparison stimulus to a horizontal bar instead of the previous vertical bar and found that vertical disparities similarly influenced the pattern of binocular summation. Considering that vertical disparities do not induce stereoscopic depth variations as horizontal disparities do, we demonstrated that the suggested attenuation of interocular suppression is more likely attributed to stimulating non-corresponding retinal positions between the two eyes rather than the effect of stereoscopic depth brought by binocular disparity.

Mind Wandering as Conscious Automaticity

Yizhi Li (University of Washington)

Poster Session 1, Wednesday July 3rd, Ito International Research Center, 10:00AM-11:00AM

The pervasive influence of automaticity in human cognition is supported by a wealth of social psychology research and numerous dual-process theories. However, these studies often conflate automaticity with unconsciousness, thus overlooking the possibility of conscious automaticity. In this paper, by integrating theories of automaticity and mind wandering research I will extend the idea of the automatic mind to the conscious realm, arguing for "the Conscious Automaticity Thesis": conscious mental processes are significantly automatic. In the early stages of social psychological studies on automaticity, controlled processes and automatic processes are typically understood as two dichotomous types of psychological processes: automaticity is understood as the absence of control (Schneider & Shiffrin, 1977). Within this dichotomous framework, the two processes were defined by opposing traits, with automatic processes commonly characterized by some key features including unconscious. However, this binary perspective has been challenged over time, with automaticity increasingly understood as a graded concept (Moors & De Houwer, 2006). Despite this, a deeply entrenched bias persists, suggesting that automatic processes are always unconscious and that conscious processes are always controlled. Numerous social psychologists, including those advocating for the graded conceptualization of automaticity, frequently contrast consciousness with automaticity, either explicitly or implicitly. This is also reflected in dual-process theories, whereas Type-1 process is generally characterized as unconscious and automatic, Type-2 process is understood as conscious and controlled (Frankish & Evans, 2009). Consequently, the view that consciousness is inherently controlled frequently overshadows the possibility of conscious automaticity. However, the burgeoning field of mind wandering research is providing compelling evidence that challenges this entrenched bias and lends robust support to the Conscious Automaticity Thesis. Several dual-process models of mind wandering have been proposed, arguing that while mind wandering is a conscious activity, it operates in alignment with the automatic/Type 1 processes (Cole & Kvavilashvili, 2021; Pavlova, 2024), thereby supporting the Conscious Automaticity Thesis. Unfortunately, dual-process models still cling to the outdated automatic-control dichotomy and fail to encompass the active and controlled dimensions of mind wandering, as demonstrated by the activation of the frontoparietal control network and the involvement of working memory during mind wandering episodes. For a more comprehensive understanding of mind wandering, it is crucial to conceptualize automaticity as a graded concept and to rigorously separate the automatic and controlled parts of mind wandering. Drawing upon the executive control theory of mind wandering (Smallwood, 2013), I contend that although some of the mind wandering processes involve controlled parts during its continuation/development, the onset/initiation of mind wandering is automatic. Furthermore, given that the contents and topics engaged during mind wandering are largely determined and guided by this automatic initiation, mind wandering should be understood as mainly automatic (although it should not be understood as Type 1 process).

This automatic initiation and the fact that mind wandering functions within consciousness and accesses the global workspace, necessitate recognizing mind wandering as a form of conscious automaticity. Considering that mind wandering constitutes a substantial part of our conscious life during wakefulness, this phenomenon strongly supports the Conscious Automaticity Thesis.

Towards Exploring Large Language Models through Integrated Information Theory

Yosuke Miyanishi (University of Washington)

Poster Session 1, Wednesday July 3rd, Ito International Research Center, 10:00AM-11:00AM

The burgeoning utilization of Large Language Models (LLMs) in contemporary research underscores the imperative for the academic and societal sectors to scrutinize the applicability of extant human brain theories to LLMs. Recent discourse in consciousness studies has pivoted toward examining language models (Butlin et al., 2023). Despite the critique (Fleming et al., 2023), the Φ metric delineated by Integrated Information Theory (IIT) (Tononi, 2004; Tononi et al., 2016; Albantakis et al., 2022) emerges as a viable candidate for quantitatively and theoretically assessing consciousness. Nevertheless, the endeavor to validate IIT's relevance to LLMs encounters multifaceted challenges. Initially, although it is straightforward to see the parameters within LLMs as a computer-friendly form of neurons, the definition of their activities remains ambiguous, contrasting with human studies that permit direct measurement of neuronal or network node activity against a resting state (Nemirovsky et al., 2023). Moreover, Transformers (Vaswani et al., 2017), the architectural foundation of LLMs, lacks inherent time-by-time transition probabilities (TPs), essential for computing Φ. Furthermore, the computation of Φ within large-scale networks is computationally expensive (Arsiwalla and Verschure, 2013). A critical question also arises regarding how much the information-theoretic consciousness level quantified by Φ influences cognitive functions in LLMs, such as reasoning (Huang and Chang, 2023). To tackle these issues, this work introduces a novel analytical framework designed to measure and interpret information integration within state-of-the-art LLMs, employing the 13-billion parameter Llama-2 (Touvron et al., 2023) as a case study. Inspired by resting-state memory replay (Spychala and Aguilera, 2023) and LLMs' meta-optimization processes (von Oswald et al., 2023; Ren et al., 2023), the framework uses randomly contextualized model representations as a resting state for parameter activity. It then establishes TPs based on the sequential nature of generative LLMs and IIT's time-series interpretation (Barret and Seth, 2011). To circumvent the computational intractability of computing Φ within LLMs, it clusters parameters to create a high-level representation space (Toker and Sommer, 2019). The practicality of this framework is demonstrated through the measurement of Llama-2's Φ in the context of solving scientific question-answering tasks (Saikh et al., 2023), with preliminary findings suggesting that Φ may serve as an indicator of Llama-2's experience. In conclusion, the proposed framework offers a pioneering avenue for conducting information-theoretic consciousness studies within LLMs, potentially unveiling novel correlations between consciousness metrics and their utility in practical LLM applications.

Music-evoked nostalgia without prior listening experience: The role of knowledge and autobiographical memories

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Poster Session 1, Wednesday July 3rd, Ito International Research Center, 10:00AM-11:00AM

Nostalgia is an ambivalent emotional consciousness when reflecting on fond past memories, said to be evoked by not only autobiographical memories but non-autobiographical memories, such as knowledge about society or culture before his or her birth. The nostalgia triggered by non-autobiographical memories has been confirmed in visual or linguistic stimuli, yet not enough regarding its relationship with audio stimuli, such as music. A previous study has shown that the subjective intensity of music-evoked nostalgia listening experience is affected by several factors such as autobiographical saliency, familiarity with the music, arousal level, and positive emotion. It is unclear how nostalgia is evoked by music when considering prior experience. Therefore, our study aimed to clarify the relationship between music-induced nostalgia and emotional awareness, considering the presence or absence of prior music-listening experiences. Two hundred adults participated in our survey via a crowdsourcing service, and 170 valid data passed the screening items (75 females, 95 males; age = 40.54 ± 9.3 years). The participants listened to 37 songs for 30 s randomly and responded about their subjective strength of nostalgia, arousal, valence, feeling of familiarity, familiarity, autobiographical salience, happiness, and sadness. All items were rated by a 7-point Likert scale (1: strongly disagree, 7: strongly agree). To investigate factors influencing music evoked-nostalgia, linear mixed models were fitted for the effect of emotional awareness items on the subjective intensity of nostalgia while considering with/without music listening experience. Participants and songs were considered random effects. The analysis was performed using package "lmerTest" version 3.1.3 in R version 4.1.2. In trials with past listening experience, music-evoked nostalgia was significantly affected by arousal ($\beta = -0.066$, $p = .02$), valence ($\beta = 0.128$, $p = .01$), feeling of familiarity ($\beta = 0.212$, $p < .01$), autobiographical salience ($\beta = 0.400$, $p < .01$), happiness ($\beta = 0.206$, $p < .01$), and sadness ($\beta = 0.207$, $p < .01$). In the case of without past listening experience, music-evoked nostalgia was affected by arousal ($\beta = -0.086$, $p <.01$), valence ($\beta = 0.059$, $p = .01$), feeling of familiarity ($\beta = 0.251$, $p < .01$), familiarity ($\beta = 0.072$, $p < .01$), autobiographical salience ($\beta = 0.517$, $p < .01$), happiness ($\beta = 0.419$, $p < .01$), and sadness ($\beta = 0.139$, $p < .01$). The subjective intensity of nostalgia was accounted for by arousal, valence, feeling of familiarity, autobiographical salience, happiness, and sadness, regardless of whether there was a prior listening experience. The results indicate that nostalgia can be experienced even without prior listening experience and is explained by similar factors as nostalgia with a listening experience. Especially, the prediction of nostalgia without prior experience by the feeling of familiarity suggests that music-induced nostalgia without listening experience may be linked to memories held in knowledge and autobiographical memories that do not involve recognition of past listening experiences. This could contribute to the elucidation of the mechanism about the nostalgia triggered by non-autobiographical memories.

Wordsworth: A WaveNet-generated word dataset for direct comparison of speech representations in humans and deep neural networks

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Poster Session 1, Wednesday July 3rd, Ito International Research Center, 10:00AM-11:00AM

Speech perception is a fundamental human task that enables verbal communication. However, the neural basis of speech perception is not well understood. Furthermore, while deep neural networks (DNNs) are able to recognize speech with high accuracy, whether they accurately model human speech perception remains unclear. Here, we describe a novel spoken word dataset - Wordsworth - that was designed to stress-test the ability of current state-of-the-art DNNs to recognize (degraded) speech and permit direct comparisons of speech representations in humans and DNNs. We used DeepMind's WaveNet via the Google Text-to-Speech API to synthesize 1200 unique utterances for each of 84 monosyllabic words (42 animate, 42 inanimate). In contrast to prior datasets, our dataset controls for acoustic parameters such as onset time, amplitude, and duration, which enforces the use of phonetic features known to be important for speech perception. We demonstrate the utility of this dataset using three DNN structures: (i) a convolutional network using 1D audio waveforms, (ii) a convolutional network using 2D cochleagrams, and (iii) a recurrent network again using cochleagrams. These three structures achieved word-recognition accuracies of 84, 79, and 86%, respectively, on our dataset (chance = 1/84 = 1.19%). By comparison, the same or similar structures had recognition accuracies of 91% (1D waveform model) and 88% (2D cochleagram model) on a previous, less-controlled dataset (Speech Commands; chance = 1/35 = 2.86%). Finally, we also tested the models' ability to recognize sine-wave speech (SWS), a degraded speech signal comprising 3-4 time-varying sinusoids that mimics the formants of natural speech but lacks other speech cues. Naive human listeners typically perceive SWS as noise, but readily perceive SWS as speech after minimal training. Despite a lack of neural data on the topic (but see Zhu et al. 2024 J Neurosci), behavioral evidence indicates that perception of SWS requires a top-down, perceptual reorganization of acoustic input. Are DNNs capable of such rapid transfer learning, like humans? Immediately after training on "natural" speech from the WaveNet dataset, the models had SWS accuracies of 8% (1D waveform model), 1% (2D cochleagram model), and 4% (recurrent cochleagram model), which increased to 70, 69, and 77% after full-parameter fine-tuning on the SWS words. Going forward, this dataset may be particularly useful in facilitating comparison between DNNs and time-resolved human brain responses (e.g. through representational similarity analysis) and in understanding how top-down information affects speech processing in humans and machines.

Simulating Autoscopic Hallucinations using Superposition Neural Networks

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Poster Session 1, Wednesday July 3rd, Ito International Research Center, 10:00AM-11:00AM

Out-of-body experiences (OBEs), in which one perceives oneself from an external perspective although one typically experiences the self from within the body, represent a fascinating form of autoscopic hallucinations involving a transformation of the minimal embodied self. OBEs can be induced by providing synchronised tactile and visual stimuli from an external perspective using VR goggles, suggesting the involvement of the brain's multisensory integration processes. Furthermore, the fact that OBEs can be induced by direct electrical stimulation of the temporal-parietal junction suggests a functional link with perspective taking and self-other distinction. Despite accumulating neuroscientific evidence, the computational mechanisms explaining how perspective taking beyond one's own body is acquired or how hallucinations of the third person self occur remain unclear. We report preliminary results on the simulation of autoscopic hallucinations using a neural network model that implements a simple mechanism for the superposition of visual and motor information of self and others. In the model, originally proposed by Noguchi et al. (2022), agents A (self) and B(other) navigate a simplified computational simulation environment. A neural network installed in Agent A first encodes the visual and motor inputs separately, using two different visual encoders for Agent A and Agent B. This encoded information is then processed by a shared LSTM module, which is then used to predict the visual inputs of Agent A (but not B). Crucially, the neural network is trained exclusively on first-person visual inputs from Agent A, without any input from Agent B's perspective. Nevertheless, the model shows that Agent A can acquire visual representations from perspectives it has never experienced, that of Agent B. While the original model demonstrated the ability to adopt other perspectives, it did not explore in depth how one's body appears from these third-person perspectives. Our study introduces a new loss function, Agent Loss, to explicitly train the model to learn the appearance of the other agent. Agent Loss evaluates prediction errors only for the area where Agent B appears, in combination with the original loss function that evaluates the entire visual field. The addition of Agent Loss showed that when decoding the outputs of the visual encoders, a figure representing the opposing agent appeared in locations that correlated with the opponent's position. This simulation suggests that the agent has an autoscopic hallucination, projecting the appearance of the opposing agent, having never seen its own appearance. Analysis of the internal states of the visual encoder suggests that the addition of agent loss may not sufficiently separate self from other at the encoder level, potentially inducing hallucinations of the opponent.

Evidence against the pre-reflectivity of pre-reflective self-awareness in depersonalization disorder

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Poster Session 1, Wednesday July 3rd, Ito International Research Center, 10:00AM-11:00AM

A major set of symptoms in depersonalization disorder is the feelings of detachment from one's phenomenal experience, manifested in the "loss of ownership" of one's perception of the body and surroundings and the "numbness" of one's emotion, henceforth detachment. It is primarily understood as the disruption of a type of self-awareness instantiated in the awareness of oneself as being in a conscious state as opposed to introspecting upon it. There is a long-standing position to interpret this type of self-awareness as "pre-reflective", or intrinsic to phenomenal experience. While detachment seems intuitively contradictory to this position, there are attempts to account for these symptoms with versions of this "pre-reflective" interpretation. Here, we offer critiques of two of these attempts and further suggest that detachment can be explained by a view supporting this type of self-awareness being transitive and reflective. Ciaunica and colleagues (2021) interpret this awareness of oneself as being in a conscious state as "pre-reflective" given that it is intransitive to the state (i.e. not taking the state as an object of; hierarchical related) and necessarily precedes any reflection of it. Detachment, they suggest, is rather caused by the loss of "transparency" (i.e. "not requiring explicit attention") to this intrinsic self-awareness. We argue that this notion of "transparency" is obscure in its neurocognitive mechanism given that explicit and implicit representations are fundamentally distinct and that being able to lose "transparency" should entail it being either extrinsic to the conscious state or rather a hierarchically binding element instead of a same-level feature. Aligning with the latter possibility, the higher-order thought (HOT) theory has previously suggested that this type of self-awareness is transitive as it is intrinsic to a phenomenal conscious state which has to constitute a higher-order representation of a first-order state. Liang & Lane (2010) held an unresolved objection to HOT with the case of somatoparaphrenia (the loss of ownership to the body), which we here agree with but further note that Rosenthal's response does not explain other forms of detachment such as emotional numbness. Conversely, we argue that detachment can be explained under the framework of the higher-order representation of a representation (HOROR) theory, which assumes transitivity but also reflectivity of the type of self-awareness concerned. Specifically, HOROR suggests that for a phenomenally conscious state to encode self-awareness, it requires self-referential mental content (e.g. autobiographical memory schema) to be integrated with the first-order state in the re-representational process. The same integration process is also required for certain phenomenal qualities of emotional experience (LeDoux & Brown, 2017). From this perspective, detachment could essentially be accounted for by the disruption in retrieving self-referential information. Key References: Lane, T., & Liang, C. (2010). Mental ownership and higher-order thought: response to Rosenthal. Analysis, 70(3), 496–501. LeDoux, J. E., & Brown, R. (2017). A higher-order theory of emotional consciousness. Proceedings of the National Academy of Sciences, 114(10). Ciaunica, A., Charlton, J., & Farmer, H. (2021). When the window cracks: Transparency and the fractured self in depersonalisation. Phenomenology and the Cognitive Sciences, 20(1), 1–19

Emotional Facial Expressions Influence Moral Decisions Without Eliciting Conscious Feelings

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Poster Session 1, Wednesday July 3rd, Ito International Research Center, 10:00AM-11:00AM

Research shows that emotions can influence behavior without being represented in phenomenal consciousness. So far, demonstrations of such “unconscious emotions” have been restricted to simple behaviors. For example, subliminal emotional facial expressions influence people’s consumption behavior (Winkielman & Berridge, 2005) or decisions about simple gambles (Winkielman et al., 2022). However, it is unclear whether unconscious emotions can influence complex social decisions, and what are the underlying mechanisms. Current research explored whether unconscious emotions influence choices involving harm or benefits to others using a moral gamble paradigm. Specifically, participants made a series of 21 choices about animal lives. In study 1, the choices were in the Loss domain (i.e., loss of pandas) and in study 2 they were in the Gain domain (i.e., saving of pandas). There were two options in each of 21 trials: A certain option (i.e., sure loss/save of 10 pandas) and a gamble option (i.e., 50% probability of losing/saving 10 pandas, or 50% probability of losing/saving N pandas). We parametrically manipulated N from 10 to 30 across trials to test how emotional influence depends on the option properties. To induce emotions, we used happy, neutral, and angry facial expressions. Each study had two between-subjects conditions: the expressions appeared either suboptimally (nearly subliminally) or unobtrusively (longer presentation time but disguised as a different task). We then measured participants’ decisions. In both studies, we also measured subjective feelings to examine if induced emotions were conscious and played a role in decisions. We found that expressions influenced decisions. In the loss domain, suboptimal and unobtrusive smiles (vs. frowns) robustly increased the choice of the risky over the certain options. Interestingly, in the gain domain, the effect was opposite in direction and smaller in size – smiles (vs frowns) slightly decreased risk taking. This pattern suggests that our results reflect a combination of two separate mechanisms linking affect and risk. The first mechanism involves positive affect enhancing salience of the gamble’s upside, promoting risk-taking. The second mechanism involves smiles endorsing default risk tendencies. According to Prospect Theory (PT), in the loss domain people are risk-seeking by default. Consistently, we found that smiles robustly enhance risk-seeking. In the gain domain, PT states that people are risk-averse. Consistently, smiles enhanced risk-aversion, though to a lesser extent. Furthermore, the influence of unconscious emotions depended on choice properties: expressions had a greater influence on choices among options with similar values rather than dissimilar values. Finally, affective influences on decisions were dissociated from conscious feelings. Specifically, in the suboptimal condition, emotional faces had no significant effects on valence ratings. The only significant effects on valence were in the unobtrusive condition (H > N in gains, H > A in losses) but even then they were unrelated to choices. Moreover, expressions had no significant effects on arousal ratings across both suboptimal and unobtrusive presentation conditions. Overall, this pattern suggests that affective influences on choice are unconscious, or dissociated from conscious feelings. Presumably, the influence of emotion on moral decisions may involve low-level, implicit route.

Conscious AI: Artificial Consciousness Meets Ethical Awareness

Aïda Elamrani (University of Washington), Guido Manzi (IndeepAI), Michael Graziano (Princeton University)

Poster Session 2, Wednesday July 3rd, Ito International Research Center, 4:00PM-5:00PM

The metaphysical questions about consciousness continue to be debated. Yet, artificial intelligence is making fast progress which often intersects with neuroscience. The computational functions which are typically associated with human consciousness are increasingly being imitated in artificial agents. The ubiquity of these new agents, and the unforeseeable societal transformation they bring, has justifiably raised serious ethical concerns since the very inception of the field.

More recently, Foundation Models have marked a new milestone in the ethical agency of AI. Particularly, Large Language Models display the capacity to formulate plausible ethical judgements, which effectively sets them as explicit ethical agents according to foundational definitions in machine ethics. The next step, full ethical agents, is achieved through human-grade mentality. As AI transitions to Artificial Consciousness (AC), it becomes imperative to assess the ethical impact of such agents. Given the lack of consensus within the scientific study of consciousness, two cases need to be considered: AC with phenomenal experience (strong AC), and purely functional AC with no sentience (weak AC). We seek to evaluate the risks and opportunities posed by these agents.

Through a thorough review of the literature, as well as from novel arguments, we find that most of the risks are either rooted in the fear of causing artificial suffering, or of mishandling superintelligence. These concerns are also igniting a debate over the moral status of artificial agents and whether such potential competitors are desirable in the current global geopolitical and ecological context.

In comparison, we find the case of opportunities from AC more compelling. Firstly, as was emphasised before, research in AC is not necessarily seeking to build agents endowed with phenomenal experience. Secondly, under the metaphysical assumption that such states could be obtained from electronic computers, AC technologies do not necessarily entail the implementation of algedonic or valenced states. Furthermore, several worries attributed to AC are already raised by AI regardless of the dimension of consciousness. More crucially, we show that such systems hold the conditions to solve key ethical issues stemming from current AI, notably through the computation of advanced cognitive functions such as empathy and understanding. Critically, we cannot ignore that such research is inevitable, and should be carried transparently rather than in isolated, hidden labs.

To conclude, we argue for a dual meaning of Conscious AI, where artificial consciousness mirrors ethical awareness. Conscious AI seeks a harmonious alignment of advanced cognitive technologies with human values. This vision paves the way for a future where AI is not only designed to think but also to care, amplifying our humanity rather than diminishing it.

Building a common platform for the systematic combining of different types of ontologies specific to various disciplines in order to study the subject of cognition and experience from constructivist approach science

Akito Fujino (University of Washington)

Poster Session 2, Wednesday July 3rd, Ito International Research Center, 4:00PM-5:00PM

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We have cognition and experience. The subject of these actions is called “I” in ordinary language. How does this “I” have cognition and experience?

What can we answer to this question based on the facts about the Homo sapiens body that have been studied in life sciences and cognitive neuroscience? Every science has its own ontology. These unique ontologies are unique constructs of each science, built on a unique epistemology. From the perspective of Natural Computation[1], the universe is a computer that compute its next state.(Natural computation is a worldview advocated by Masami Hagiya and colleagues that views things, including the entire universe, as a set of data and commands.) This universe computation is a kind of power balance game. The Natural Computation could be the foundational epistemology for the question. When viewed from the perspective of the universe as an analog computer that computes the power game of things with such complex interrelationships and seeks its own next state, the “I” is supposed to be a part of it. In such a computational universe, how can we describe accurately the “I” (as The Ordinary Language School philosophers call it, the special thing that is the subject of a sentence, and the subject of actions, emotions, experiences, cognition, and sensations) ? In other words, how is “I” being implemented in living body from the perspective of Natural Computation? How could we describe the implementation that nature has done? To answer these questions, we need a factually accurate description of “I” from the perspective of various empirical sciences (Physiology, Anatomy, Molecular Biology, Thermodynamics,etc.).

We report on the effectiveness of the construction of some ontologies with some kind of computability as a theoretical platform for such descriptions. It could be an effective solution. One possible concrete implementation form for such an ontology is a computable ontology based on Embodiment, Enaction, and Action Theory (in Philosophy) and the Network Thermodynamics[2]. And we also report on some problems that inevitably arise in the construction of such ontology that has computability that simultaneously satisfies several conditions required for describing facts obtained from various academic studies.

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Neural markers of Shared Conscious Experiences in Classical Music Improvisation

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Poster Session 2, Wednesday July 3rd, Ito International Research Center, 4:00PM-5:00PM

From teamwork in professional environments to the shared experiences within close-knit communities, or even in moments of collective celebration and solidarity, human life is rich of situations in which individuals experience heightened states of interconnectedness and shared awareness within a group. In the realm of classical music, a notable example of such a shared experience is group improvisation performance, consisting of a collaborative process where musicians create music spontaneously in real time without predetermined compositions or arrangements. This multifaceted practice requires a high level of musical skill, creativity, and communication among the performers, fostering a sense of connection and synergy within the group. During these exhilarating experiences, performers claim to enter a state of flow where they are fully absorbed in the present moment and deeply connected to the music and each other. This study aimed to characterize such an improvisational state of mind and heightened consciousness level using quantitative measures from information theory, examining the EEG data of a cellist and pianist improvising together. Specifically, we investigated the differences between the so-called strict and letgo modes of playing: the former involves a close adherence to traditional structures of classical music, maintaining a disciplined approach to rhythm and melody, while the latter suggests a more free-form and risk-taking approach to spontaneous improvisation.

We examined and compared these contrasting musical paradigms with various metrics, including Complexity via State-Space Entropy Rate (CSER), Cluster Entropy, and Stochastic block networks. Firstly, we observed a significant difference in neural complexity, with increased signal complexity in the letgo mode. Additionally, we explored information communication within and across the two brains, finding that letgo performances entail diverse brain regions cooperating cohesively together, while brains during strict pieces are characterized by a larger number of small interdependent communities. Finally, the subjective experience of the musicians aligned with the quantitative results in what we term moments of togetherness - special passages in the music where performers felt a particularly enhanced affinity with each other. In fact, these moments matched with an increased information transfer and brain cooperation across the two brains.

These findings underscore increased neural signal diversity and interdependence during improvised musical performances, providing quantitative support for musicians' personal and collective experiences, and suggesting novel methodological approaches for characterizing shared conscious experiences.

"EEG connectivity markers of 'pure awareness' experience during Transcendental Meditation"

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Poster Session 2, Wednesday July 3rd, Ito International Research Center, 4:00PM-5:00PM

Transcendental Meditation (TM) is a popular mantra-based contemplative practice explicitly designed to access and maintain transcendent states [1]. TM proponents posit that a reduction in mental and physical activity through mantra repetition engenders an experience of "pure awareness", described as "self-awareness isolated from the processes and objects of experience characterized by the absence of the very framework (time, space, and body sense) and content (qualities of inner and outer perception) that define waking experiences" [1,2]. Here, we describe the largest EEG study to date investigating the experience of "pure awareness" during Transcendental Meditation. EEG was recorded on 40 experienced meditators with at least 5 years of regular practice (twice a day, 20 minutes per session), and on 40 controls (i.e. non-meditators individually matched by age and sex). Although empirical evidence indicates that "pure awareness" increases frontal coherence in the alpha band (9-11 Hz) [3], other potential connectivity markers capturing neural integration have not been explored. The current study tries to fill this gap using a newly developed computational library that directly computes >250 bivariate connectivity metrics (the PySPI toolbox [4]). While meditators were instructed to practice TM for 30 minutes with eyes closed, controls performed a counting task in silence for 30 minutes. We also recorded 10 minutes of resting-state baseline before and after meditation and counting. We focused on connectivity metrics that capture distinct modes of neural communication: information theoretical metrics (e.g. Transfer Entropy, Directed Information, WSMI), which captures neural dynamics associated with information integration and transfer, and spectral connectivity metrics based on neural synchrony (e.g. Coherence, PLI, Granger Causality) which captures rhythmic neural regimes associated with more stationary, stable dynamics [5]. PySPI computes the interaction of each channel with the set of 128 others, one by one, for each statistical method. Critically, we constructed classifiers for each channel pair and each bivariate measure, for these 10 meditators and then evaluated the performance of these classifiers on a further set of N=30 unseen meditators. Our conclusion was based on this N=30 generalization results. Our preliminary analyses showed that information theoretical metrics outperformed spectral connectivity metrics in classifying meditators from controls, and meditators from their baseline. Our results expand our current understanding of the neural markers of transcendental states of consciousness. [1] Travis F. Transcendental experiences during meditation practice. Annals of the New York Academy of Sciences. 2014; 1307(1):1–8 [2] Vieten C, Wahbeh H, Cahn BR, MacLean K, Estrada M, Mills P, et al. (2018) Future directions in meditation research: Recommendations for expanding the field of contemplative science. PLoS ONE 13(11): e0205740. [3] Travis F, Tecce J, Arenander A, Wallace RK. Patterns of EEG coherence, power, and contingent negative variation characterize the integration of transcendental and waking states. Biological psychology. 2002; 61(3):293–319. [4] Cliff, O. M., Lizier, J. T., Tsuchiya, N., & Fulcher, B. D. (2022). Unifying Pairwise Interactions in Complex Dynamics (arXiv:2201.11941). arXiv. https://doi.org/10.48550/arXiv.2201.11941 [5] Vinck M, Uran C, Spyropoulos G, Onorato I, Broggini AC, Schneider M, Canales-Johnson, A. Principles of large-scale neural interactions. Neuron 111: 987–1002 (2023).

Agitation as a predictor of clinical outcome in Disorders of Consciousness

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Poster Session 2, Wednesday July 3rd, Ito International Research Center, 4:00PM-5:00PM

Introduction Agitation can be defined as inappropriate behaviours that are not associated with delirium and can disrupt everyday tasks and care. It is very frequently observed in patients with severe brain injury. Some studies have shown that agitation may be associated to outcome and recovery of consciousness. However, these studies included mixed populations (i.e. patients with and without disorders of consciousness, DoC) or did not use the recommended tools to measure consciousness levels (i.e., the Coma Recovery Scale-Revised, CRS-R). In this study we investigate the possible prognostic value of agitation in a cohort of patients of DoC. Methods We performed a retrospective analysis exploring the association between agitation and outcome at 24 months in a sample of patients (n=119) with prolonged (>28 days) DoC. Agitation was measured at admission with the Overt Agitation Severity Scale (OASS); outcome was measured with the CRS-R and the Disability Rating Scale (DRS). We performed three main analyses to investigate our hypothesis: i) how demographic and clinical data differed as a function of diagnosis and etiology; ii) how OASS subscores differed as a function of diagnosis and etiology; iii) how demographic and clinical data predicted outcome at 24 months follow-up with a logistic regression model. Results We included 119 patients (Unresponsive Wakefulness Syndrome, UWS=62, Minimally Conscious State, MCS=57). We found that, overall, patients in a MCS showed significantly higher OASS scores in the upper and lower limb subscales, compared to patients in an UWS ($p<.001$ and $p=.007$, respectively). Patients who had emerged from the MCS (eMCS) at 24 months (n=41) follow-up showed significantly higher OASS scores, higher CRS-R Index and lower DRS scores at enrollment (all $p<.05$). Patients in MCS at enrollment who were eMCS at 24 months also showed significantly higher OASS scores ($p<.002$) and CRS-R Index ($p<.010$). Moreover, our logistic regression model (80.7% accuracy) found that traumatic etiology, higher CRS-R Index scores and higher OASS scores increased the probability of a more favourable outcome at 24 months. Discussion and Conclusions These results suggest that agitation is associated with favorable outcome in DoC. The neural mechanisms underlying agitation are not fully understood. Nevertheless, it was hypothesized it might arise from neural dysregulation and network remodeling; which might explain the role of agitation with the positive outcome observed in our study. The association between higher level of consciousness and agitation of upper and lower extremities, but not in vocalization or oro-facial movements, can be explained by the overlap that may exist between these items of the OASS and the conscious motor behaviors evaluated by the CRS-R (e.g., automatic oriented movements). Many studies on prognosis have shown that high CRS-R scores and other factors such as young age and traumatic etiology are predictors of more favorable outcomes. To our knowledge, this study provided first evidence of agitation as a diagnostic and prognostic factor for patients with DoC. Funding This study was supported by Conselleria d'Innovació, Universitats, Ciència i Societat Digital of Generalitat Valenciana (CIDEXG/2022/15), MSCA RISE FP 2022 101108141, MSCA RISE 2017 DOCMA 778234.

Placebo-suggestion modulates conflict resolution but not visual perception of unambiguous stimuli

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Poster Session 2, Wednesday July 3rd, Ito International Research Center, 4:00PM-5:00PM

To what extent can subjective experience override reality? A striking illustration of such phenomena involves the placebo effect. Placebo effects (as well as the experience of symptoms without pathophysiological disruption) are widely documented in the clinical field and have been shown to influence other aspects of our cognition and behavior. However, the mechanisms and conditions that underlie their influence remain unclear. Especially considering if the latter conclusions can extend to perceptual processing or are confined to post-perceptual decision (i.e., metacognition).

In a first experiment, while controlling interindividual differences of suggestibility, we investigated if a placebo suggestion (sham tDCS described as improving visual processing) can enhance visual perception (orientation and categorization) of unambiguous stimuli with an objective response (two-alternative forced choice). Twenty participants performed the task and the use of a tachistoscope allowed us to compute individual threshold and manipulate it with a submillisecond precision. We found no effect. These results contrast with a positive effect of placebo suggestion on cognitive conflict resolution (Magalhães De Saldanha da Gama et al., 2013) and implicit learning (Colagiuri et al., 2011).

To assess if the effectiveness of a placebo suggestion depends on the properties of the task, we conducted a second experiment. In Experiment 2, 34 participants performed a cognitive conflict resolution task (Stroop task) and the orientation task from our Experiment 1. The placebo suggestion was that an (unknown sham – placebo) tDCS would activate their visual areas so their perception would improve (processing speed and vividness of colors.) They performed both tasks in a control session and a placebo session (within-subject design).

For the Stroop task, which involves conflict resolution, inhibition and flexibility, it was found that the effect of the placebo (sham tDCS) stimulation significantly improved the latency of reaction times for all three conditions and decreased the number of errors made on incongruent trials only (i.e., conflict monitoring). For the orientation task, in submillisecond duration, the effect of the stimulation (placebo) had no effect on either the latency of reaction times or the accuracy. Moreover, Bayesian evidence supports these latter conclusions.

This study demonstrates that placebo does not have the same effect on a high-level cognitive conflict task and on a lower-level perceptual task. We provisionally conclude that placebo suggestion appears to influence perceptual processes and cognitive control processes differently.

The effect of preferred music and binaural beats on the detection of consciousness signs in patients with severe acquired brain injury

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Poster Session 2, Wednesday July 3rd, Ito International Research Center, 4:00PM-5:00PM

Background: Previous studies including patients with disorders of consciousness (DoC) showed that music enhanced arousal and attention when compared to white noise or disliked music or when compared to a control non-musical auditory stimulus, suggesting a potential impact of music therapy on consciousness recovery. Recent (German) treatment guidelines actually started recommending music therapy for DoC patients. Another interesting potential sensory stimulation is binaural beats. Binaural auditory beats are a perceptual phenomenon that occurs when presenting separately to each ear two tones that slightly differ in their frequency. It has been suggested that binaural beats can influence cognition. A recent meta-analyses based on 22 studies showed an overall medium, significant, consistent effect size, particularly on attention. Such stimulation has nevertheless never been investigated systematically in patients with disorders of consciousness. Objective: In this project, our aim was to compare, for the first time, the short-term effect of preferred music vs. binaural beats on DOC patient's responsiveness. More specifically, our hypothesis was that listening to patient-preferred music would lead to an increase in behavioral responsiveness as compared to baseline and that listening to binaural beats (with Beta waves, 20-30hz) would produce different results (either lower or higher responsiveness) as compared to patient-preferred music. Methods: A within subject design was used with one session and 2 conditions (beats and music) presented in pseudo-randomized order between subjects. Stimuli were presented in one single contact using earbuds at the patients' bedside. Frequencies of behavioral responses were recorded at baseline and after each condition using selected items of the Coma Recovery Scale-Revised (CRS-R). Results. Seventy-seven patients (24 VS, age: 51+/-20, 41 males, 27 Anoxia, TSI: 0.4-8y) were recruited for this study. Non parametric statistical tests were used since data were not normally distributed. Comparing the three conditions using Friedman tests revealed several trends but significant effects were obtained for variables related to arousal only. Comparing conditions using Conover post-hocs, higher arousal and more frequent response to command were observed only in response to music vs. baseline as well as more frequent visual tracking, particularly, in non-anoxic etiology, in response to music vs. baseline. Very interestingly, when using preferred music (in less extent beats), we found a misdiagnosis of 21% (5/24) in VS and 29% (4/14) in MCS- (due to response to command) when compared to baseline without stimulus presentation. Conclusion. According to our results, preferred music (and not binaural beats) seems to promote arousal but also improves the detection of important signs of consciousness (such as response to command and visual pursuit/fixation)

Deep CANALs: A Deep Learning Approach to Refining the Canalization Theory of Psychopathology

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Poster Session 2, Wednesday July 3rd, Ito International Research Center, 4:00PM-5:00PM

Psychedelic therapy has seen a resurgence of interest in the last decade, with promising clinical outcomes for the treatment of a variety of psychopathologies. In response to this success, several theoretical models have been proposed to account for the positive therapeutic effects of psychedelics. One of the more prominent models is "RElaxed Beliefs Under pSychedelics" (REBUS), which proposes that psychedelics act therapeutically by relaxing the strength of maladaptive high-level beliefs encoded in the brain. The more recent "CANAL" model of psychopathology builds on the explanatory framework of REBUS by proposing that canalization (the development of overly rigid belief landscapes) may be a primary factor in psychopathology. Here, we make use of learning theory in deep neural networks to develop a series of refinements to the original CANAL model. Our primary theoretical contribution is to disambiguate two separate optimization landscapes underlying belief representation in the brain, and describe the unique pathologies which can arise from the canalization of each. Along each dimension, we identify pathologies of either too much or too little canalization, implying that the construct of canalization does not have a simple linear correlation with the presentation of psychopathology. In this expanded paradigm, we demonstrate the ability to make novel predictions regarding what aspects of psychopathology may be amenable to psychedelic therapy, as well as what forms of psychedelic therapy may ultimately be most beneficial for a given individual.

From Paranoid to Non-Paranoid Schizophrenia: Comparative Analysis of Whole-Brain Dynamic Functional Network Connectivity, Meta-State Parameters and Power Spectra

Behnaz Jarrahi (University of Washington)

Poster Session 2, Wednesday July 3rd, Ito International Research Center, 4:00PM-5:00PM

Paranoid schizophrenia is a subtype of schizophrenia that is often manifested by abnormal perceptual experiences such as paranoia, delusions, and hallucinations. These symptoms may reflect certain disruptions in an individual's "stream of consciousness," a continuous flow of thoughts mediated by the activity of different brain regions. The stream of consciousness is not static; instead, it exhibits time-resolved fluctuations, especially prominent in the resting state or the brain's baseline condition. These fluctuations may carry important information about the unique ways in which paranoid schizophrenia disturbs thought processes and sensory perceptions. In this study, we compared the temporal properties of brain networks in patients with and without paranoid schizophrenia. We leveraged the publicly available schizophrenia dataset from the Center for Biomedical Research Excellence (COBRE). The dataset included 69 schizophrenia patients (13 females, 18-65 years old age range) diagnosed based on the Structured Clinical Interview for DSM Disorders. 41 patients in this cohort were classified as paranoid schizophrenia while the remaining patients exhibited other subtypes including residual, disorganized, catatonic, and schizoaffective. To examine the dynamics of spontaneous brain activity at rest, we employed the dynamic Functional Network Connectivity (dFNC) method based on group-independent component analysis (GICA) of resting state fMRI data. We estimated the number of clusters using Akaike's Information Criterion (AIC) and computed dFNC using sliding time window correlation and k-means clustering of windowed correlation matrices. Furthering our analysis with k-means, we examined meta-state metrics including the unique windows, state changes, state span, and total travel distance between successive meta-states. Fast Fourier Transform (FFT) technique was also applied to resting state network time courses to assess the BOLD spectral power. The results indicated alterations in dynamic connectivity across distinct resting state networks in the paranoid subtype, including the subcortical, central executive, precuneus, visual, salience, and sensorimotor networks. Specifically, compared to non-paranoid patients, the paranoid subtype exhibited increased dFNC between the amygdalohippocampal network and a higher visual network but reduced dynamic connectivity between the right-lateralized central executive network (frontoparietal area) and precuneus network (Bonferroni-corrected $p<0.05$). Crucially, there were also significant between-group differences in the span of meta-states (i.e., maximum L1 distance between states) and the sum of L1 distances between successive meta-states, with no observable differences in dwell time. The spectral group comparison further revealed significant shifts in the power spectra of the subcortical and visual networks in the paranoid subtype, at the mid to high-frequency bands. By exploring the temporal variations in brain networks, this study provides new insights into the nature of consciousness alterations in paranoid schizophrenia.

Through Others We Become Ourselves: Simulating the Emergence of Self-Esteem and Group Dynamics of Socio-emotional Deep Active Inference Agents

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Poster Session 2, Wednesday July 3rd, Ito International Research Center, 4:00PM-5:00PM

In this study, we explore the replication of human-like sociality within artificial environments, particularly focusing on how social interactions influence one's subjective sense of self and others over time. Utilizing deep-parametric active inference, we develop a Bayesian model to simulate the dynamics of esteem among socio-emotional agents. This model allows agents to form esteem through interactions that reflect subjective fitness estimates, influenced by social cues. This process embodies Lev Vygotsky's notion that "Through others, we become ourselves," highlighting the role of social exchanges in shaping one's experience. Our simulations employ advancements in deep-parametric allostatic control and affective inference to create a virtual grid world. Here, agents seek social affirmation by engaging in conversations, where they share opinions about themselves and others. This interaction fosters a varied social landscape, marked by the emergence of influencers, outsiders, and cohesive social cliques. Thus, we demonstrate the intricate relationship between the need for affirmation and the formation of social structures, showcasing how computational models can mirror human development in becoming "aware" of others, and as such, of themselves. By highlighting the spontaneous organization of social cliques and the significance of esteem in these virtual societies, our findings offer insights into the mechanisms of "self"-development and the inherently social nature of consciousness, bridging human psychological phenomena and artificial intelligence. This approach not only enriches our understanding of social dynamics but also provides a foundation for further investigations into the complex interplay between individual and collective consciousness within agent-based systems.

Decomposing thermodynamic dissipation of neural dynamics via spatio-temporal oscillatory modes

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Poster Session 2, Wednesday July 3rd, Ito International Research Center, 4:00PM-5:00PM

Recent developments in stochastic thermodynamics have elucidated various relations between the entropy production rate (thermodynamics dissipation) and the physical limits of information processing in non-equilibrium dynamical systems, which have been actively used and opened new perspectives in the analysis of real biological systems. Even in neuroscience, the importance of quantifying the entropy production has attracted increasing attention to understand the properties of information processing in the brain. However, the relationships between entropy production rate and neural oscillations, such as delta, theta, and alpha waves, which are prevalent in the brain, are unclear. Here, we derive a novel decomposition of the entropy production rate. We show that one of the components of the entropy production rate, called the housekeeping entropy production rate, can be decomposed into independent positive contributions from spatio-temporal oscillatory modes. Our decomposition enables us to calculate the contribution to the housekeeping entropy production rate from oscillatory modes, as well as the spatial distribution of the contributions. To demonstrate the utility of our decomposition, we applied our decomposition to the electrocorticography (ECoG) dataset recorded during awake and anesthetized conditions, where the properties of oscillations change drastically. We showed that the contributions of oscillatory modes from the delta band were larger in the anesthetized state than in the awake state, while those from the theta and alpha bands were smaller. These results allow us to interpret the change in the neural oscillation in terms of stochastic thermodynamics and the physical limit of information processing.

Visceral cortical neurons induce disgust reactions in mice

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Disgust represents a fundamental negative emotion, elicited by ingesting unpalatable food and exposure to excrement, among other stimuli, and appears to have been evolutionally conserved as a mechanism to avoid potentially toxic or pathogenic substances. In mice, disgust elicited by intraoral stimuli is believed to be expressed as disgust reactions in taste reactivity, characterized by orofacial and somatic movements elicited in response to taste stimuli such as bitter substances. Although it has been shown that pharmacological inhibition of the posterior ventral pallidum induces disgust reactions, the neuronal excitation responsible for inducing such reactions remains elusive. Here we show that the activity of visceral cortical excitatory neurons induces disgust reactions. Using whole-brain activity mapping and *in vivo* calcium imaging during free behavior, we identified the neuronal activity in the visceral cortex, proximal to the proposed hedonic hot spot, is associated with the occurrence of disgust reactions. While optogenetic activation of the visceral cortical neurons alone failed to induce disgust reactions, combined with intraoral water infusion, it induced significant disgust reactions. The optogenetically induced disgust reactions were associated with the expression of the phosphorylated pyruvate dehydrogenase, a molecular marker of neuronal activity inhibition, in the posterior ventral pallidum. The visceral cortical neurons projected to various brain regions, including the interstitial nucleus of the posterior limb of the anterior commissure and the central nucleus of the amygdala, but not to the ventral pallidum. Our findings suggest that the visceral cortical neuronal activity is associated with and is sufficient to induce disgust reactions against intraoral water. The simultaneous activation of these neurons and neurons coding intraoral water may induce disgust reactions by inhibiting the posterior ventral pallidum via indirect neuronal connections. The present study proposes a causal link between the activity of the visceral cortical neurons and the experience of disgust.

Psilocybin, Global Functional Connectivity, and Inter Subject-Object Connection

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Poster Session 2, Wednesday July 3rd, Ito International Research Center, 4:00PM-5:00PM

Introduction and Background The experience of connection and relatedness is central to emotional well-being. This study explores psilocybin's effects on feelings of unity and its link with global functional connectivity (GFC) alterations in the brain, a relatively uncharted territory in psilocybin research on inter subject-object connection. Utilising fMRI data from the most comprehensive psychedelic imaging dataset, we examined GFC changes in 60 psychedelic-naive individuals across different fMRI sequences—eyes-closed rest, meditation, music, and eyes-open naturalistic stimuli—before and after ingesting 19mg of oral psilocybin. Methodology Our analysis accounted for subjective experience variability and the timing of these experiences to assess how differences in the sense of unity influence mindset and GFC patterns. We used the Freesurfer left-right-symmetric cortical surface template with ~32k vertices to provide a detailed view of functional connections across the brain, facilitating a high-resolution examination of GFC alterations. Our findings' consistency with prior psychedelic studies was also evaluated, using analyses with and without global signal regression to validate our results. Findings Unity experiences, quantitatively measured using the Altered States of Consciousness scale (11D-ASC) post-psilocybin, showed a strong association with significant enhancements in intersubjective mindset qualities and psychological well-being reported the following day. Notably, sensory effects like hallucinations had minimal correlation with mindset alterations, underscoring the unique impact of unity experiences. Additionally, shifts from eyes-closed to eyes-open MRI sequences after psilocybin intake correlated with marked GFC increases, pointing to the significant role of sensory input on functional brain connectivity under psilocybin. Implications and Future Directions Our research illuminates how different brain regions co-activate during unitive experiences and across varying scan sequences under psilocybin influence. Highlighting the potential of single psilocybin use in enhancing connection and mindset among healthy adults, our study also tackles the challenge of correlating subjective experiences with GFC changes. This effort is vital for advancing our understanding of GFC patterns under psychedelics and the overall impact of psychedelics on brain function. Leveraging the most extensive psilocybin dataset currently available, our study not only elucidates the phenomenological structure of these unitive experiences but also explores the therapeutic possibilities of psychedelics. It emphasizes the importance of optimizing sensory environments in psychedelic-assisted therapies, taking into account the holistic interplay of environmental, psychological, and neurobiological factors. Ultimately, our work contributes to the ongoing discussion about the therapeutic potential of psychedelics, highlighting how they can improve emotional well-being by transforming the way individuals relate to themselves, others, and the world, while revealing insights into the neural underpinnings of subject-object relationships.

The Acting Self: measuring self-other prefrontal cortex activations and self-character distances in actors during a monologue performance

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Poster Session 2, Wednesday July 3rd, Ito International Research Center, 4:00PM-5:00PM

Background: One way to measure the sense of self is by measuring medial prefrontal cortex (mPFC) activation when hearing your own name compared to other names. Therefore, we measured actors' mPFC responses to hearing their own, character and stranger names during acting and non-acting conditions. Participants: 38 UK-based professional actors with 2+ years of industry experience. Equipment/Measures: Shimadzu (Japan) LIGHTNIRS functional near-infrared (fNIRS) system with 22 channels across the PFC. Biosignalsplux (Portugal) physiology system was used to measure breathing rate. We developed a 28-item questionnaire with responses coded on a 1 (strongly disagree) - 5 (strongly agree) and 0 (not at all) – 100 (complete overlap) Likert scale about the actor's preparation of their monologue, how their experience may have differed from their stage/film performance and similarities with their character. We also asked the actors an additional 5 open-ended questions to obtain in-depth responses about their characterisation techniques, whether there is a distance between self and character, and their experience of performing in a lab environment. The open-ended questions were analysed using thematic content analysis. Procedure: Actors performed a monologue, coloured in a mandala colouring book (control), and read aloud from a telephone book (control). Each of these three tasks were conducted whilst seated, lasted 2 minutes and were repeated 4 times in the same listed order. During each task, the actor's first name, character name and a stranger's name (control) were called out from a speaker at pseudo-random time intervals between 17-22 seconds. The recording session lasted 24 minutes. The interview segment followed this and lasted 20 minutes. Neural Findings: The channel associated with the mPFC that had significant findings was Channel 4, which revealed higher brain activity during the monologue condition compared to control conditions, as well as, higher activation of actors hearing their own name compared to the stranger name during the monologue condition. Channel 4 also had higher activation when actors heard their own name in the monologue condition compared to the telephone book (control) condition. Interview Findings: 32 actors reported that they try to minimise the distance between themselves and their character, especially on an emotional level. 19 actors reported that it is not possible to fully become the character, and that distance enables them to let go after performing the role. Distance is also preferred for the actor's safety when a character is morally bad. When there is minimal distance between themselves and the character there is still a part of their consciousness that is self-aware and occupied with practical considerations e.g., stage awareness. Regarding the experimental set-up, actors reported that not having a live audience as well as restricted movement affected their distance from the character. Conclusions: Higher own name activation during the monologue condition compared to stranger name could be due to an increased level of self-awareness during a performance. Overall, the method of acting training and character morality affects the distance between the actor's self and their character.

Learning to suppress a distractor does not depend on working memory resources

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Poster Session 2, Wednesday July 3rd, Ito International Research Center, 4:00PM-5:00PM

Over the last decade, the additional singleton task has been widely used to study visual statistical learning. In this paradigm, participants are instructed to find a target while ignoring a series of distractors. In some trials, a salient singleton distractor is added to the search display, making the task more difficult. However, if the singleton appears more frequently in one particular location of the display, participants eventually learn to suppress attention towards this location. It has been suggested that this type of learning is probably implicit and independent of working memory (WM) resources. To our knowledge, only one study has explored the impact of WM in suppression effect (Gao and Theeuwes, 2020). However, there are reasons to suspect that the amount and type of WM load used in that study may have been suboptimal to detect any effects on distractor suppression. The aim of the present study was to explore the impact of WM load on distractor suppression addressing these issues. Contrary to our expectations, our results confirm that this type of learning is indeed highly resilient even to strong manipulations of working memory load.

Does effort change my mind

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Poster Session 2, Wednesday July 3rd, Ito International Research Center, 4:00PM-5:00PM

Our beliefs shape our understanding of the world and ineluctably influence our decisions and actions. Once a belief is installed, it seems terribly difficult to change it. Debates on climate change and more recently on vaccination convincingly illustrate this reluctance. A good illustration of such belief polarization is offered by the confirmation bias. This holds that people selectively focus on information that is in line with their own belief but ignore contradictory information. The idea of a confirmation bias excels at explaining our behaviour but is by itself not informative about the underlying cognitive mechanisms. We argue that subjective experiences, rather than logical arguments, play a pivotal role in belief updating. Recent work indeed found a relation between the amount of experienced confidence and the size of the confirmation bias. However, the influence of other subjective experiences on belief updating remains unexplored. Here, we investigated how objective task performance and subjective effort ratings relate to belief updating. Participants chose between two options in a random-dot motion task and indicated the amount of effort they invested in making their decision. After that, participants were provided with new information and given the chance to change their opinion. Objective performance on the random dot motion task (rt and accuracy) related to the effort rating in predictable ways. Contrary to earlier findings, however, objective performance was unrelated to frequency of belief updating. Subjective effort but not objective performance predicted whether a participant would change his/her belief. Finally, the more effort a participant invested in his/her decision, the more frequently he/she changed his/her opinion. We conclude that the subjective experience of effort is an important determinant of belief updating and that effort relates inversely to belief change.

Neural Networks Evolved To Maximise Predictive Power Over Their Environment Develop Emergent Dynamics

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Poster Session 2, Wednesday July 3rd, Ito International Research Center, 4:00PM-5:00PM

Introduction: In contrast to the stochastic activity of single neurons, consciousness seems to follow a remarkably stable, self-determining trajectory (Chan et al., 2020). Owing to this paradox of apparent causal autonomy from – despite ontological dependence on – the neuronal scale, consciousness is widely considered a prime example of an emergent phenomenon that is "greater than the sum of its parts" (Luppi et al., 2023). If consciousness relies on emergent dynamics, the question arises: How and why did the brain evolve to accommodate such emergent phenomena? In this study, we test the hypothesis that selection pressure to maximise predictive power over a range of environments may have tuned the architecture of the brain to exhibit emergent dynamics, thereby possibly laying the dynamical foundations required for consciousness. Methods: We measured the emergence of the computational output of recurrent neural networks (RNNs) that were trained to predict the dynamics of seven different chaotic dynamical systems, representing the network's environment. Emergence was measured using the framework of Rosas and Mediano et al. (2020), which posits that macroscale system variables are emergent if they possess self-predictive information that is not contained in the system's parts. The RNNs were trained leveraging the reservoir computing scheme (Platt et al., 2021), which consists of two separate stages of optimisation, herein referred to as training and evolving, respectively: Training involves using standard linear regression to fit the weights of a linear output layer to predict the environmental dynamics from the RNN's neuronal activations. Evolving involves using an evolutionary algorithm to optimise hyperparameters, corresponding to structural properties of the RNN that enable effective training. Importantly, RNNs were evolved with two different objective functions: 1) to maximise prediction accuracy, or 2) to maximise emergence. Results: We discovered a strong relationship between prediction accuracy and emergence, such that evolving RNNs to produce accurate predictions led to greater emergence. Vice versa, evolving RNNs to produce emergent predictions led to improved prediction accuracy. This finding replicated across all tested task environments. Moreover, we also noted a strong correlation of prediction accuracy and emergence during training: gradually including more data points in the linear regression for fitting the output weights yielded increasingly more accurate predictions and, concomitantly, more emergent dynamics. Finally, we investigated whether evolving RNNs to maximise emergence, rather than prediction accuracy, may offer advantages. Interestingly, after evolving RNNs to one particular environment A, accuracy-optimised RNNs tended to outperform emergence-optimised RNNs in predicting the dynamics of the same environment A; Yet, emergence-optimised RNNs demonstrated enhanced transfer to unfamiliar environments, outperforming accuracy-optimised RNNs in predicting the dynamics of a different environment B. Conclusion: Taken together, our study reveals two mechanisms that can account for the development of emergent dynamics in RNNs: Emergent dynamics may result 1) indirectly from maximising predictive power over familiar environments, and 2) directly from emergence-favouring selection pressure to facilitate transfer learning to unfamiliar environments. These findings offer insights into the factors that may have shaped biological brains to accommodate emergent dynamics and thereby possibly provided a necessary condition for consciousness.

An Eastern approach to the qualia problem: Proposing a 4-stage model on the development of consciousness

Hiromitsu Miyata (University of Washington)

Poster Session 2, Wednesday July 3rd, Ito International Research Center, 4:00PM-5:00PM

The qualia problem, a core challenge in consciousness studies, is deemed to highlight a mystery in the endeavor to elucidate the mind in multidisciplinary areas of science including psychology, cognitive science, neuroscience, etc. The qualia problem posits that our experience is inherently subjective, and that it theoretically cannot be uncovered by using objective methods of empirical science. In this presentation, I intend to propose a novel approach to these hard issues of consciousness on the basis of perspectives drawn from Eastern tradition-based mind-body practice and the philosophical insights of Kitaro Nishida. Specifically, internal information-processing models assumed in the cognitive paradigm are inevitably built upon dichotomous divisions such as subjectivity and objectivity, first-person and third-person perspectives, etc. Such dualistic ideas, which generally constitute the core base of modern science, is considered to form the root from which the qualia problem emerges. In contrast, Eastern tradition-based mind-body practices including Zen Buddhism, martial arts, and yoga do not assume such dualism. Instead, these practices initially aim for a pure state of consciousness with no divided or analytical ideas, followed by an attempt to attain higher stages of mind-body integration. Higher mind-body states attained through these practices are represented by the Japanese old phrase *Shin-Shin Ichi-Nyo* (body and mind as one), which makes a good contrast with the Cartesian mind-body dualism. On the premise of these ideas, as opposed to the models assumed in the cognitive paradigm, I propose an alternative, Eastern-perspective-based model on the development of consciousness. Having gained insight from *An inquiry into the good* by Kitaro Nishida (Nishida, 1911), the model assumes 4 stages as follows: Stage 1 is a stage of pure intuition, which involves pure/naïve experience before analytical or dichotomous processes have emerged. Stage 2 denotes to a stage of thinking, characterized by analytical processes of dividing given things into two. Stage 3 is a stage of intention, which involves a motive towards actively integrating the former stages. Finally, Stage 4 is an attained stage of intellectual intuition, at which all former stages have been integrated in highly integrative, harmonious, and/or compassionate ways. We normally reside at Stage 2, but can go down to Stage 1 through mind-body and/or contemplative practices, and again go up to Stage 2 and higher Stages 3 and 4 through more advanced contemplation. Flexible shifts between these stages can occur in practical, instead of theoretical, ways in wider domains of expertise. Based on this model, the qualia problem can be grasped as a thinking of Stage 1 from the standpoint of Stage 2. Furthermore, the problem can cease to exist at around Stages 3 and 4, where subjectivity and objectivity have been integrated as a higher unity. Such “higher extinction” of the qualia problem can be analogous to the solution of the *koan* (paradoxical question) used in Zen Buddhism, which is deemed to encourage practitioners to go beyond normal dichotomous thinking and attain higher spiritual awakening. These ideas may also explain why the qualia has rarely been questioned within the Eastern traditions including Japan.

Inter-subject Synchronisation of Heart Rate is Driven by Narrative Comprehension

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Poster Session 2, Wednesday July 3rd, Ito International Research Center, 4:00PM-5:00PM

Conscious mental states have been linked to interactions between the brain and body. One example of this is the synchronisation of heart rate changes between different individuals who are consciously listening to the same narrative. Although attention to a common stimulus seems crucial for heart rate synchrony, it is unclear what exactly drives the intersubject correlations of heart rate (ISC-HR) observed in the literature. In the work presented here, we explore the effects of narrative coherence on ISC-HR. We collected cardiac data through electrocardiogram (ECG) whilst participants listened to an audiobook. The audiobook was segmented into 1-minute intervals, and each segment was presented under one of two experimental conditions: unscrambled story (maintaining the narrative structure) and scrambled story (where word order is shuffled to impede comprehension). Following each segment, participants answered comprehension and lexical identification questionnaires to track their comprehension and attention levels, respectively. As expected, comprehension scores following scrambled story segments were significantly lower than on the normal, unscrambled segments. Similarly, we found a significant effect of scrambling condition on ISC-HR, with higher ISC-HR during unscrambled narratives, suggesting that narrative-level tracking drives the inter-individual synchronisation of heart rate fluctuations. Nevertheless, ISC-HR was significantly above zero when listening to scrambled, narratively meaningless, segments, indicating a partial influence of low-level acoustic properties on ISC-HR. Separating these contributions, and the neural circuits that drive them, will be valuable to understanding the role of brain-heart interactions in conscious processing. Moreover, ISC-HR could in future serve as a diagnostic tool for evaluating patients with disorders of consciousness (DOC). Currently, clinical assessments of awareness rely on purposeful behaviours, risking misdiagnosis of overtly unresponsive patients. ISC-HR appears to be a valuable marker of conscious processing of narratives and therefore may serve as a useful physiological marker of residual cognition in patients, thereby addressing limitations of current diagnostic approaches.

Critique of Empirical Theories in Consciousness under Phenomenological Practice

Hongju Pae (University of Washington)

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Consciousness, which is inherently entwined with subjectivity, presents a significant challenge in formulating an operational definition, thereby complicating its scientific investigation. This complexity has led to a division in the definition of consciousness: (a) qualia, which refers to subjective and private experiences, and (b) awareness, which is more amenable to empirical experiments due to its observable nature. However, such dichotomy overlooks the essence of consciousness, which cannot be naively reduced into either category. Phenomenal consciousness and access consciousness are in an inseparable relationship, and only when both are explained under a single framework can we truly say we have understood consciousness. To truly initiate a meaningful exploration of consciousness, we must revisit how the phenomenon of consciousness unfolds itself to us: Back to the Consciousness itself.

This presentation leverages phenomenology to display the holistic nature of consciousness. I propose four properties of consciousness discovered by phenomenological practice: (1) Pre-reflective self-acquaintance, (2) Being contextually and environmentally situated, (3) Spatio-temporal expandability, and (4) Ability to focus volitional attention toward intentional matter. While phenomenology may not be the definitive golden rule elucidating all aspects of consciousness, it is imperative not to overly simplify the conscious experience by being preoccupied and fixated on one's theoretical orientations.

Subsequently, I introduce and discuss how the four prevailing empirical theories within the contemporary discourse of the science of consciousness address the given properties of consciousness. This inquiry will critically assess the Global Neuronal Workspace Theory (GNWT), Higher-Order approaches, Integrated Information Theory (IIT), and approaches within the Predictive Coding and Active Inference paradigm, focusing on the specific aspects of consciousness each theory aims to elucidate.

GNWT and Higher-Order Theories originate from a similar premise of reductionist perspective, sharing both their strengths and limitations. Reducing consciousness into functional property tends to offer convenience in experimental design and interpretation, yet, if such a reductionist link between the explanandum and explanans turns out to be incorrect or the explanandum to be inherently irreducible, we risk missing the entirety of the explanandum.

In contrast to other theories of consciousness that establish their foundations on a reductive interpretation of experience through discoveries of neural correlates, IIT's approach employs a methodology that originates from the phenomenal characteristics of experience. Consequently, IIT may stand as the sole theory capable of elucidating the qualia. However, while fixated on qualia, IIT fails to explain other important aspects of consciousness, such as intentionality and pre-reflective self-acquaintance.

Predictive Coding and Active Inference approaches endeavor to illuminate the contextual interactivity between the external world and consciousness through frameworks such as embodied cognition are undertaken, it is regrettable that these efforts inherently presuppose an internal-external dichotomy as a pivotal framework, thereby encumbering their potential.

By demonstrating the possibility of synthesizing the categories of consciousness that each of these theories seeks to explain, I assert a need for a more inclusive empirical study of consciousness that expands our understanding of its multifaceted nature. Instead of competing with each other, different theories of consciousness should, more than ever, be integrated.

A homeostatic whole-brain model to study diverse states of consciousness

Ivan Mindlin (University of Washington), Ruben Herzog (Paris Brain Institute), Jacobo Sitt (Paris Brain Institute), Rodrigo Cofre (Institute of Neuroscience, Paris-Saclay)

Poster Session 2, Wednesday July 3rd, Ito International Research Center, 4:00PM-5:00PM

Current advances in experimental and theoretical neuroscience have successfully described different states of consciousness based on brain activity. However, given the unfathomable complexity of the brain, there is still a big gap between neural mechanisms and descriptions. One approach to bridge this gap is the use of whole-brain models. One strategy to narrow this gap involves employing whole-brain models that can replicate brain-like activity. By fitting them to real-world data or conducting virtual experiments, we can elucidate mechanistic explanations for the emergence of a brain state. The Dynamic Mean Field (DMF) is a realistic model used to propose neural mechanisms for various states of consciousness, including wakefulness, anesthesia, disorders of consciousness (DoC), and the psychedelic state induced by LSD. While widely used, the DMF struggles to produce metastable or bistable dynamics, limiting the range of states it can model. To overcome this, we introduce a homeostatic plasticity rule on inhibitory synapses, creating a more parsimonious parameter space where both metastable and bistable dynamics can emerge, eliminating the need for ad-hoc mechanisms. In the DMF, each node comprises interconnected excitatory and inhibitory neural populations. These nodes are linked through excitatory synapses with other nodes. In addition to biophysical constants, the model has a global free parameter (G) determining overall coupling strength and a node-level parameter scaling input from inhibitory to excitatory populations. In its original paper from Deco et al, this Feedback Inhibition Control (FIC) parameter is tuned for each node such that the overall firing rate of the whole brain stays at 3.4Hz. We incorporated an homeostatic plasticity rule such that the FIC values are self-regulated. This rule relies on a decay parameter (DCY), a learning rate (LR), and a target firing rate parameter. DCY controls the extent to which the current FIC value influences the calculation of the new FIC value. LR dictates the speed at which the synaptic weight adjusts based on the difference between the current firing rate and the target rate. With these changes, the model can adaptively alter the FIC, enabling self-regulation akin to a homeostatic process. We observe an inverse relationship between the DCY and LR parameters, indicating a homeostatic process that maintains desired firing rates. The plasticity rule broadens G range, overcoming a prior bifurcation limitation. For G values below this threshold, FIC converges to the static solution. The DCY-LR homeostatic relationship linearly depends on the target firing rate. Neuromodulating local responsiveness with 5HT-2A receptor density produces realistic firing rates, unlike the static DMF version. A parameter space search of G and LR reveals metastable and bistable dynamics, potentially enabling DMF to replicate wake, sleep, and hybrid states like mind wandering or local sleep. Adhering to the democratization aim of Herzog et al, we evolved the efficient DMF implementation of the model by adding a plasticity rule to the FIC. Doing so, we expanded the capacities of the DMF, enabling parsimonious and interpretable mechanistic insights for a wider spectrum of states of consciousness.

A micro-phenomenological state space for use in the neurophenomenological study of short-acting psychedelic tryptamines

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Poster Session 2, Wednesday July 3rd, Ito International Research Center, 4:00PM-5:00PM

Introduction: The use of short-acting psychedelic tryptamines N,N-Dimethyltryptamine (DMT) and 5-Methoxy-N,N-Dimethyltryptamine (5-MeO-DMT) for research into human consciousness is growing. In the lab, both molecules radically and safely alter the structure and contents of consciousness within a short - and thus manageable - timeframe. However, notable properties distinguish each molecule from the other. The character of the subjective experience differs: at peak doses DMT elicits immersive experiences of complex other worlds inhabited by perceived presences, while 5-MeO-DMT elicits a radical deconstruction of the experience of self and other, a state described variously as 'void', or 'pure' consciousness. They also differ at the pharmacological level, being chemically isomorphic except for presence of a single additional methoxy group on 5-MeO-DMT. And, where both work as agonists at 5-HT2a, 5-MeO-DMT has significantly higher affinity at 5-HT1a. It is not yet understood how these pharmacological and phenomenological differences relate. Phenomenological models are needed for this research, and this poster presents an empirically based phenomenological model comparing the DMT and 5-MeO-DMT experiences. Methods: Over a series of lab and naturalistic studies, where DMT or 5-MeO-DMT were used, the micro-phenomenological (MP) interview method was used to collect rich and systematic phenomenological reports. These interviews focused on the phenomenological structure, rather than content, of the experience. Using the MP analysis method categories representing the phenomenological distinctions that structure the subjective experience of these molecules were extracted. The categories were then organised into hierarchical semantic networks, as well as coarse grained temporal models detailing typical patterns the unfolding of the experience followed. Results: This poster presents MP models of DMT and 5-MeO-DMT experience. These models are then synthesised into a selection of key phenomenological dimensions that encompass both the DMT and 5-MeO-DMT experiences, forming a phenomenological state space for short acting tryptamine experiences. The dimensions that form the state space follow three conceptual clusters: the structure of a perceived environment, the configuration of self and other, and the sense of immersion into the experience. Placing DMT and 5-MeO-DMT experiences into this state space and its clusters reveals disparate attractors for each molecule. Discussion: The neurophenomenological paradigm calls for disciplined, empirical phenomenology to enrich the study of the mind and brain. The MP models presented here can be used to make precise and empirically based comparisons between subjective and neurobiological phenomena. A relevant target for such comparisons that emerges from the models is the construction vs deconstruction of complexity in experience, and how this relates to hierarchical cortical structures and the disparate distribution of 5-HT2a and 5-HT1a receptors in the brain.

Neural correlates of auditory consciousness during sleep

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Poster Session 2, Wednesday July 3rd, Ito International Research Center, 4:00PM-5:00PM

Throughout the sleep-wake cycle, our perceptual experience undergoes significant fluctuations according to the level of consciousness. While awake, we are acutely attuned to our surroundings, and can provide subjective reports about conscious percepts. During sleep, it is not clear whether conscious percepts cease to exist, or whether they exist but remain unobservable due to the inability to produce conscious reports. In this context we address whether islands of consciousness emerge during sleep, reflecting conscious experience of external sensory stimuli that remain unreported. To explore this phenomenon we developed a study involving asleep participants, who were presented with auditory stimuli of varying intensity around their auditory detection threshold. We conducted this experiment during a nap in patients with drug-resistant epilepsy who underwent stereoelectroencephalography (SEEG) using intracerebral multiple contact depth electrodes. We started by comparing high-gamma activity according to stimulus intensity across the different sleep stages in predefined regions of interest including the superior temporal gyrus, inferior frontal cortex, insula, and posterior parietal cortex. In our current sample, we collected mainly non-rapid eye movement (NREM) sleep, including 3.5% of N1, 81.5% of N2, and 1.5% of N3, but also 13.5% of REM sleep. We focused primarily on N2 as it is the most prevalent in our sample, and because it is known to be more permeable to external stimuli than deeper stages. We examined REM sleep as well as it is also known to be associated with sensitivity to external stimuli and is characterized by brain activity enabling endogenous conscious experience during dreaming. Neural correlates of consciousness (NCCs) during wakefulness were defined as the difference in high-gamma activity between detected vs undetected sounds. The effect of reporting was ruled out by comparing NCCs when participants had to report the presence vs the absence of the stimulus, and by quantifying high-gamma activity during passive listening. Taking advantage of the opportunity to have SEEG recordings in the same individuals while awake and asleep, we are now in the process of training multivariate decoders to distinguish between detected and undetected auditory stimuli from the awake experiment, and apply them on sleep data. This analysis specifically tests the transferability of neural correlates of conscious perception of wakefulness to sleep. We expect to find transferability of NCCs mostly in N2 and within the superior temporal gyrus. We will discuss the extent to which the transfer of multivariate patterns from wakefulness to sleep supports the existence of islands of consciousness irrespective of reports.

Computational and Experimental Studies of Husserl's Theory of Horizons

Jeff Yoshimi (University of Washington), Liza Oh (UC Merced)

Poster Session 2, Wednesday July 3rd, Ito International Research Center, 4:00PM-5:00PM

Building on earlier work (Yoshimi, 2011, 2016), we present computational models of and empirical support for Edmund Husserl's phenomenological account of "horizons." According to Husserl, the way we see objects is determined in part by a horizon, a collection of ways we expect those objects would appear relative to different movement patterns. As we interact with an object we instantiate a path through such a horizon, and at any moment we have some temporal awareness of where we have been in the horizon and what we expect is coming next. This account can be formalized in terms of Markov chains whose vertices correspond to different perspectives on the object and whose edges correspond to transitions between those perspectives (this is one of several ways of formalizing the theory but has the advantage of being relatively easy to link to empirical data). The account can be generalized from the base perceptual case of perspectives on a physical object to horizons of abstract knowledge, experiences of other agents, and to bodily skill. Work on the formalization of this theory in terms of Markov chains is summarized and used to motivate testable predictions. The theory suggests that the horizon associated with a particular type of experience becomes both more dense (encompassing more possible experiences with the object) but also more refined (producing more specific expectations relative to perspective / action pairs). This in turn suggests a specific series of changes to the Markov chain associated with that horizon. Data from two experiments on skill acquisition (one behavioral, the other using behavioral data and EEG) are used to generate Markov chain representations and to test the Husserlian predictions. A re-analysis of existing data (Nalepka et al. 2017) is also presented. For the three behavioral datasets the predictions of Husserl's theory are confirmed; for the EEG data the predictions are partially confirmed. Nalepka, P., Kallen, R. W., Chemero, A., Saltzman, E., & Richardson, M. J. (2017). Herd those sheep: Emergent multiagent coordination and behavioral-mode switching. Psychological science, 28(5), 630-650. Yoshimi, J. (2011). Phenomenology and connectionism. Frontiers in psychology, 2, 288. Yoshimi, J. (2016). Husserlian phenomenology: A unifying interpretation. Dordrecht, Holland: Springer.

A voice without a mouth no more: A new perspective on the relationship between the neurobiology of language and consciousness

Jeremy ISkipper (University of Washington)

Poster Session 2, Wednesday July 3rd, Ito International Research Center, 4:00PM-5:00PM

Humans are 'language cyborgs' with distinctive language-augmented cognitive abilities. Philosophers and psychologists have long debated whether these 'neuroenhancements' bear any relationship to consciousness. However, both contemporary research examining the 'neural correlates of consciousness' and the neurobiology of language have ignored this question. Yet, our recent review and meta-analysis suggest a causal connection between the neurobiology of language and consciousness, one that cannot be accounted for as a confound of verbal report. Based on this review, we proposed a 'HOLISTIC' neurobiological model to explain the relationship between language and consciousness. This model builds on our research demonstrating that putative 'language regions' (like 'Broca's area') are only the tip of the language iceberg in the brain. Rather, these regions are connectivity hubs or cores, dynamically coordinating a varying distribution of peripheral brain regions, encompassing the whole brain. Rather than simply reflecting, these core-periphery arrangements cause consciousness in the 'insufficient, but necessary part of an unnecessary but sufficient' (INUS) conditional sense. The specifics of this model are copacetic with empirical theories of consciousness: 1) As in higher-order theories, activity in core language-related regions is a re-representation of information from distributed peripheral regions, e.g., 'red' re-represents colour processing in visual areas; 2) As in global (neuronal) workspace theories, these language cores form a workspace linking a distributed set of peripheral, e.g., interoceptive, sensorimotor, and memory systems; 3) As in information integration theories, core-periphery networks must integrate these systems, e.g., the visual and auditory sensory modalities; and 4) As in reentrant processing theories, integration involves recurrent feedforward and feedback processing mechanisms, e.g., use of speech-associated mouth movement information to predict acoustic input. Based on this model, we hypothesised that pharmacological interventions with psychedelic drugs and other compounds that profoundly perturb consciousness will be associated with the neurobiology of language. Indeed, anecdotal reports suggest that the phenomenology of aphasia, described following recovery, partially resembles that of psychedelics, including increased connectedness with the world ('oneness') and loss of the sense of self ('ego dissolution'). We conducted meta-analyses and five studies with propofol and classic psychedelic drugs (ayahuasca, LSD, and psilocybin). All results suggest a correlation between the brain regions and networks associated with language and changes in consciousness. These included connectivity alterations between language-related and, e.g., visual processing regions and an association between language-related regions and 'ego dissolution'. Results support the HOLISTIC model. They suggest that 'alternate states of consciousness' at least partially derive from a release of the hold language has on the brain. That is, the neurobiology of language categorically organises the perceptual and interoceptive information it encounters and forms higher-level constructs like the (narrative) self, which we become conscious of when engaged. Without this mechanism, conscious experiences would be more connected and self-less, as observed. More generally, this is an opportune moment in history to reconsider the relationship between language and consciousness given refinements in our understanding of the neurobiology of language (like its whole brain reach) and the emergence of clever large language models.

Same-race faces attract eye movements in the absence of awareness

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Poster Session 2, Wednesday July 3rd, Ito International Research Center, 4:00PM-5:00PM

Humans are fast at categorising faces by race. When consciously perceived, faces of a different racial group are categorised faster and elicit faster saccadic eye movements than faces of the same racial group as the observer (e.g., de Lissa et al., 2021). However, the extent to which face race categorisation can occur in the absence of awareness remains unclear. When suppressed from visual awareness, same-race faces break interocular suppression faster than other-race faces (Stein, End, & Sterzer, 2014; Yuan et al., 2019) and masked other-race faces modulate the early electrophysiological markers of face processing (Pesciarelli, Leo, & Serafini, 2021). Given that in the absence of visual awareness, oculomotor responses to threat-related emotional faces differ according to face emotion (angry or fearful; Vetter, Badde, Phelps & Carrasco, 2019), we investigated how face race modulates eye responses at the unaware level. Using continuous flash suppression (CFS), we rendered Caucasian and Asian faces unaware and tracked participants' gaze. Caucasian participants (N = 24) completed forced-choice tasks on face position and face race (objective measures of awareness) and rated the face image's visibility (subjective measure of awareness). When subjective face visibility was zero and performance in the forced-choice tasks was at chance level (full suppression from awareness), Caucasian observers' gaze moved closer toward Caucasian faces (same-race) compared to Asian faces (other-race). There was no difference in break-through rates or behavioural measures between face races. These results provide the first evidence that, in the absence of visual awareness, same-race faces attract the eyes more than other-race faces, contrary to the classic other-race effect during conscious perception. Our findings suggest that the mechanisms supporting unconscious ocular processing of face race are shaped by the richer representations of same-race faces due to visual expertise.

Aesthetic Chills: A Replicable Path to Self-Transcendence

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Poster Session 2, Wednesday July 3rd, Ito International Research Center, 4:00PM-5:00PM

Self-transcendence (ST) is a positive altered state of consciousness associated with ego-dissolution, connectedness, and moral elevation, which mediates well-being, meaning-making, and prosociality. Conventional paths to ST such as religious practice, meditative practice, and psychedelics pose nontrivial barriers to entry, limiting ST's study and wide application. Aesthetic chills (henceforth "chills") are a peak psychophysiological response characterized by a pleasurable, cold sensation, and subjective qualities and outcomes intuitively similar to ST. However, evidence is lacking directly relating chills and ST. We exposed 2937 participants to chills-eliciting stimuli, then assayed chills intensity, mood and ST measures. Controlling for prior state and trait differences, chills were robustly associated with ST. Analyses of main effects and covariance structure found that chills occurrence and intensity, and ST measures, form a tightly interrelated construct. These findings suggest that ST experiences are reliably evokable via exposure to aesthetic chills-evoking audiovisual media. We discuss implications of chills-evoking media for tractable studies of ST and democratized applications of ST towards human flourishing.

Feeling Our Place in the World: An Active Inference Account of Self-Esteem

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In this paper, we articulate a nuanced model of self-emergence and environmental co-construction to elucidate the intricate dance between individual cognition and social milieu, highlighting the profound impact of environmental demands and social interactions on the formation and confidence in one's self-model. At the heart of our exploration is the sociometer theory, reconceptualized within the active inference framework as a critical mechanism for navigating social landscapes. This theory posits self-esteem as a reflection of perceived social acceptance and belonging, functioning as an internal gauge that measures the alignment between one's actions and the expectations or norms of their social group. Through this lens, self-esteem is a complex inferential process that integrates feedback from the environment to adjust one's sense of self-worth and belonging. The self, as conceptualized within the active inference framework, represents a dynamic, hierarchical model constructed by the brain to predict and interpret sensory inputs related to one's own existence and agency in the world. It is a cognitive and affective representation that encompasses bodily sensations, psychological states, and the narrative identity that we construct over time. This model of the self acts as the foundation upon which subjective experience and self-awareness are built. Consciousness emerges from the intricate interplay between the self-model and the external world, allowing individuals to experience a continuous, unified sense of identity amidst a changing environment. Through active inference, the brain constantly updates this self-model, leading to a fluid yet coherent experience of being. This ongoing process highlights the integral role of the self in organizing experiences, thoughts, and actions, thereby situating consciousness at the core of our interaction with the world and others. We delve into how the self is continuously molded by the demands of the environment, emphasizing that this environment is dynamically co-constructed through interactions with others. Each individual's model of the self is perpetually updated in response to social feedback, in line with Husserlian notions of Intersubjectivity, which in turn influences their interactions and the collective social environment. This dynamic feedback loop underscores the active role of self-esteem in mediating one's engagement with the world and others. The relationship between self-esteem and consciousness is explored through the prism of active inference, which posits that the brain's primary function is to minimize the discrepancy between expected and received signals from the environment. This predictive mechanism extends to the domain of social cognition, where the self-model includes predictive beliefs about one's social value and standing. The accuracy and confidence in these predictions directly influence the affective valence associated with self-awareness, thereby affecting self-esteem. Our model showcases the predictive power of active inference in understanding the complex interplay between self-awareness, social cognition, and environmental interaction. This approach has significant implications for the development of artificial intelligence and artificial consciousness. By elucidating the mechanisms through which self-esteem and self-awareness emerge from social inference, we pave the way for creating more sophisticated, socially aware AI systems capable of simulating human-like awareness and adaptive behavior.

Changes in nREM sleep duration following thalamic Low Intensity Focused Ultrasound Pulsation: preliminary data

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Background: When patients survive a severe brain injury but fail to recover consciousness, they often enter a prolonged disorder of consciousness (DoC; i.e. vegetative state – VS – or minimally conscious state – MCS). There are currently no approved therapeutics to bolster further consciousness once these conditions become chronic, but thalamic low intensity focused ultrasound pulsation (tLIFUP) has recently been investigated as a novel, non-invasive neuromodulation approach. Non-REM (nREM) sleep elements such as K-complexes and sleep spindles have generators in the thalamus and their presence has previously indicated better outcomes for patients with DoCs. Objective: In this study, we assessed whether LIFUP to the thalamus could increase patient's behavioral responsiveness in parallel to nREM sleep in patients with prolonged DOCs. Methods: Fourteen patients (age range: 21-70 years) classified as being in MCS (11 MCS+, 2 MCS-) or VS (n=1) based on the Coma Recovery Scale-Revised (CRS-R) were included in this study. Etiologies included traumatic brain injuries (n = 6), anoxia (n = 7), and stroke (n=1). Time since injury range from one to six years. Nocturnal polysomnography (PSG) was recorded and automatically scored using the Dreem2 headband based on frontal (Fp1, F7, F8) and occipital (O1, O2) electrodes. On average, recordings had a quality index of 70%, a sleep duration above 5h. Percentage of sleep spent in nREM were compared pre/post tLIFUP using a paired t-test. The changes in nREM sleep percentage were also correlated to changes in CRS-R scores after tLIFUP. Results: Using a paired t-test, a significant increase was observed in: 1) The CRS-R total scores ($t=7.1; p<.001$) and in the following subscores: Visual ($Z=2.7; p=.004$), Auditory ($Z=1.8; p=.04$), Communication ($Z=1.8; p=.04$), and Arousal ($Z=1.7; p=.04$); 2) The amount of nREM sleep, more exactly, N2 sleep stage % ($t= 2.5$, $p =.03$) with an increase of 12% on average. However, no significant correlation was found between the changes in CRS-R (total scores) and N2 (%). Factors such as age, etiology, and time since injury did not seem to significantly affect the percent change in N2 sleep stage. Conclusion: These preliminary data reveal a significant increase in behavioral responses following tLIFUP as well as an increase in nREM/N2 sleep stage which is characterized by sleep spindles mainly generated by the thalamus and thalamo-cortical loops. Our data suggests potential synergistic effects as well as preliminary therapeutic effects of tLIFUP in prolonged DOC patients. However, our study had a small sample size and was open label. A randomized sham-controlled clinical trial should be performed in the future.

Salience as affordance: implications for aberrant salience hypothesis of psychosis from active inference perspective

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The aberrant salience hypothesis of psychosis (ASH) suggests that positive symptoms arise when external stimuli or internal thoughts become “salient” during the prodromal period, and when such perplexed feelings grow and crystallize into delusion to make sense to the patients. The ASH is of great importance because it suggests that psychosis is the matter of conscious experiences, and it provides a consistent explanation of the development of and recovery from psychotic symptoms. One problem, however, is that the term “salience” is ambiguous. On the one hand, “perceptual salience” refers to the property of being perceptually conspicuous compared to one’s surroundings, while “motivational salience” is taken to mean the function of imparting emotional valence to an object. The purpose of this paper is to clarify the relationship between perceptual salience and motivational salience. This is expected to contribute to the elaboration of the ASH proposed in psychiatry. In this paper, we will first clarify the current definition of salience by dividing it into perceptual salience and motivational salience. Then, we show that the idea of salience as affordance is supported by two research fields (philosophy of psychology and information-theoretic models of the brain (active inference)). By rethinking salience from this perspective, salience can be classified into epistemic affordance, exploitive affordance, and aversive affordance. These affordances attract attention and motivate different behaviors: epistemic affordance motivates information seeking; exploitive affordance motivates reward harvesting; and aversive affordance motivates threat avoidance. By rethinking salience in this way, ASH can be refined. We propose that both epistemic and aversive affordances should be considered in ASH. Our hypothesis is that both epistemic and aversive affordances are enhanced in schizophrenia. The former motivates approach to the target, while the latter motivates avoidance of the target, resulting in conflicts. Such conflicts cause psychological distress to the patient and require some kind of cognitive resolution. This is not apparent from the “misattribution of salience” explanation used in the original ASH. Finally, we discuss the correspondence between the above and brain regions, and further discuss the scope of application of the ideas proposed in this paper.

Electrophysiological correlates of nonconscious processing of faces and fearful expressions using dichoptic forward masking

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Threat superiority theories propose that fearful faces are prioritized for processing over neutral faces, even when not consciously perceived. Many studies seem to support this hypothesis. However, their results appear heterogeneous, and reports of negative results have become more frequent recently. Thus, despite decades of research, it is still debated if affective stimuli are processed differently from neutral stimuli when they are not consciously perceived. To obtain more reliable results, we employed a stereoscopic forward masking paradigm that bears two advantages over other techniques of consciousness manipulation: (1) With forward masking, no stimuli follow the critical target. The resulting ERP is thus less obstructed by irrelevant stimuli. (2) Consciousness can be manipulated without altering stimulus durations or target-mask-SOAs but by presenting masks and targets to the same or different eyes. Whereas the former presentation successfully prevents conscious perception of the target, the latter does not. We presented 48 male and female participants with fearful and neutral intact and phase-scrambled faces, rendered either conscious or unconscious by stereoscopic forward masking. The results show typical effects of expressions for conscious faces in the form of enhanced occipitotemporal negativities in the time range of the N170 and the early posterior negativity (EPN). Effects of nonconscious expressions were absent, as tested with Bayesian statistics, but the data indicate that nonconscious faces differed from nonconscious scrambles, suggesting nonconscious face processing but the absence of nonconscious emotion processing. We conclude that rudimentary face processing is still possible under stereoscopic forward masking, but there is no differentiation between nonconscious fearful and neutral expressions.

Validation of the Psychedelic Predictor Scale

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Access to psychedelic drugs is liberalizing, yet responses are highly unpredictable. It is therefore imperative that we improve our ability to predict the nature of the acute psychedelic experience to improve safety and optimize potential therapeutic outcomes. This study sought to validate the 'Psychedelic Predictor Scale' (PPS), a short, widely applicable, prospective measure intended to be predictive of salient dimensions of the psychedelic experience. Using four independent datasets in which the PPS was completed prospectively – two online surveys of 'naturalistic' use (N = 741, N = 836) and two controlled administration datasets (N = 30, N = 28) – we conducted factor analysis, regression, and correlation analyses to assess the construct, predictive, and convergent validity of the PPS. Our approach produced a 9-item scale with good internal consistency (Cronbach's α = 0.8) containing three factors: set, rapport, and intention. The PPS was significantly predictive of 'mystical', 'challenging', and 'emotional breakthrough' experiences. In a controlled administration dataset (N = 28), multiple regression found set and rapport explaining 40% of variance in mystical experience, and simple regression found set explained 16% of variance in challenging experience. In another (N = 30), rapport was related to emotional breakthrough explaining 9% of the variance. Together, these data suggest that the PPS is predictive of relevant acute features of the psychedelic experience in a broad range of contexts. In other words, the conscious state prior to ingesting psychedelic drugs is predictive of the resulting alterations in consciousness. We hope that this brief 9-item scale will be widely adopted for improved safety of psychedelic experiences in controlled settings and beyond.

Decoding Subtle Gradations in Phenomenology: EEG Predicts Meditative Depth Across Multiple Site Visits in Vipassana Experts

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In this proof-of-concept study involving expert Vipassana practitioners (n=34), we successfully decoded self-reported meditative depth using source-localized EEG activity in the theta, alpha, and gamma bands, revealing a remarkable accuracy in predicting these gradations in unseen sessions across two separate visits. Our finding suggests that neither conventional EEG channel-level methods nor an a priori chosen set of default mode network regions adequately captured the complex, non-linear neural dynamics associated with varying meditation depths, echoing the nuanced phenomenology characteristic of discrete meditative states. Additionally, we introduce “spontaneous emergence” as an effective experiential sampling method, where participants naturally report their meditative depth. This approach, more ecologically valid and less intrusive than traditional probing, yielded comparable decoding performance. These results hold implications for advancing neurofeedback techniques in meditation, indicating new directions for more precise neural patterning and computational methods, and enhancing our understanding and facilitation of meditative practices.

Salience influences the sense of agency's ability to affect memory

Nicholas Hon (University of Washington), Juzheng Teo (National University of Singapore)

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Previous work has demonstrated that having a strong sense of agency (SoA) can positively impact memory for acted-upon stimuli. On the other hand, in the same work, a weak sense of agency was generally not found to have any influence over memory. In typical studies, though, a strong sense of agency also tends to occur very infrequently as a consequence of the experimental design used. Thus, in typical studies, a strong sense of agency may also be very salient because its infrequent occurrence. This raises the question of whether the salience of an agency experience plays a key role in determining whether it is influential over memory. To assess this, we examined memory for acted-upon stimuli with an experimental set-up in which a weak sense of agency occurred very infrequently, while a strong sense of agency occurred very frequently. In this case, the weak sense of agency would be the more salient of the two because of its infrequent occurrence. We observed 2 key findings. First, there was a memory enhancement produced by both strong and weak agency experiences. Second, we found that the memory enhancement produced by the more salient weak agency experience was of a larger magnitude than that of the less salient strong agency one. This suggests that, while it is possible for a strong sense of agency to positively impact memory performance on its own, salience can render even a weak sense of agency influential over memory.

Nightmares about climate change: Prevalence and association with climate anxiety

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Poster Session 2, Wednesday July 3rd, Ito International Research Center, 4:00PM-5:00PM

Introduction Nightmares, dreams characterized by intense negative emotions, are associated with various clinical disorders. They are divided into idiopathic nightmares, where nightmare content lacks clear connections to waking events, and post-traumatic nightmares, where nightmares unambiguously reflect real-life existential threats. However, a subset of nightmares defies easy classification—those related to anxiety about potential but currently unrealized existential threats in waking life. Climate change is an example of potentially existential threat that has not yet been fully realized (at least in Nordic countries) but according to science, will lead to serious adverse consequences in the near future. Anxiety related to potential threat of climate change, climate anxiety, is a domain specific anxiety where worry about climate change causes uncontrollable worry and somatic symptoms, including sleep problems and nightmares. Anxiety related nightmares are often categorised as idiopathic but their content can also be specifically related to the topic of domain specific anxiety, making them dreams about potential future trauma and blurring lines between idiopathic and post-traumatic nightmares. In the current study we aim to explore frequency of climate change related nightmares and their association to climate anxiety, sleep and wellbeing. Methods We utilized data from the Climate Nudge survey (https://osf.io/3s8uc) conducted in 2022 investigating attitudes, emotions, and opinions related to climate change among Finnish adults. The survey, conducted by the market research company Kantar, gathered responses from 3867 participants aged 19 to 90. The sample was drawn from a panel representing the Finnish population in terms of age, gender, and place of residence. The Climate Nudge surveys include various measures related to lifestyle, attitudes toward climate change and wellbeing. Climate anxiety is measured with a Finnish version of the Climate Anxiety Scale, which assesses cognitive and somatic symptoms anxiety related to climate change. Nightmares are investigated with two items, one measuring overall nightmare frequency and another specifically climate change related nightmares. Results Preliminary analyses show that, among all participants (N=3867), climate change-related nightmares are rare, with 1.3% reporting them often, 15.6% having had them sometimes, and 83.1% of participants never having experienced climate change-related nightmares. However, among participants who are “extremely worried” about climate change (n=297), 6.0% report nightmares about climate change often with 35.0% experiencing them at least sometimes. Women and younger participants report experiencing climate change related nightmares more frequently than men and older individuals and frequent nightmares are associated with more insomnia symptoms and decreased subjective life satisfaction. Discussion Our results demonstrate that domain specific anxiety about a threat that most Finnish citizen have not yet experienced in a concrete way but are very aware of is strongly associated with nightmares about that threat. In addition to clinical implications these results have for research and mitigation of climate anxiety, they provide a case of specific nightmares about a potential threat – a phenomenon that could be further explored in the light of theories of dream function.

Electrophysiological analysis reveals unstable short-term functional connectivity meta-state dynamics in disorders of consciousness

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Poster Session 2, Wednesday July 3rd, Ito International Research Center, 4:00PM-5:00PM

Survivors of severe brain damage may go through a transient state of coma, marked by an absence of arousal and awareness. As they emerge from this state, they can be categorized into disorders of consciousness (DoC), including unresponsive wakefulness syndrome (UWS) and minimally conscious state (MCS). UWS is characterized by eye opening and reflex movements, while MCS involves varying levels of awareness, such as eye tracking or command following. Notably, patients who show emergence from MCS (EMCS) form a distinct category outside DoC. Recently, there has been increasing scientific interest on the dynamic nature of functional interactions among neuronal ensembles, known as dynamic functional connectivity (dFC). Mounting evidence suggests that the conventional approach of averaging FC over a relative long period of time, referred to as static functional connectivity (sFC), may obscure valuable insights into the ever-changing functional connectome within the brain. Various imaging techniques, including functional magnetic resonance imaging (fMRI) and electroencephalography (EEG) have revealed dynamic fluctuations in functional connectivity exhibiting non-trivial structures that align with distinct collections of network configurations. In this study, we investigated dFC fluctuations using 60 seconds of continuous high-density (183 electrodes) EEG resting state recordings from 78 prolonged DoC patients (23 in UWS and 55 in MCS), 18 patients in EMCS and 36 healthy controls (HC). This method identifies temporally repeating patterns of brain network configurations, referred to as “meta-states”, which act as attractors in a dynamical system, utilizing recurrence plots (RPs) derived from high-temporal-resolution FC data and community detection algorithms. The primary objective of this study was to provide insights into how the inherently dynamic electrophysiological brain activity may be altered by DoC in the canonical frequency bands (delta, theta, alpha, beta). Additionally, we explored the potential use of information about these complex dynamics as biomarkers for distinguishing DoC subtypes by means of a leave one out classification analysis. The results showed that while DoC and EMCS patients present meta-states that are similar from a network perspective to the ones found in healthy controls, their dynamic sequencing is fundamentally altered. For instance, meta-state dwell times are significantly lower in the alpha and beta bands for severe brain injured patients compared to controls, with the beta band presenting a pattern of increasing average meta-state duration with increased level of consciousness, including significant differences between UWS and MCS. In addition, the patients show faster dynamics in the meta-state attractor space, which coupled with the previous result points to DoC and EMCS being related to unstable brain state activation. Moreover, a preliminary classification analysis yielded promising results, with a kappa value of 0.66 in a 4-group classification scheme. In conclusion, our method shows a promising pipeline for the purpose of both gaining insights into dynamic functional connectivity in DoC and for developing model-free EEG biomarkers.

Using Cybernetics to understand models of consciousness

Rachid Lopez (University of Washington)

Poster Session 2, Wednesday July 3rd, Ito International Research Center, 4:00PM-5:00PM

This project evaluates the Thomas Demarse and Karl Dockendorf experiment ''Adaptive Flight Control With Living Neuronal Networks on Microelectrode Arrays.'' This experiment consisted of cultivating rat brain cells and connecting them to a virtual flight simulator using microelectrode arrays. There are a lot of philosophical implications arising from the experiment, as it is a bundle of cells employing sophisticated tasks out of a fusion between biological and artificial components. It also challenges ontological categories, as it can be labeled as a Cyborg, an Organoid, a Xenobot, and an animat. But it is the exception of these categories and not the norm. The intelligent functions arising out of such experiments raise questions regarding the nature of consciousness and whether certain mental states can be engineered with biological systems. Given the complexity of the experiment, I will provide an analysis of the phenomenon through a position of Emergence, specifically as a case of Weak Emergence. Since the trajectory of the cells goes from simpler to more complex properties, I believe Emergence is not only applicable to the experiment but can contribute to a more accurate conceptualization of this and many other projects in Cybernetics and Synthetic Biology. I will also be analyzing models of cognitive functions and applying them to the experiment, and how these functions apply to positions such as global workspace theory and the neural correlates of consciousness.

From Unconscious to Unreliable? Measurement Error Biases Evidence on Studies of Unconscious Processing.

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Poster Session 2, Wednesday July 3rd, Ito International Research Center, 4:00PM-5:00PM

A growing body of literature asserts that some fundamental psychological processes, such as working memory or semantic association, can take place unconsciously. Typically, these studies involve the presentation of subliminal stimuli that influence task performance (e.g., improvement in response speed or accuracy). The interest in these studies lies in assessing whether the effect of subliminal stimuli on task performance is independent from participants' awareness, which is evaluated through self-reports or classification tasks. Chance-level performance in these awareness tests would suggest that participants were not conscious of the stimuli. To assert that the effect of subliminal stimuli is unconscious, the regression method proposed by Greenwald et al. (1995) is often applied, where task performance is regressed on the measure of awareness. If the intercept is significant, it is concluded that, with a zero level in the measure of awareness, there is still an effect on the task due to the presence of subliminal stimuli. However, this method assumes that both variables are sufficiently reliable in a research field where the reliability of experimental measures is generally very low. Fortunately, there are various methods that allow correcting the estimates and their standard errors based on the reliability of the model variables. The aim of this work is to evaluate how robust the conclusions of articles are when using this method, considering the measurement error of the variables. We conducted a literature review to select recent published articles that cited the seminal article by Greenwald et al. and used this method to conclude that a psychological process is unconscious. From these articles, we selected those that reported sufficient information to carry out the analyses. In all of them, we calculated the reliability value that would make the conclusions of the original studies not hold. The results show that, although there is some heterogeneity among the minimum reliability values, these values are relatively high, threatening the validity of the inferences of these studies.

Toward a causal test of prefrontal-occipital functional connectivity during conscious access to visual stimuli: a dual-site tACS and EEG study

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Poster Session 2, Wednesday July 3rd, Ito International Research Center, 4:00PM-5:00PM

Introduction In order to address the challenging question of prefrontal cortex (PFC) contribution to conscious access during visual perception, we designed an experiment to causally test the involvement of long-distance PFC-occipital functional connectivity between a perceptual module (occipital cortex) and PFC using dual-site trans-cranial alternate current stimulation (tACS). Methods We included 17 healthy right-handed volunteers in our study. Each participant received 3 types of stimulation (in-phase: 0°; anti-phase; 180°; sham) divided into 3 sessions, in a double-blind cross-over randomized order, each separated by a minimum of 48h wash-out period. For 20 minutes, 6Hz bi-site tACS (1000 μA peak-to-peak intensity) was delivered simultaneously to the left dorsolateral PFC and the left posterior parietal cortex, with a cathode placed at the vertex (F3, P3 and Cz). During each session the subjects performed a task-based on the backward metacontrast masking paradigm developed by Del Cul and colleagues (Del Cul et al., 2007). The behavioural measures used to assess conscious access to the stimulus were objective performance, measured by forced-choice accuracy in a number comparison task, and subjective visibility, measured by self-reported conscious visibility. Results At the group level, we obtained a significant stimulation*session interaction ($F(2.82,45.15)=3.46$, $p=0.026$, effect size statistic=0.13). Restricted contrasts showed a significant degradation of conscious access during anti-phase online stimulation as compared with sham stimulation: ($t(16)=-2.81$, $p=0.0063$, effect size statistic=-1.04), but also during in-phase stimulation compared to sham stimulation: ($t(16)=-2.71$, $p=0.0077$, effect size statistic=-0.89). In order to better understand this last effect, we speculated that it could be related to inter-individual variability of the optimal frequency to connect PFC to occipital cortex. We therefore ran individual analyses. First, we computed individual statistics: only two subjects showed a significant improvement of visibility during online 6Hz in-phase tACS as compared to sham-stimulation (chi2(1)=6.01, p=0,014 and chi2(1)=7.52, p=0.006). Second, we computed for each participant the optimal EEG frequency of conscious access defined as the frequency showing the greatest differences in fronto-occipital functional connectivity (wPLI) between time-window preceding conscious access (-0.3s to 0.2s from stimulus onset), and time-window of conscious access as predicted by GNW theory (0.2s to 0.7s after stimulus onset) for 'seen' stimuli prior to tACS. Interestingly, only 4 participants showed an estimated optimal frequency of 6Hz, corresponding to the one used for everyone during in-phase stimulation. These 4 participants included the two subjects with a significant behavioral increase of conscious visibility during in-phase tACS, and two other participants who showed a trend in the predicted direction. Discussion We found that anti-phase theta stimulation decreased stimulus visibility. However, in-phase theta stimulation did not increase, - and actually even decreased -, stimulus visibility at the group level. Although, these results suggest a crucial role of fronto-occipital connections in visual awareness, the non-tailored tACS stimulation represents a limitation that does not explain the large disparity of results across subjects. Our post-hoc analyses suggest that single-subject tailored fronto-occipital tACS stimulation could increase conscious access.

Taking consciousness for real: increasing the ecological validity of the study of conscious vs. unconscious processes

Rony Hirschhorn (University of Washington), Uri Korisky (Tel Aviv University), Liad Mudrik (Tel Aviv University)

Poster Session 2, Wednesday July 3rd, Ito International Research Center, 4:00PM-5:00PM

The study of consciousness has developed well-controlled, rigorous methods for manipulating and measuring consciousness. Yet, in the process, experimental paradigms grew farther away from everyday conscious and unconscious processes, which raises the concern of ecological validity. Here, we suggest that the field can benefit from adopting a more ecological approach, akin to other fields of cognitive science. This approach helped challenge existing hypotheses, yield more potent effects, and enable new research questions. We argue that such a move is critical for studying consciousness, where experimental paradigms tend to be artificial and small effect sizes are relatively prevalent. We identify three paths for increasing ecological validity in consciousness studies – changing the stimuli and experimental settings, changing the measures, and changing the research questions – and review works that have already started implementing these approaches.

Active evidence accumulation without awareness of change

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Poster Session 2, Wednesday July 3rd, Ito International Research Center, 4:00PM-5:00PM

One unchanging fact about the world is that it keeps changing. When a change occurs, however, must an observer be aware of the change to seek new information, integrate it, and update held representations accordingly? In the following preregistered study, we asked whether active evidence accumulation, in the form of gaze allocation and representational update, depends on awareness to change. In a single-trial, change-blindness paradigm, 134 subjects attended a minute long, slowly changing, video of a face, either containing a semantically meaningful change (change in facial expression), or meaningless change (noise). We tracked subjects' gaze during the trial, and after the video ended collected subjects' rating of the emotion of the face and measures of awareness to the change. In the meaningful change condition, stimuli started in a neutral expression, changed gradually to a sad or happy expression, and returned to neutral; the change was slow enough for 65% of the subjects in this condition to remain unaware of the change. Stimuli in the meaningless change condition showed throughout presentation time either a sad, happy or a neutral expression. We hypothesized (preregistered) that subjects watching the emotionally changing face, will judge it to contain a degree of emotion reflecting integration of information over time, despite being unaware of the change. Moreover, we hypothesized that in the same condition, subjects' gaze will be attracted to the highly changing areas of the stimulus in the emotionally changing face (specifically, the eyes, nose and mouth), compared to the meaningless stimulus, again even when unaware of the change. The results supported our hypotheses: stimuli changing in expression were perceived by subjects unaware of the change to be more emotive than the neutral meaningless change stimuli, and less emotive than the sad and happy ones. Additionally, subjects unaware of the expression change fixated more, and dwelled longer on average, on the highly changing areas of the emotionally changing face, compared to subjects in the meaningless change condition. These results suggest that information is collected, and representations are updated, even when no change is detected. Unlike previous studies, our results cannot be explained by integration of the onset and offset percepts, because our emotionally changing stimuli started and ended with a neutral expression. Additionally, as overt attention was directly measured, our results address long-standing questions about whether implicitly detected changes attract attention. The findings hold implications for studies of awareness, attention, change blindness, and Bayesian inference, among others.

Numerical magnitude modulates sense of agency

Ryuhei Yasuda (University of Washington), Kyoshiro Sasaki (Kansai University)

Poster Session 2, Wednesday July 3rd, Ito International Research Center, 4:00PM-5:00PM

The sense of agency is the feeling that one's own actions cause changes in the environment. A previous study reported that the sense of agency increases with the speed of visual motion triggered by motor action, indicating that the sense of agency depends on the quantity of the action outcomes (Kawabe, 2013). The present study examined whether the numerical magnitude of the action outcomes also affects the sense of agency. Experiment 1 was conducted online, and dot stimuli appeared after participants pressed a key. Then, the participants rated the sense of agency for each key press using a 10-point scale. As a result, the sense of agency was estimated higher as the number of dots increased. Experiment 2 attempted a self-replication of this phenomenon in a laboratory, and similar results were successfully obtained. Experiment 3 examined whether the same phenomenon could be obtained not only by the number of dots but also by the value of digits. The results showed that the sense of agency was evaluated higher as the value of the digits increased. Our findings suggest that numerical magnitude contributes to the formation of the sense of agency.

TMS-EEG during absence seizures reveal sleep-like mechanisms

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Background: Transitory sleep-like behavioural activity during wakefulness is present in several neurological disorders, including epilepsy. In particular, absence seizures manifest as loss of conscious perception and accompanying behavioural arrest that can last for less than a minute. As a transient and recurrent phenomenon, absence seizures represent a unique opportunity to investigate transitory episodes of loss of consciousness. We hypothesised that during these seizures there is sleep-like bistability, which is the tendency of neurons to fall into a silent period after an initial activation during physiological sleep. Methods: To test our hypothesis, we performed single pulse navigated TMS-EEG on a person with frequent absence seizures. During the experiment, the subject experienced 10 to 30 absence seizure per hour, and TMS-EEG was performed both ictally and interictally, within a period of 5 consecutive hours. Stimulation was targeted to the medial premotor area. The subject was relaxed, sitting on a chair, and fully awake throughout the recording. The pulses were delivered with a jittered frequency of 0.3Hz. We computed time-frequency decomposition of the channel under the stimulation. The results shown below are made extrapolating only the trials in which a clinically confirmed absence seizure was within the 300ms before the TMS pulses and confronting it with trials in which no trace of absence seizure was recorded in the 2 seconds around the TMS pulses. Results: We found suppression of the high frequencies (>20Hz) underpinned by increase in slow EEG activity (<4 Hz) in the trials assessed up to 300ms after an absence seizure. Our findings are in keeping with cortical sleep-like bistability during absence seizures. Conclusions: These preliminary data suggest shared mechanism between the loss of consciousness in absence seizures and during physiological sleep. Upon validation in additional patients, our findings may contribute to a better understanding of the pathophysiology of epilepsy and other disorders of consciousness.

The Significance of Phenomenological Detection of Consciousness at the Bedside and Neurosciences

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Poster Session 2, Wednesday July 3rd, Ito International Research Center, 4:00PM-5:00PM

In recent years, methods for detecting consciousness in patients with disorders of consciousness have begun to focus not only on central nervous system responses, such as neuroimaging responding to cognitive tasks, but also on peripheral nervous system responses, such as heartbeats, heart-evoked responses, and pupil diameters. This presentation aims to demonstrate an emotional disconnect between the consciousness detection methods desired by clinicians, including patient families, at the bedside based on phenomenology-oriented care and the consciousness detection methods based on actual neuroimaging responses in the cerebral cortex. Patient families and caregivers prefer physical reactions on the mind-body spectrum and prefer care in the context of phenomenology-oriented care. In contrast, clinicians, especially neurology specialists, prefer to consider neuroimaging as evidence of consciousness detection. Since both the central nervous system and peripheral nervous system responses can serve as indicators of emergence from Unresponsive Wakefulness Syndrome or Minimally Conscious State, this presentation suggests that assessment of peripheral nervous system responses should take priority at the bedside, and assessment of consciousness targeting the cerebral cortex should be treated as a last resort for detecting Totally Locked-in Syndrome patients who may not exhibit any physical reactions (and may be misdiagnosed as being in a Persistent Vegetative State)

Towards a (universal) mathematical theory of consciousness

Steven Phillips (University of Washington), Naotsugu Tsuchiya (Monash University)

Poster Session 2, Wednesday July 3rd, Ito International Research Center, 4:00PM-5:00PM

Integrated Information Theory (IIT) begins with five axiomatic properties of phenomenological experience: (1) intrinsic, (2) compositional, (3) informational, (4) integrative and (5) exclusive---each one is supposedly self-evident and independent from the other four [Tononi (2015). Scholarpedia] and a zeroth, existence axiom [Albantakis, et.al. (2023). PLoS Computational Biology.]. However, the veracity of these axioms and their lack of formal precision is controversial. We address these problems by showing why/how the five properties follow from a formal (category theory) concept of universal construction, called limit, as the "optimal" coalescence of subject-specific perceptual information into a coherent experience for the given event. Intuitively, in the context of a category (event) C, a limit acts like the best (first-person) view onto a subset of perceptually accessible aspects of that event. [Formally, a limit is a universal cone to a diagram (functor) D:J→C picking out a (sub)collection of objects and arrows of "shape" J in C. A cone is an object (vertex) V and a natural transformation phi:V→D acting like a subject-specific perspective on that collection. The limit is the "best" (universal) such perspective: e.g., the limit to sets A and B is the set of all pairs (a,b) and the projections recovering the first and second elements of every pair---the diagram is the (pair-shaped) functor (A,B):2→C.] Our focus is (5) exclusion---the phenomenon experienced is to the exclusion of all other phenomena that we could have experienced during that event---as this axiom is the most controversial. Everything outside the diagram (shape of experience) is excluded from consideration, i.e. the limit of experience. For example, visual feature binding is the limit to a (wedge-shaped) diagram picking out the separable (e.g., colour and shape) feature-location maps. Computationally, limits are terminal objects (in the corresponding comma category): without sufficient time, separable features should fail to coalesce into the subjective experience of "seeing" the object. Connections to other properties also follow: (4) consciousness is experienced as a whole and cannot be split into independent consciousnesses---the limit object (vertex) cannot be split or reduced to some other object; (3) consciousness is informative in picking out one experience from many other possible experiences---the limit is the most informative cone as all cones to the given diagram factor through the limit; (2) experience (quale---broad sense) is composed of various aspects (quale---narrow sense)---a cone (broad) is composed of legs (narrow) from vertex to base (feet), which cohere with the base (diagram image); and (1) a limit is a universal morphism interpreted as the first-person perspective on the event perception (diagram). If our proposal is on the right track, then in principle other mathematical treatments of IIT [e.g., Kleiner & Tull (2020). Frontiers App.Math.Stat.; Northoff et.al. (2019). Entropy.] can be (re)assessed accordingly. For instance, the cause-effect structure that underpins IIT's measure of consciousness is analogous to a category acting on a set of states and may be reconstructed from their category of representations, which is another kind of universal construction [see reconstruction theorem, nlab.]

Scope of attention interacts with cue-timing to affect performance as well as metacognition of change detection

Suraj Kumar (University of Washington), Narayanan Srinivasan (Indian Institute of Technology Kanpur, India)

Poster Session 2, Wednesday July 3rd, Ito International Research Center, 4:00PM-5:00PM

Attention has been shown to influence visual awareness. Our awareness of change is not very good (change blindness) arguably due to our limited-capacity to detect changes (Simons, 2000). On the other hand, some have argued for large-capacity to detect changes by varying the timing of the spatial-cue in spatial array tasks (Landman et al., 2003). However, although most of our perception is for natural scenes around us, the issues related to change detection for natural scenes are not quite clear. It is also not clear what role different attentional processes play in it. Therefore, in the current study, using natural-scene stimuli in a spatial-cueing task, we manipulated the scope of attention and cue-timing, and measured participants' change detection sensitivity as well as metacognition. Scope of attention (narrow, broad) was manipulated by changing the size of the square-shaped hollow spatial-cue (cueing a small or large portion of the scene). Cue-timing was manipulated by randomly presenting these cues either during the first image (pre-cue), in-between the two images (ISI-cue), or during the second image (post-cue). We hypothesized higher detection sensitivity and metacognition for narrow scope of attention compared to broad scope of attention, and for pre-cues compared to ISI and post-cues. We also hypothesized an interaction between the scope of attention and cue-timing with highest performance and metacognition for small-size pre-cues compared to all the other conditions. We ran a 2x3 within-subject design with cue-size (small, large) and cue-timing (pre-cue, ISI-cue, post-cue) as the two variables (N = 24). Participants performed a spatial-cueing task in which two images of a natural-scene were presented one after another (1000 ms each) with a blank display between them (2000 ms). The cue was randomly presented (100 ms) either during the first image (pre-cue), the second image (post-cue), or the time-gap between them (ISI-cue). For pre and post conditions the cue could appear 450 ms after the onset of the first and second scenes respectively. For the ISI condition, the cue could appear 950 ms after the offset of the first scene. Participants pressed 'A' or 'D' keys to indicate change/no-change followed by a confidence-rating (CR) scale (unsure, slightly-confident, almost-certain, and certain). There were 156 trials in total (change/no-change equally likely) for each participant. All the conditions were counterbalanced. Signal detection theory metrices (sensitivity and criterion) along with meta d-prime were computed for change detection in all six conditions. Results showed significantly higher d-prime and meta d-prime values for small-cues compared to large-cues. Additionally, higher d-prime and meta d-prime values were found for pre-cues compared to ISI and post-cues. Furthermore, an interaction was found for cue-size and cue-timing with highest d-prime and meta d-prime values for the small-size pre-cues. There was no significant correlation between d-prime and meta d- prime values in all the conditions. Taken together, these results show that change detection performance and metacognition for natural-scenes depend on different attentional processes as well as cue-timing. The limited/large capacity debate cannot be resolved until different attentional mechanisms and timing be brought into the discussions.

A method to measure metacognition of feelings

Sweta Basu (University of Washington), Narayanan Srinivasan (Indian Institute of Technology, Kanpur)

Poster Session 2, Wednesday July 3rd, Ito International Research Center, 4:00PM-5:00PM

Metacognition is the ability to think about one's own cognition. Metacognitive sensitivity for perceptual tasks is measured using Receiver Operating Characteristic (ROC) curve analysis or finding meta-d' of participants with the help of their reported confidence ratings and the correct/incorrect responses they give. Unlike perceptual judgments, there is no accepted way to measure accuracy for feelings. Given the importance of emotion regulation, it is important to have higher metacognitive sensitivity about one's own emotions and measure that sensitivity. We recently developed a method for measuring emotional metacognitive sensitivity using different normative measures of emotion (based on mean ratings) that allow us to talk about accuracy by computing the difference between those normative ratings and the participant's own emotional ratings. Sixty emotional scenes from IAPS database were shown and participants (n=56) reported their own valence ratings (besides arousal and familiarity) and also what 'others might feel' on a 100-point scale. The difference was dichotomized into 'correct' and 'incorrect' emotion categories and used along with their confidence ratings about their felt emotions to construct ROC curves. The area under ROC was calculated as the measure of a person's metacognitive sensitivity about their felt emotions. For each participant, area under the curve (AUC) was calculated with four different normative measures: mean value from the IAPS database for that picture, mean value for that picture from our participants, mean value for ratings of 'other's feelings' from participants in our study and the value from the same participant on what others would feel. AUCs ranged around 0.45-0.65 for most participants. To check for consistency between these AUC values, we computed correlations between each of these AUCs, which were significant (ranging from 0.571 to 0.915) indicating potential value of our developed metacognitive measure for feelings. To further validate with a 2AFC valence judgment, we are conducting a follow-up study with 60 IAPS images. Participants (n=18) had to denote whether the pictures were 'pleasant' or 'unpleasant' followed by their confidence in their choice among the two options. Here, the 'correctness' of the response was measured by comparing the response directly with the IAPS ratings and if the two were congruent (e.g. 'pleasant' for IAPS pictures with high valence ratings) they are considered correct and vice versa. Using this correct/incorrect categorization and the confidence ratings ROC curves were constructed. The AUROC2 calculated values for the participants ranged from 0.28 to 0.93. To further validate the measure, we used the same data to calculate the meta-d' for each participant which ranged from 1.45 to 4.51. We then correlated the AUROC2 and meta-d' measures and found significant correlation ($r = 0.535$) between the two measures further validating the credibility of this measure for use in measuring metacognitive sensitivity for one's own feelings. We are following up and measuring metacognitive sensitivity for the participants again to detect test-retest reliability. We feel that the development of a robust metacognitive sensitivity for felt emotions would enable us to not just measure but also predict our abilities to regulate our own emotions.

Estimation of Integrated Information and Major Complexes Based on Multitask Graph Neural Networks

Tadaaki Hosaka (University of Washington)

Poster Session 2, Wednesday July 3rd, Ito International Research Center, 4:00PM-5:00PM

Integrated Information Theory (IIT) has been attracting attention as a theory with the potential to mathematically describe the quality and quantity of consciousness generated in causal systems, such as neural networks. IIT 3.0 primarily aims to identify the subsystem involved in the emergence of consciousness, known as the 'Major Complex', and to quantify the system-level integrated information corresponding to the magnitude of consciousness, referred to as the 'Big Phi'. However, the computation of the IIT is a nested optimization problem that requires an exponential number of operations relative to the number of nodes in the system. This study aims to circumvent this computational difficulty by using deep Graph Neural Networks (GNNs) to estimate both the magnitude of integrated information and the major complex directly, instead of solving complicated optimization problems. To accomplish this, the system is modeled as a graph consisting of nodes and edges. As an initial step in our research, we gathered the IIT 3.0-based exact solution for the system-level integrated information and the major complex for graphs of different topologies ranging from 5 to 8 nodes, with varying node states. The collected graph-solution pairs constitute the dataset in our supervised learning framework with GNNs. In GNNs, a graph structure comprising node features and weighted edges is used as input, and the process of aggregating and integrating information from neighboring nodes to update each node's features is repeated. The parameters involved in these 'graph convolutions' are sequentially trained to reduce the task-specific loss function. We define the features of each node not only as the node state itself, but also as the number of neighboring nodes, state transition probabilities, etc. Our GNN is also designed to perform multitask processing that simultaneously estimates the value of system-level integrated information for each graph and classifies whether each node is included in the major complex. We conduct experiments using 85.5% of the total graphs as training data, 9.5% as validation data, and the remaining 5% as test data. The mean absolute error between the true system-level integrated information and its estimate on the test dataset is 0.236 (the mean integrated information in our dataset is 2.416) and their correlation coefficient is 0.994. For the estimation of the major complex, the accuracy per node is 0.943, and the accuracy per graph (i.e., the percentage of perfect matches, meaning all nodes in the graph are correctly classified) is 0.772. The results indicate that our GNN produces reasonably accurate estimates when sufficient data is available for learning. The proposed method is also applicable to the latest version of IIT 4.0 and is expected to contribute to its advancement.

Association of bidirectional network cores in the brain with consciousness and cognition

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Poster Session 2, Wednesday July 3rd, Ito International Research Center, 4:00PM-5:00PM

The brain is a complex network of interacting regions. Understanding the roles and mechanisms of this complex network requires elucidating which of its structural features relate to specific cognitive functions. Among such relationships, recent developments have highlighted the link between network bidirectionality and conscious perception. Previous research suggests that both feedforward and feedback signal propagation are essential for conscious perception, leading to the hypothesis that subnetworks with bidirectional interactions play an important role in consciousness. However, it remains unclear which brain subnetworks exhibit bidirectional interactions and how these subnetworks are associated with consciousness. In this study, we propose a framework for extracting subnetworks with strong bidirectional interactions, termed 'cores' of a network, from brain activity. We applied this framework to fMRI data from a resting state and seven cognitive tasks to identify regions forming strongly bidirectional cores. We then explored the association of these cores with various cognitive functions, including conscious perception. We found that the cores were more likely to include regions of the cerebral cortex, which are crucial for conscious perception, and less likely to include subcortical regions. Additionally, within the cortex, more central core regions were more likely to elicit changes in conscious perception upon electrical stimulation. This association suggests a link between bidirectional cores and conscious perception. Furthermore, a meta-analysis and a comparison with the cortical functional connectivity gradient suggest that more central core regions were related to lower-order sensory-motor functions. Moreover, an ablation study emphasized the importance of incorporating bidirectionality over mere interaction strength for these outcomes. Overall, the proposed framework provides new insights into the roles of network cores with strong bidirectional interactions in conscious perception and lower-order sensory-motor functions.

Brain states and mental states in the physicalisitic approach to consciousness

Tzu-AngKuo (University of Washington), Allen Houng (National Yang Ming Chiao Tung University https://www.nycu.edu.tw › nycu National Yang Ming Chiao Tung University)

Poster Session 2, Wednesday July 3rd, Ito International Research Center, 4:00PM-5:00PM

In the physicalistic approach to consciousness, brain states are considered correlated with mental states. However, it is unclear to which extent this correlation holds. For example, it is unclear whether all mental states can be realized by brain states - which holds only if there is an embedding of sets from the mental states into the brain states. In this paper we discuss whether such an embedding exists. I will define brain states in terms of physical states. Then we give a proof of the finiteness of the set of the brain states. Furthermore, I discuss whether the set of all mental states in a brain are finite - if it is infinite, then such an embedding fails.

Crossmodal correspondence can induce crossmodal transfer between audiovisual stimuli in category learning

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Poster Session 2, Wednesday July 3rd, Ito International Research Center, 4:00PM-5:00PM

Crossmodal correspondence describes nonarbitrary associations that exist among different basic physical stimulus attributes, features, or experience dimensions in different sensory modalities (Spence, 2019). For example, it has been found that people preferred to associate high pitch with small size. Crossmodal transfer is a neurocognitive process in which learners' experience and knowledge gained through one sensory modality enables them to use a different sensory modality to accomplish a similar task (Karim, Mizan, & Himi, 2023). It remains unclear whether crossmodal correspondences can modulate crossmodal transfer between audiovisual stimuli in category learning. To address this issue, we adopted an implicit association task and a matching task in Experiment 1 to determine whether there were crossmodal correspondence effects between audiovisual stimuli. The results revealed that the crossmodal correspondence effects were observed between pitch-elevation dimensions and timbre-shape dimensions but not between pitch-size dimensions in the two tasks. In Experiment 2, an A/not A prototype category learning task was used to testify whether the category knowledge can be transferred between crossmodal correspondence dimensions verified in Experiment 1. The results showed that participants could transfer the categorization knowledge from auditory to visual but not from visual to auditory in pitch-elevation and timbre-shape dimensions. The results indicated that crossmodal correspondence can induce crossmodal transfer but there might be an asymmetry in the crossmodal transfer of the category knowledge. These findings provided new evidence for crossmodal correspondence existed in both implicit and explicit tasks and shed light on the relationship between crossmodal correspondences and crossmodal transfer.

Predicting veto decisions from brain activation

Yu HeiShum (University of Washington), Carl Michael Galang (Berlin School of Mind and Brain, Humboldt-Universität zu Berlin), Marcel Brass (Berlin School of Mind and Brain, Humboldt-Universität zu Berlin)

Poster Session 2, Wednesday July 3rd, Ito International Research Center, 4:00PM-5:00PM

We sometimes cancel our intention and change our mind at the last moment. This ability, known as "veto" (Libet, 1999) or "intentional inhibition" (Brass & Haggard, 2007), has been considered to be an important aspect of intentional action and self-control. Benjamin Libet argued that while our intentions to act are determined by unconscious processes preceding them, vetoing such intentions do not have such unconscious precursors. While previous studies (Fried et al., 2011; Soon et al., 2008; 2013) have applied multivariate pattern analysis (MVPA) to decode human decisions to act, to our knowledge, no previous study has attempted to decode human decisions to veto their own intentions. The current study addresses this gap by adopting MVPA to decode participants' decisions to veto their own intentions with electroencephalogram (EEG) data. Participants (n =50) performed the Veto Libet task with their EEG signals measured. During the Veto Libet task, participants were instructed to fixate at the center a clock with a clock hand rotating on the clock face. In each trial, participants were asked to formulate an intention to press the SPACE key and decided whether to veto their decision after the intention to act was formed. Participants were instructed to veto approximately 50% of the trials. After each trial they were instructed to report the moment they experienced their intention to act regardless of whether they implemented or vetoed this decision. Participants were instructed to decide spontaneously to veto the intention or not without preplanning their decision. In the preliminary analysis we epoched the data time-locked to the reported intention onset, with an epoch length of -1500ms to 1000ms. Then, we applied discriminant analysis to classify the participants' decision (i.e., whether they executed the action or not in that particular trial). Permutation tests were subsequently used to determine the significant accuracy threshold and cluster size. The results of the permutation test showed that significant clusters with classification accuracy greater than chance were found in a time-window between 200 ms before the intention onset and 200 ms after the intention onset. The current results the idea that intentional inhibition can be predicted from brain activity before participants decide to act. While the specific nature of the signal has to be further clarified, the results demonstrate that intentional inhibition is predicted by brain signals preceding conscious intentions.

Investigating the unconscious component of memorability by breaking continuous flashing suppression

Yung-Yi Hsu (University of Washington), Po-Jang (Brown) Hsieh (National Taiwan University)

Poster Session 2, Wednesday July 3rd, Ito International Research Center, 4:00PM-5:00PM

Prior studies indicate that the memorability of a stimulus, or the likelihood of it being remembered, remains consistent across individuals. Besides, there are studies supporting that memorability processing is more bottom-up than top-down. Because of its pervasive and inherently involuntary nature, we investigated the potential for memorability to be an unconscious process in this study. We used bCFS (breaking-continuous flashing suppression) paradigm to measure the visibility threshold of memorable and forgettable face images to infer the difference when they are processed unconsciously. The result shows no difference between the two groups compared with the statistically significant race-familiarity effect. There is no evidence supporting the idea that there is a difference when the images are processed under CFS unconsciously. This discovery implies that variations in memorability during cognitive processing likely emerge at the conscious level. Future research endeavors will be essential for identifying the key components that contribute to successful memory encoding and elucidating the role of memorability in our perceptual processing.

Anesthesia disrupts integration of sensory features in the cortical hierarchy

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Poster Session 2, Wednesday, July 3rd, Ito International Research Center, 10:00AM-11:00AM

How does anesthesia affect neural processing in the cortical hierarchy that mediate our perceptual awareness? In our study, we investigated this question by recording intracranial electroencephalography (iEEG) from neurosurgical patients with refractory epilepsy. During both wakeful and anesthetic periods, we presented auditory sequences in a novel multi-level oddball paradigm in which the attributes of loudness (amplitude) and tone (frequency modulation) were varied. When patients were awake, typical mismatch negativity (MMN) responses were observed in the high gamma band (70–150 Hz) to both loudness and tone deviants, but the MMN showed a center-surrounding organization along the axis of primary-to-associative auditory cortex with distinct latencies for the two sound attributes. Moreover, when the changes of loudness and tone co-occurred in the same trial, the latency of the MMN responses to the multi-level feature deviant moved earlier to be consistent with the latency of loudness deviant. These results demonstrated the integration of sensory features in the cortical hierarchy for perception. However, during general anesthesia in the same group of patients, all the MMN effects were absent, albeit the basic auditory responses to individual sensory features were still present in the primary auditory cortex. These results suggest that anesthesia influences perceptual processing at the level of cortical hierarchy for integrating sensory features that are crucial for conscious awareness.

Contextual Inference Underlies Decision Making in Schizophrenia: An Active Inference Model

Adam TManoogian (University of Washington), Adeel Razi (Monash University), Jakob Hohwy (Monash University)

Poster Session 3, Thursday July 4th, Ito International Research Center, 10:00AM-11:00AM

The learning and decision making processes underlying differences in performance on behavioral tasks in schizophrenia patients are not yet clear. Traditionally established cognitive patterns such as ‘jumping to conclusions’ and a ‘bias against disconfirmatory evidence’ are proving inconsistent under scrutiny or aligned only to certain symptoms at times of severity. Despite the wide history of context misinterpretation in schizophrenia, the influence of contextual inference in decision making tasks remains underexplored. In this case, the patient must decide on the relevant context (with associated statistics and values) to retrieve and then update. We argue that including an ongoing process of latent state inference can better capture behavioral tendencies, such as increased switch rates and a failure to form precise beliefs. In short, uncertainty that is usually interpreted as overall volatility, we can instead distinguish as uncertainty about the structure of the task. Here, we use an active inference agent modified with contextual updating in a probabilistic reversal learning task. Contextual updating is explored with bayesian nonparametrics. Their role is complemented by previous findings of classical neural network memory models of schizophrenia. We build on preliminary simulations with model fits to previously published data. Finally, we discuss the potential role of memory components. Working memory, commonly deficient in schizophrenia, is controlled for in our model. Updating and retrieval processes are measured in our model and compared to the concept of context. We include future directions for neurobiological targets, including prefrontal cortex - hippocampal circuitry.

Transcendental Technology: Reimagining the Psychedelic in the Digital Age

Alexandre HiroHoney (University of Washington)

Poster Session 3, Thursday July 4th, Ito International Research Center, 10:00AM-11:00AM

This presentation explores the intersection of emerging technologies and the representation of altered states of consciousness, specifically focusing on the psychedelic experience. It argues that the material conditions of art, shaped by contemporary technological advancements, are fundamentally altering how we represent and understand these elusive states.

The project draws inspiration from Marshall McLuhan's media theory and Walter Benjamin's The Work of Art in the Age of Mechanical Reproduction, which analysed how the printing press altered art's mystical aura but made it more democratic. The presentation critiques the pervasiveness of a facile orientalism in past attempts to represent the psychedelic, primarily a hangover of the 60s and 70s California counterculture. This exoticising gaze, often evident in the works of figures like Timothy Leary and Terrence McKenna, fails to capture the essence of the psychedelic experience and hinders a nuanced understanding. By bringing thinkers such as Jean Baudrillard (hyperreality) and Hiroki Azuma (database consumption vs. narrative consumption) into the fold, we can develop a more nuanced understanding of the relationship between the real and the virtual, and how psychedelics intervene by making us aware of the plasticity or virtuality of "real" perceptual experience. There is a political dimension to this too, as Mark Fisher explored in his posthumous Acid Communism.

Building upon this critique, the presentation adopts a Hegelian dialectical framework to posit that the aesthetics of any era are fundamentally shaped by the available material conditions. This implies that the "psychedelic experience," often described as a transcendental or even spiritual encounter, is unavoidably influenced by the technological tools and artistic mediums employed for its representation.

Therefore, the presentation argues for a reimagining of the psychedelic aesthetic through the lens of contemporary technologies. By analyzing diverse case studies, it explores how artists are leveraging postwar and contemporary technological advancements to offer fresh perspectives on the psychedelic domain.

Case studies include the Japanese underground animation Cat Soup, known for its dreamlike imagery and exploration of altered states, the work of 3D CG/AI artist Tomoro Kinoshita, who creates immersive digital landscapes with a mesmerizing quality, and Andrea Khan's BOLUS, a London PhD project utilizing generative AI to recreate a medical ketamine trip. I will also look at deep learning networks like Stable Diffusion and StyleGAN, known for their ability to evoke dreamlike imagery.

Through these diverse examples, the presentation demonstrates the potential of emerging technologies to push the boundaries of representing the psychedelic experience. By engaging with generative AI, immersive virtual reality, and other cutting-edge technologies, artists are creating new pathways for exploring and communicating the subjective nuances of altered states of consciousness. This shift not only offers fresh artistic possibilities but also opens avenues for scientific inquiry into the nature of consciousness itself.

This presentation, by critically engaging with established artistic depictions and exploring the potential of new technologies, proposes a reimagining of the psychedelic aesthetic for the digital age. This exploration fosters a deeper understanding of the relationship between material conditions, artistic representation, and the human experience of altered states of consciousness.

Reducing the Kanizsa Illusion via semantic priming: a case for cognitive penetrability

Amir Tal (University of Washington), Nataly Davidson Litvak (Tel Aviv University), Liad Mudrik (Tel Aviv University)

Poster Session 3, Thursday July 4th, Ito International Research Center, 10:00AM-11:00AM

Visual illusions are often considered key examples for cognitive impenetrability, as they are held not to be affected by non-perceptual processes. We revisit this claim in five preregistered experiments focused on the Kanizsa illusion, where a nonexistent shape is experienced due to filling-in of illusory contours. Three Pac-Man-like shapes inducing the Kanizsa illusion of a triangle were preceded by a prime that was either semantically related to the Pac-Man characters or not. We hypothesized that the semantic prime would promote a non-holistic interpretation of the Kanizsa inducers as individual Pac-Man characters, thus biasing participants against perceiving the illusion. In Experiment 1, the semantic prime was a picture of a Pac-Man maze. In Experiments 3 and 4, it was the word 'Pac-Man'. As expected, a difference between the prime groups was found, with fewer detections of the Kanizsa triangle shape when participants were semantically primed with Pac-Man related stimuli. To show that the effect does not stem from mere attentional engagement by a meaningful prime, a non-Pac-Man related semantic prime was used in experiment 2, and no difference between the groups was found. Finally, in Experiment 5, we showed the opposite effect, with semantic priming of the illusory shape ('Triangle') enhancing the probability of seeing the Kanizsa illusion. Taken together, the results suggest that semantic priming can affect the probability of experiencing the Kanizsa illusion, thus supporting claims of cognitive penetrability.

Is this my rubber hand? A critical reflection on body illusion experiments

Andreas Kalckert (University of Washington)

Poster Session 3, Thursday July 4th, Ito International Research Center, 10:00AM-11:00AM

The introduction of the rubber hand illusion (RHI) has significantly impacted the field of cognitive neuroscience, offering a novel way to investigate the processes underlying body ownership and self-awareness. Introduced over 25 years ago, it has sparked considerable interest in the study of embodiment, leading to a proliferation of research paradigms aimed at understanding these complex phenomena. However, despite extensive investigations, several aspects of body ownership illusions remain elusive, prompting recent critiques of experimental paradigms. Critics have questioned the authenticity of these effects, stirring debate on the perceptual and neural underpinnings and contributions to the understanding of body ownership. Moreover, the heterogeneity in methodological approaches and definitions poses a significant challenge, reflecting in the varied conduct of experimental paradigms. Notwithstanding these criticisms, the notion of multisensory integration remains a compelling explanatory framework for these experiments. This paper seeks to defend this perspective while highlighting areas of the RHI paradigm that warrant further exploration. Specifically, it aims to address the illusion's temporal dynamics and the subjective nature of the experience, areas that have received insufficient attention in past research. I will present new data and critical reflections on current practices that offer a more nuanced understanding of RHI experiments, focusing on the onset of the illusion experience, the use and interpretation of questionnaire data, and the variability in individual experiences. Here, i advocate a perspective that sees the RHI as a composite of sensations of touch referral and ownership experiences that may follow different perceptual rules, leading to different reports by participants, and eventually lead to different interpretations by studies. By advocating for a more uniform approach and consensus on methodological aspects, I aim to address current challenges in the field and, consequently, enrich our understanding of embodiment from an experimental viewpoint. I propose that reconciling these facets upholds the conceptual merit of the RHI as a multisensory illusion, providing insights into the cognitive processes underpinning the bodily self.

Assessing Harmonicity and Complexity in DMT-Induced Psychedelic States

AntoineBellemare-Pepin (University of Washington), Christopher Timmerman (Imperial College), Philipp Thölke (Université de Montréal), David Nutt (Imperial College), Robin Carhart-Harris (University of California San Francisco), Karim Jerbi (Université de Montréal)

Poster Session 3, Thursday July 4th, Ito International Research Center, 10:00AM-11:00AM

The Binary Hierarchy Brain Body Oscillation Theory (Klimesch, 2013) proposes that biological systems rely on harmonic structures to communicate and facilitate integrative functions. According to this theory, the binary hierarchical relation between spectral peaks (e.g. 1:2, 1:4, and 1:8) could be indicative of particular brain states (Klimesch, 2013) and multiple binary ratios have been observed between delta, theta and alpha peaks in several conditions and tasks (Bartsch et al., 2007; Isler et al., 2008; Palva et al., 2005; Sauseng et al., 2008). In this study, we investigate the harmonic relationships among EEG frequency peaks to assess their potential in characterizing brain dynamics during the DMT psychedelic experience. We hypothesize that DMT enhances harmonicity relative to placebo, with such harmonicity reflecting various phenomenological aspects of the experience. To test this hypothesis, we applied metrics inspired by music theory to capture more subtle harmonic properties of brain signals. In particular, we extend the concept of binary ratios by considering more complex frequency ratios to describe the dynamics between different frequency bins of the frequency spectrum. We propose an analysis pipeline that compares computational models of harmonicity, Power Spectral Density (PSD) and Lempel-Ziv Complexity (LZC) in terms of their ability to distinguish DMT from placebo experience and characterize the relation between phenomenological components and brain dynamics. Drawing from music theory, various models exist to quantify the harmonicity of frequency peaks within signals, offering a framework that can be applied across different signal types. Specifically, we utilized Empirical Mode Decomposition (Rilling et al., 2003) to decompose the signals into a set of Intrinsic Mode Functions (IMF), from which we derived frequency peaks. We then assessed the configuration of these peaks through metrics that capture their arithmetic proportions, namely harmonic similarity (Gill and Purves, 2009), inter-harmonic concordance, and subharmonic tension (Chan et al., 2019). Furthermore, we enhanced these analyses by introducing a method to compute a harmonicity value for each frequency in the spectrum (i.e. harmonic spectrum), enabling the derivation of various metrics that capture the underlying harmonicity within EEG signals. We used EEG data collected from 13 healthy participants during DMT and placebo sessions using a 32-channel electroencephalograph (Timmerman et al., 2019). Analyzing 5-second intervals from the DMT injection onset to 18 minutes after, we employed Generalized Linear Mixed Models (GLMM) to determine if harmonicity metrics could differentiate between DMT and placebo effects and predict phenomenological report dimensions. Additionally, we factored in Power Spectrum Density (PSD) estimates and mean peak frequency values into our model to assess their impact on harmonicity measures. Harmonicity metrics significantly differentiated DMT from placebo and correlated with the progression of visual, bodily, and emotional/metacognitive components throughout the psychedelic experience. More specifically, we observed a general rise in broadband harmonicity and a centro-frontal uptick in harmonic similarity corresponding with intensified visual experiences. To conclude, models integrating harmonicity seem to offer insights beyond conventional PSD and complexity measurements, suggesting that the interrelationship of frequency peaks in the brain may be indicative of more nuanced states of consciousness.

Neural Mechanisms of Temporal Perception: A Function-First Approach to Operationalizing Time-Consciousness

Aramis D. M.Valverde (University of Washington)

Poster Session 3, Thursday July 4th, Ito International Research Center, 10:00AM-11:00AM

The study of time consciousness has long been fraught with conceptual ambiguities, a lack of firm empirical foundations, and a lack of consensus on key terminology. Persistent challenges in aligning philosophical theories with neuroscientific data have hindered progress towards a comprehensive understanding of how we perceive and process the passage of time. This presentation seeks to help address these issues by investigating the neurocomputational underpinnings of temporal perception through two specific models. First, I analyze a model of striatal duration evaluation mechanisms in mice, using this as a basis to understand the neural computations central to temporal discrimination tasks and encoding time intervals. Second, I present a theoretical model closely related to the striatal model that could govern the perception and judgement of the rate of time's passage in humans. It explores the interplay between cognitive and neurological factors in shaping the subjective experience of time's flow. This model is particularly concerned with uncovering the mechanisms that might account for variations in the perceived speed of time under various conditions, offering insights into the phenomenal perception of time's passage in humans. Key to this approach is the adoption of a function-first framework, made possible by recent advances in experimental neuroscience. This framework not only redefines and operationalizes existing notions in time-consciousness in a more empirical and systematic manner, but it also enriches the conceptual discourse on consciousness. This methodology aligns conceptual theories with empirical neuroscientific research, offering a grounded perspective in the ongoing discourse on time-consciousness and establishing a concrete precedent for future inquiries into the neural underpinnings of human perception.

Picturing Consciousness : Mental images reconstruction with EEG and Bubbles

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Poster Session 3, Thursday July 4th, Ito International Research Center, 10:00AM-11:00AM

The nature of what emerges in consciousness during mental imagery remains a mystery. Reconstructing the characteristics of mental images has significant implications, particularly in the field of brain-machine interfaces, but previous attempts have often resulted in low-resolution reconstructions due to the complexity of the search space. We introduce an innovative method, inspired by the Bubbles method of Gosselin & Schyns (2001), which simplifies the search space by randomly sampling visual information through small Gaussian apertures (bubble masks). We hypothesized that this approach, combined with electroencephalography (EEG) recordings, would enable mental images to be reconstructed with greater clarity, revealing their key features. Furthermore, we aimed to determine if specific verbal instructions, such as directing participants to imagine certain objects within the images, would help refine the resolution and emphasize specific regions over others. Participants from University of Montreal (preliminary sample: N = 7) took part in 6 two-hour EEG sessions. EEG activity was recorded, alternatively, during imagination (of the whole image or specified regions) and during perception of the same images covered by bubble masks. EEG activity between the imagination and perceptual tasks was correlated for each image and for each participant. Bubble masks were weighted by the corresponding correlation coefficients and summed to generate "classification images" of mental images. Analyses were performed to reveal the significant pixels, allowing for a comparison of pixel density across distinct regions of the image in response to different verbal instructions. We found that verbal instruction could modulate reconstruction, revealing the targeted regions more than the others. These results provide a better understanding of the neural mechanisms at work in the formation of mental images and pave the way for a new method of revealing the content of consciousness which could be promising for enhancing communication in brain-machine interfaces.

Event-Related Responses to Congruent and Incongruent Sentences in Comatose Acute Brain Injury Patients.

BrianManolovitz (University of Washington), Danielle Bass (University of Miami), Ana Bolaños Saavedra (University of Miami), David Monroy (University of Miami), Esther Monexe (University of Miami), Gabriela Aklepi (University of Miami), Brian Arwari (University of Miami), Nina Massad (University of Miami)

Poster Session 3, Thursday July 4th, Ito International Research Center, 10:00AM-11:00AM

Objective: Mortality is high in comatose patients with severe acute brain injury (ABI) and is largely driven by the decision to withdraw life-sustaining therapies (WLST). In this study, we investigated the differences in brain activation detected by electroencephalogram (EEG) between congruent and incongruent sentences shortly after TBI, indicating a higher level of cognitive processing. Methods: This is a prospective single-center study conducted at a level-1 trauma center in the Neuroscience Intensive Care Unit. We recruited ABI patients who are unresponsive to commands as per the Coma Recovery Scale-Revised (CRS-R), and functionally independent with intact hearing prior to injury. We tested brain event-related potentials (ERPs) on 10-20 montage EEG in response to 25 congruent and 25 incongruent sentences (last word represented the semantic of congruent/incongruent). We analyzed differences in ERPs at 250ms to 500ms following the last word. We used a one-way ANOVA corrected for multiple comparisons using the Benjamini-Hochberg method for FDR-correction to see detected differences between the congruent and incongruent sentences. Significant differences in ≥ 2 channels signified the ability to differentiate between congruent and incongruent sentences. Glasgow outcome scale extended (GOSE) was obtained at discharge, 1-, 3-, 6-, and 12-month post injury. Reaching a GOSE ≥4 at any point was interpreted as functional recovery. Results: We recruited a total of 56 patients (32 TBI, 21 ICH, 3 SAH). The average age was 51 +/- 18 years old, 11 females (19%), with an average GCS was 5 +/- 3. On average, each patient had 5 +/- 2 EEG assessments. WLST occurred in 19 (33%) patients. Distinguishing the semantic differences between the congruent and incongruent sentences was seen in 10 patients (18%). Functional recovery was similar between the two groups (10% vs 12%), however, patients without WLST achieved functional recovery in higher rates in those who distinguished the semantic differences between congruent and incongruent than those who did not (25% vs 18%). Conclusion: ERP differences between congruent and incongruent sentences were seen in 18% of ABI patients with coma. Distinguishing the semantic differences between the congruent and incongruent sentences correlated with better functional outcomes as measured by GOSE when looking at patients who did not undergo WLST.

Are there scientific theories of conscious experience? Explanations beyond mechanisms.

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Poster Session 3, Thursday July 4th, Ito International Research Center, 10:00AM-11:00AM

Scientific models of conscious experience are grounded on different premises, with little dialogue between them. Moreover, within consciousness science, there is great confusion regarding what constitutes a hypothesis, framework, model, and proper theory. These distinctions are essential for placing and comparing ideas on their right theoretical status and converging to more unified accounts of conscious experience. Therefore, in this talk, we start by exploring conceptual distinctions on what constitutes a framework, theory, and model and what may be a theory of conscious experience. We, therefore, clarify the theoretical landscape and conclude that there are no proper theories but a diversity of models. We then show the limitations of current mechanistic accounts, which makes them incomplete. Finally, we move on to how to avoid these issues, taking a broader perspective: we introduce constraint-type explanations, mereological constitution and causation, and a sound axiomatic strategy for empirical and theoretical research. This critical and constructive reading motivates open dialogue and intellectual humility. We end our contribution by offering collaborative paths and calling for consensus between neuroscientists, phenomenologists, physicists, and computer scientists, among others. We argue this might be the only way to (dis)solve the main open question about conscious experience. The presentation is based on two publications currently under review, and expected to be accepted by the end of May 2024.

Neurophysiology of mismatch negativity generation: a biophysical modeling study

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Poster Session 3, Thursday July 4th, Ito International Research Center, 10:00AM-11:00AM

The mismatch negativity (MMN) is a widely studied event-related brain response that offers insight into how the brain encodes redundant sensory information, generates predictions, and processes mismatches between predicted and actual sensory input. Most commonly studied in audition, the MMN can be elicited by any discriminable change in an otherwise regular stimulus pattern, and is known to be affected by brain state, lesions, and neurologic/psychiatric disorders. Despite its potential clinical relevance, a growing body of animal work, and the fact that the generators of the MMN are known to be in auditory cortex, its underlying neurophysiology (i.e. cell types, laminae, circuits) is not well understood. This hinders translation of circuit-level animal findings and mitigates the utility of the MMN as a neurologic psychiatric biomarker. Here, we used biophysical modeling (Human Neocortical Neurosolver) to examine the neurophysiology underlying the MMN as measured in a classical auditory oddball paradigm. We focused in particular on (i) increased NMDA conductances (which are known to covary with MMN amplitude in humans) and (ii) somatostatin-driven disinhibition (for which prominent animal models exist) in layer 2/3 pyramidal neurons. Although the response to standard tones could be modeled using a canonical cortical input sequence (feedforward-feedback), we could not model the increased response to deviant tones - and thus could not reproduce the MMN - through increased NMDA conductances alone despite complete disinhibition of the layer 2/3 pyramidal neurons. The results suggest that current circuit-level models of MMN generation are incomplete and may require involvement of additional circuit components or cortical laminae (e.g. layer 5).

Deconstructing and reconstructing experience via short-acting psychedelics and neurophenomenology

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Poster Session 3, Thursday July 4th, Ito International Research Center, 10:00AM-11:00AM

Psychedelics provide powerful means to study consciousness, however their effects are lengthy and variable, and thus difficult to control. DMT and 5-MeO-DMT - in combination with neurophenomenological methods - may significantly advance these limitations as they induce short acting experiences where a reliable state of disconnection from the external environment is experienced. While DMT induces a reconstruction of an immersive world consisting of vivid imagery, bodily effects, and entities, 5-MeO-DMT experiences can almost completely eliminate the sense of self, thoughts and sensory contents while preserving wakefulness, resembling so-called minimal phenomenal experiences. In two separate studies, we employed a neurophenomenological approach using fMRI (in a DMT vs placebo study with 20 participants) and EEG (in a naturalistic 5-MeO-DMT study with 30 participants) as well as micro-phenomenological interviews to determine how features of experience induced by these compounds relate to spectral power, and brain connectivity. We hypothesised that specific modulation of brain connectivity regions and changes in the power of brainwaves would underpin immersive experiences (of entities, and imagery) induced by DMT, and experiences induced by 5-MeO-DMT, respectively. Detailed interviewing revealed several features of experiences of entities, visual imagery, emotions, and bodily feelings, which related to specific modulations in brain connectivity induced by DMT compared to placebo. Similarly, experiences of 'void' induced by 5-MeO-DMT related to a reduction of the power of alpha and posterior beta brainwaves assessed with EEG. These studies illustrate the efficacy of employing neurophenomenology to exploit the use of short-acting psychedelics to explore consciousness. More specifically, it provides the first evidence of the neural correlate of entity experiences and how the deconstruction of conscious experience induced by 5-MeO-DMT relates to the disruption of top-down brain mechanisms.

Navigating subjective experience: The role of mind-wandering in inference

Cormac Dickson (University of Washington)

Poster Session 3, Thursday July 4th, Ito International Research Center, 10:00AM-11:00AM

Authors: Cormac Dickson, Elliot Wimmer, Matt Nour, Stephen M. Fleming Title: Navigating subjective experience: The role of mind-wandering in inference The ability to infer novel relationships from prior experience in a timely manner is a fundamental component of human intelligence. Sleep has been identified as a key period for such inferences. However much of human wakefulness is spent in a state of mind wandering, disengaged from the world around us. Recent empirical work using MEG and intracranial recordings have linked mind-wandering, via activity in the default mode network and self-report, to neural replay, a computation hypothesized to support inference. These rapid bursts of activity suggest that there may be more to mind-wandering than is revealed through first person accounts alone. However, we know very little about the functional role of mind-wandering, including whether it encourages the kind of inference processes facilitated by sleep. We carried out an online pilot study (89 subjects) to test a hypothesis that mind-wandering is linked to transitive inference. Participants learned by trial and error to select the correct stimulus from a set of 5 stimulus pairs, (A-B, B-C, C-D, D-E, E-F). The participants were not informed that the correct response in each case is governed by the relative position of the stimuli within a longer sequence (A-B-C-D-E-F). Participants then underwent a between-subjects cognitive load manipulation (0-back vs. 2-back) to prevent or encourage the occurrence of mind-wandering, prior to a delayed test which assessed both their knowledge of the original training pairs (A-B, B-C, C-D, D-E, E-F) and additional transitive pairs which had never directly experienced before (B-D,C-E, and B-E). Pilot results show that subjects who engaged in the 0-back task both a) reported an increase in task-unrelated thought and b) improved their performance on the transitive inference pairs relative to the 2-back group, with no difference in performance on the original premise pairs. Interestingly, our results show that increased transitive inference performance occurs without an increase in self-reported thought about the pairs. In addition, despite the performance increase, participants in the 0-back condition did not have a corresponding increase in confidence, suggesting that the improvements in performance were achieved without explicit awareness. We are currently seeking to replicate these results in N=89 subjects in a larger sample of N=300.

Can perceptual reality monitoring account for self-awareness? Insights from the HOROR theory

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Poster Session 3, Thursday July 4th, Ito International Research Center, 10:00AM-11:00AM

The perceptual reality monitoring (PRM) account of consciousness proposes that whether mental contents are conscious is determined by whether they reflect reality. Specifically, mental contents are processed by a discriminator system evaluating whether they reliably reflect features of the external world, one's internal imagination, or random neural activities (noise). The quality space of those identified as real are then subsequently indexed as to be part of external perceptual awareness or mental imagery (Dijkstra, Kok, & Fleming, 2022). The current PRM account only explains the mechanism underlying perceptual awareness. Here we suggest that PRM may also account for self-awareness, incorporating ideas proposed in the higher-order representation of a representation (HOROR) theory and its introspective extension (Renero & Brown, 2022). Self-awareness is of two distinctive types: aware of oneself as being in a perceptual state and as the one who introspect upon that state. Regarding the former, HOROR theory distinguishes whether one is aware of being in a conscious perceptual state by whether this higher-order state represents the self as being in the first-order state, instantiated in the integration of self-referential mental content (e.g. autobiographical memory schema; Brown & LeDoux, 2020). Regarding the latter, while higher-order theories typically account for introspective self-awareness as having some kind of third-order state, the HOROR theory argues that an introspectively conscious state remains second-order but represents the self as the subject experiencing the first-order state as opposed to being in that state. While currently unspecified in the HOROR theory, we hypothesize that under its framework introspective self-awareness should also involve self-referential mental content but through a different process. Infusing the PRM approach with principles of HOROR, we argue that self-awareness can be seen as being conscious of self-referential mental content alongside perceptual content in certain ways. Specifically, a perceptual state one is aware of being in consists of internally generated self-referential information sent upstream together with perceptual information, both of which are distinguished from noise but indexed as reflecting internal and external reality, respectively. This process allows one to be aware of the external world alongside a mental imagery consisting of a self-representational state, together formulating the experience of being part of one's external awareness. Introspective self-awareness prescribes the same mechanism for external perceptual awareness and the need for appropriate mental imagery. The difference is that it also tokens an internal representation of the first-order state after its quality space has been indexed for external awareness, which is then blended with self-referential mental content to form a mental imagery consisting of one experiencing the perceptual content. In sum, we propose that PRM can account for self-awareness in terms of combining internal and external states of awareness.

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Ganzfeld-induced altered states of consciousness: The interplay between abstract cognition and perceptually grounded thoughts

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Poster Session 3, Thursday July 4th, Ito International Research Center, 10:00AM-11:00AM

Viewing a Ganzfeld, i.e., a homogeneous visual field containing no shapes nor objects of focus but merely homogeneous colored light, results in a peculiar experience. Perceptual deprivation through Ganzfeld stimulation is characterized by the occurrence of hallucinations and perceptual blackouts. These phenomena have been studied in the context of visual perception and consciousness, and have been used in artworks such as the light installations by James Turrell. The crossroad between visual perception research and art pertaining to this Ganzfeld (GF) effect has previously been highlighted by Shimojo in the context of an exhibition tour by James Turrell in Japan (1997). Here, we investigated the immersive component of the GF effect, focusing on the elicited states of consciousness, using a mixed-method approach by combining behavioral and neural measures with questionnaires, rating scales, and interviews. In a first experiment, 28 participants experienced an in-lab, cycloramic, red GF. In a second experiment, 45 participants experienced the in-lab GF with varying colors. In a third experiment, we collected data from 67 participants in a museum-based GF artwork. In all 3 experiments, participants wore an EEG device and eye-tracking glasses, and they were given a dial to report occurrences of hallucinations and blackouts throughout the 25-minute GF session. A remarkable factor of the immersive GF is the inward-directed thoughts it seems to elicit. We found support for the induction of alterations in consciousness with significant effects for all dimensions of the altered states of consciousness rating scale in all 3 experiments ($p<0.001$). Whether the immersivity of this experience merely lies in its imaginary nature is not evident as the qualitative data pose somewhat of a discrepancy. Some participants described it as a meditative experience, emphasizing they had no awareness of their body, with several participants calling it a “transcendental” or “hypnotic” experience. Others stressed the elicited bodily sensations such as floating, imbalance and dizziness in some cases. This raises questions regarding the body’s role in the immersion in the GF and a potential interplay between abstract cognition (i.e., transcendental experiences) versus feelings and thoughts that are grounded perceptually, being either directed inward (i.e., heart rate) or externally when experienced in relation with the external world (i.e., floating, getting sucked into depth). Losing balance seems to coincide with the loss of depth perception due to the lack of reference points in the GF. We found a significant effect of distorted depth perception ($p<0.001$) using an inductive content analysis of our interview data. The potential of vergence eye movements as a behavioral signature of internally directed cognition is currently being explored. In addition, the temporal dynamics of increased alpha activity relative to reports of hallucinations and the relation with abstract cognition in this experience will also be investigated.

Prevalence of zolpidem use and its paradoxical effects on consciousness in the general population: an online survey

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Poster Session 3, Thursday July 4th, Ito International Research Center, 10:00AM-11:00AM

Introduction: Zolpidem is a non-benzodiazepine hypnotic agent, which is commonly prescribed as a sleep inducer. Initially administered to manage restlessness in severely brain-injured patients with disorders of consciousness (DoC), it elicited paradoxical arousal/awareness-enhancing effects in ~5-20% of these patients. Interestingly, similar paradoxically awakening effects have been observed in the general population, yet the prevalence remains unknown. This survey aims to (1) investigate the proportion of zolpidem use in the general population, (2) compare the prevalence of zolpidem-induced paradoxical effects in the general population and in DoC patients, (3) determine the interval between the drug intake and the emergence of paradoxical effects as well as the duration of the effects, and (4) identify common paradoxical effects experienced by zolpidem users and their subjective perception of these effects.
Methods: In this prospective cross-sectional epidemiological study, an anonymous survey was developed and distributed on Alchemer and Prolific Academic online platforms. Participants were recruited through (1) Network (social media, mailing lists, and institutional websites) and (2) Crowdsourcing (Prolific Academic) approaches. The inclusion criteria were set to ≥18 years of age and fluency in English and/or French. The outcome variables included the frequency and the purpose of zolpidem use, the occurrence of paradoxical effects, and the nature of paradoxical responses. Data cleaning was performed in Excel and RStudio was used for the analyses.
Results: Overall, of the 15,289 people (mean age 32 ± 13yo; 52% female; from 84 countries on five continents) who participated in the study, 785 (4.4%) reported to have used zolpidem at least once in their life. Among zolpidem users, 129 (16.4%) reported having experienced zolpidem-induced paradoxical effects on consciousness. The paradoxical effects are most frequently reported to emerge within the first hour (58%) and last up to 6 hours (60%) or more (16%). The following paradoxical effects were reported after zolpidem use: inability to fall asleep (60%), restlessness (42%), inability to stay asleep (35%), excitation (35%), agitation (26%), increased alertness (19%), increased energy (19%), increased concentration (10%), and other (11%) (e.g., euphoria, anxiety). Among the paradoxical responders, 40% reported that they experienced paradoxical effects at every intake. Participants have also subjectively perceived these paradoxical effects as unpleasant (43%), annoying (42%), exhaustive (38%), pleasant (22%), exciting (12%), and other (6%) (e.g., embarrassed, anxious). A supplementary analysis showed that in 24% of paradoxical responders, these effects were not exclusive to zolpidem but were also induced by other medications (e.g., benzodiazepines, antipsychotics).
Conclusion: 4.4% of survey respondents reported to have taken zolpidem with a ~16% prevalence of zolpidem-induced paradoxical effects, which is comparable to what is observed in DoC patients (~5-20%). As the arousal/awareness-enhancing effects of zolpidem seem similar between the general population and DoC patients, it can be assumed that paradoxical responders' states of consciousness might be modified following zolpidem intake and analogous mechanisms might be underlying these awakening effects. Further studies with different approaches (e.g., neurophysiological, genetic) are warranted to investigate the mechanisms underlying zolpidem effects both in DoC patients and in the general population.

Mental imagery "in the wild": an experience sampling study of aphantasics and visualisers

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Poster Session 3, Thursday July 4th, Ito International Research Center, 10:00AM-11:00AM

Our ongoing conscious experience often involves quasi-perceptual representations that are independent of our external environment: mental imagery. While in daily life these may arise spontaneously, mental imagery has traditionally been studied as a voluntary phenomenon and in controlled settings (using behavioural tasks). As a consequence, not much is known about its occurrence and characteristics (i.e., vividness, intentionality) in more naturalistic contexts (i.e., daily life) across longer time-scales.

To address this gap in the literature, we adopted a novel approach and investigated imagery during daily life and its associated patterns of conscious thoughts using experience sampling methodology, while also taking into account how this varies between individuals. Indeed, people report very different mental imagery experiences, with some experiencing very little or no imagery at will - those with aphantasia.

To this end, we collected data from a large sample of 101 participants, 82 who commonly experience imagery (visualisers) and 19 aphantasics. Participants completed a series of baseline questionnaire measures of imagery, mind-wandering and attentional traits, before being prompted 10 times a day on their smartphones to report on several dimensions of ongoing thoughts, imagery, mood, and activity, over a period of 5 days.

In visualisers, mental imagery experiences were very frequently reported (around 70% of the time), and, among these occurrences, 31% were highly involuntary, and 46% were highly voluntary. However, the degree of clarity (i.e., vividness) of the visual experience occurring during a conscious thought was positively related to how involuntarily triggered the thought was ($r = 0.4$). Furthermore, within this group, higher vividness and involuntariness were associated with stronger absorption towards one's thoughts, more interfering thoughts, less focus on either ongoing activities or the external environment and more negatively valenced thoughts.

In contrast to visualisers, most aphantasics' thoughts were "imageless" (92%). Interestingly, although involuntary thought frequency across the 5 days did not differ between the two groups, involuntary thoughts in aphantasics were less interfering, less absorbing, and less strongly associated with negative valence and general negative mood compared to visualisers.

Taken together, our results provide the first comprehensive characterisation of variation in imagery experience and its associated dimensions of thoughts in daily life. Moreover, they highlight the importance of considering individual variability and intentionality levels when investigating conscious imagery experience, and pave the way for novel longitudinal and naturalistic paradigms to investigate this mental phenomenon.

Tracing the conscious updating of preparatory attentional search templates in real time with EEG

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Poster Session 3, Thursday July 4th, Ito International Research Center, 10:00AM-11:00AM

In visual search, top-down attentional selectivity is promoted by internal representations of target-defining features (attentional templates), which are assumed to be activated in advance of an upcoming search episode. We recently developed the "high-definition rapid serial probe presentation paradigm" (or RSPP-HD), a method for tracking attentional template activations in real time and with high temporal resolution, via monitoring of the N2pc component. In the RSPP-HD procedure, series of task-irrelevant probe displays are presented at regular intervals during the period between successive task-relevant search displays. When a corresponding target template is active, lateralised probe stimuli including the target-defining feature are expected to attract attention and elicit an N2pc, thereby tracking the temporal profile of preparatory template activation processes. Here, we employed the RSPP-HD to monitor the process of either maintaining or updating an active attentional template. In any given trial, a task-relevant search display unpredictably appeared at one of two potential timepoints: either "early" (750 ms after trial onset) or "late" (1500 ms after trial onset). Participants were instructed to always report the location of a particular colour-defined target if the search display appeared "early". Otherwise, an informative cue was presented at the 750 ms timepoint, instructing the participant to either (1) maintain the current colour template or (2) switch to a different template, in order to report the location of a template-matching object in the "late" search display. During the period leading up to either potential search display, lateral task-irrelevant probe displays were presented every 50 ms, each containing one of the two potential target colours. Our study demonstrates that the RSPP-HD paradigm can effectively capture the temporal profile of activating, deactivating, and reactivating multiple attentional templates during dynamic preparation for visual search tasks. Additionally, we show that voluntary template activation, maintenance, and switch processes trigger involuntary and presumably subconscious attentional shifts during search preparation. Finally, the findings detailed here offer a preliminary indication of how multiple attentional templates might be represented and maintained in parallel.

Dualities in G-Spaces May Underly Pre-Reflective Self-Consciousness

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Poster Session 3, Thursday July 4th, Ito International Research Center, 10:00AM-11:00AM

Pre-reflective Self-consciousness (PRSC) is a fundamental aspect of consciousness by which it is inherently aware of itself, including for its own possibilities of action. PRSC does not depend on secondary, reflective representation. According to the Projective Consciousness Model (PCM), consciousness can be represented as a 3D multimodal, projective geometrical internal workspace, with a subjective perspective governed by the actions of the projective group. We have proposed that projective geometrical dualities could underpin PRSC, such that subjective-objective and active-passive dichotomies and the reciprocity between the framing of information and the information being framed (e.g., the phenomenon wherein objects seem to "look back" at us when observed) might be dual aspects of a singular phenomenon. The PCM emphasizes the importance of experiential "space", i.e., as a space for multimodal experience and the interplay between the observer and the observed. We recently proposed conceptualizing experiential space within the broader framework of G-space, which represents a space acted upon by a group. We consider both the geometrical structure of experiential space (as a "container") and its contents (phenomenal colors and other sensory qualities). We aim to comprehend how such an experiential space may, by virtue of its internal structure, enable an agent to recognize its own presence and actions vis-à-vis external changes by exploring the dualities of G-spaces and their relation to PRSC. Group actions correspond to the varying perspectives an agent can adopt towards its environment while acting on it; they correspond to action outcomes in the world. The Yoneda lemma for G-spaces suggests that identifying a point in these spaces is in "duality" with representing an agent's actions within such spaces. This simplifies, e.g. for projective geometry, to the idea that the space is an orbit of any of its points. The structure of such spaces intrinsically and ubiquitously contains the operations characterizing the agent's possibilities for action and thus manifests the agent to itself, providing a rudimentary model of the pre-reflective sense of an agent's own presence and affordances. We further consider, using specific examples, that G-spaces might be too general to account for the space of internal representation (notably to ensure its resilience to perturbation and noise). We propose that perceived features must be structured as a bundle over a homogeneous space by examining the role of Principal Bundles in reconstructing space from sensory information. Our model, grounded in POMDP with group-structured state spaces, offers a promising understanding of aspects of PRSC. It tackles problems in the theory of self-awareness and provides a framework for exploring the intricate relationship between an agent's actions, its internal representation of the world, and its pre-reflective awareness of itself.

Language Models for Synthesizing Perspectives in Research Fields: Application to Consciousness Studies

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Poster Session 3, Thursday July 4th, Ito International Research Center, 10:00AM-11:00AM

Several research fields face a challenge: there is no consensus on definitions for the objects of study. For example, psychological theories on emotion have not agreed upon a consensual definition of the emotional phenomenon. This is also the case for the science of consciousness, which is searching for a scientific definition of consciousness. The progress toward scientizing these disciplines is slowed by a focus on differences, neglecting the potential for theoretical convergence.

We believe that a preliminary step required to make a term scientific is considering its application in various contexts. With language models in natural language processing, we study the different ways to define a term. Recently, language models have been compared to characters and cultural perspectives simulators. They can be used to simulate humans, thus replicating certain psychological studies. We follow a general method to study the different perspectives that exist on problematic terms (e.g., emotion or consciousness) in three steps:

(1) we generate synthetic human biographies with a language model by controlling several variables such as age, nationality, and socio-professional category;

(2) from the generated biographies, we generate diversified perspectives on the terms;

(3) we study the similarities between the perspectives by embedding them in a vector space and clustering them into several clusters.

By highlighting a plurality of perspectives with their similarities, we seek to promote a convergence between different viewpoints within a research field. Our study contributes to constructing a common framework among different perspectives, which could lead to a scientific definition of the objects to be studied.

Example of generation for steps (1) and (2):

(1) Youssef is a 45-year-old neuroscientist born and raised in Egypt. She has spent the last two decades studying the neural mechanisms underlying consciousness at a leading European university. (2) For Youssef, consciousness results from complex neural processes that give rise to self-awareness and the ability to perceive, think, and experience.

(1) Smith is a 30-year-old software engineer from Silicon Valley, USA. He is keenly interested in artificial intelligence and its potential to mimic or surpass human cognitive abilities. (2) John believes consciousness can be understood as a form of information processing where the mind operates similarly to a computer.

(1) Patel is a 60-year-old yoga instructor from India. She has dedicated her life to exploring the inner dimensions of the self through meditation. (2) Lakshmi views consciousness as an expansive, all-encompassing reality that transcends the physical boundaries of the individual self.

In step (3), we automatically identify that Youssef and Smith belong to the cluster consciousness with a focus on objective analysis and potential for technological replication while Patel belongs to the cluster consciousness in terms of personal subjective experience.

Correspondence of high-dimensional emotion structures elicited by movie clips between humans and LLMs

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Poster Session 3, Thursday July 4th, Ito International Research Center, 10:00AM-11:00AM

Large Language Models (LLMs) have recently undergone significant development, demonstrating the ability to naturally manipulate language and perform various intellectual tasks. In the domain of emotion recognition, tasks such as facial expression recognition and sentiment analysis demonstrate the ability of these models to accurately infer objective emotions. However, the extent to which LLMs can accurately infer subjective human emotions in response to emotion-inducing situations remains unclear. Recent studies have indicated that emotions have a more complex, higher-dimensional structure than previously understood, challenging traditional concepts of basic emotions and dimensional theories. The feasibility of models that correctly estimate such high-dimensional complex emotional structures is a challenging and unresolved issue. In this study, we investigated whether one of the multimodal LLMs, LLaVA, can infer the high-dimensional structure of emotions by treating reports of the distance of subjective emotion experiences while watching videos as the subjective emotion structure. To assess the correspondence of emotion structures, we used a recently developed unsupervised alignment method based on Gromov-Wasserstein optimal transport, which can reveal a more detailed structural correspondence than supervised alignment methods such as conventional representational similarity analysis. Before comparing the emotion structure between humans and LLMs, we first investigated whether the emotion structure can be aligned across different people, using the previously published behavioral experimental data (Koide-Majima et al., 2020). In the behavioral experiment, participants watched 554 dramatic videos with audio and subtitles with an average duration of 15 seconds, and reported 80 emotion categories. We divided the subjects into two groups and then applied the unsupervised alignment. We found that 31.1% of the videos were mapped to the same video across participants, with the chance level of 0.18%, confirming the existence of a somewhat common alignable emotion structure among humans. Next, we investigated whether the emotion structure of LLMs can be aligned with that of humans. In this analysis, we used a different behavioral dataset (Cowen & Keltner, 2017) than in the first analysis because the LLaVa could not receive audio input, which is necessary for the emotion assessment of Koide-Majima et al.'s dataset. In the behavioral experiment, subjects watched 2185 videos with an average duration of 5 seconds, and reported the 34 emotional categories. We extracted 6 frames from each video and entered them into LLaVA, and then collected the reports of the 34 emotional categories from LLaVa. We found that for the top 100 clips selected based on the cosine similarity between humans and LLaVa, the matching rate was 22% with the chance level of 1%, suggesting that the LLaVA can infer the averaged emotion structure of humans to some extent. Our results demonstrate that the emotion structure of LLMs can be aligned to some extent with that of humans in an unsupervised manner, indicating the ability of LLMs to capture the high-dimensional emotion structure. These results indicate the potential utility of LLMs for exploring human emotion structure in greater depth and establish a new benchmark for evaluating LLM performance.

The role of language for a theory of self-consciousness

Hui Gao (University of Washington)

Poster Session 3, Thursday July 4th, Ito International Research Center, 10:00AM-11:00AM

The role of language for a theory of self-consciousness How can I be sure, that the Self that I encounter is really mein? The Difficulty of self-consciousness has been reformulated by Dieter Henrich as the problem of circularity of consciousness theory. But where does this circularity arise from? Does it really lie in the essence of our consciousness per se, or is it a problem caused by the very nature of our metaphysical language. Fichte realizes that the real foundation of the seemingly inevitable circularity of consciousness lies in the reflexivity of language itself: although language makes thinking and self-consciousness trascendentally possible, it also brings its own reflexivity into our thinking models, which is known as the so-called reflective model of consciousness. In other words, self-consciousness just reflects the structure of language. This confusion results in the gap of the I as subject and the I as object, which makes the identification of self-consciousness impossible. Thus, is it possible to have self-consciousness even without the language? Or, could we think at all without language? Here, I propose a solution to these questions through an analysis of Fichte's critique of language to find a way out of the conundrum of self-consciousness. This approach promises to obtain a better grasp on the nature of self-consciousness and provide a defense against the circularity critique of self-consciousness theory.

Grid cell-like representation in the human entorhinal cortex reflects changes in spatial self-consciousness

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Poster Session 3, Thursday July 4th, Ito International Research Center, 10:00AM-11:00AM

Grid cells are place-modulated neurons encoding self-location in space through the integration of various sensorimotor signals from the body. The integration of such bodily signals is also fundamental for the conscious experience of selfhood (or bodily self-consciousness, BSC). Previous BSC studies showed that synchronous multisensory bodily stimulations can experimentally induce an illusory drift in self-location toward an avatar seen in virtual reality (VR). However, it has never been investigated whether these illusory changes in spatial self-consciousness accompany with the corresponding changes in grid cell-like representation (GCLR) in the human entorhinal cortex (EC). Here, we aimed to assess whether an illusory drift in self-location, induced by BSC modulation and in the absence of any active spatial navigation, can elicit grid cell-like representation (GCLR), an fMRI proxy of grid cell activity, in the human EC. Adopting the BSC paradigms using VR to MRI, we induced drifts in self-location toward every 20˚ direction spanning the horizontal plane and confirmed the classical finding that drifts in self-location were significantly larger in the experimental (synchronous visuo-tactile stimulation) versus control condition (asynchronous stimulation) ($d = 0.28$, $p < 0.001$). In fMRI, we observed significant GCLR only in the synchronous condition ($r = 0.35$, $p = 0.024$; for asynchronous condition, $r = 0.20$, $p = 0.127$). Notably, the amplitude of the GCLR was proportional to the illusory change in self-location ($p = 0.041$), associating GCLR in the EC with the illusory drift in self-location. Additionally, we found that when the illusory drifts were larger (> 0.5 virtual meter; median split), GCLR during the illusory drifts was correlated with the GCLR during the classical active virtual navigation whose spatial vector (i.e., destination and heading direction) was matched to the illusory drift in the same VR room ($rho = 0.7$, $p = 0.002$). Moreover, we report that the grid orientations of the GCLR elicited by the illusory drifts were similar to the ones during the virtual navigation (angular difference = $1.15° \pm 4.82°$, $r = 0.35$). These data suggest that the brain mechanisms underlying self-location drift in the EC are comparable to those activated during virtual navigation, and both processes are arguably based on the same cognitive map. To summarize, we demonstrated that illusory changes in perceived self-location, induced by multisensory bodily signals without alterations in visual viewpoint, are associated with corresponding changes in grid cell-like activity in the human EC. This represents the first human study to show that GCLR can be induced based on multisensory bodily cues, extending beyond classical visual cues. Our findings highlight a close relationship between BSC and grid cells, elucidating their interconnected roles in the experience of self-location.

Differential auditory mismatch responses depending on awareness and task relevance

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Poster Session 3, Thursday July 4th, Ito International Research Center, 10:00AM-11:00AM

Presenting rare among frequent auditory stimuli results in a mismatch response, where, on a neural level, the rare deviants elicit a stronger response than the frequent standards. While mismatch responses in event-related potentials (ERPs), like mismatch negativity and P3 have been studied extensively in the auditory modality, the separated effects of awareness and task relevance on different components of the ERP to deviant and standard stimuli remain to be investigated. In the current EEG study, we used a rovinlus presentation as deviant, which– after several repetitions – turns into a standard. Four different task conditg oddball design, in which speech stimuli (the German words oben [ˈoːbn̩] and unten [ˈʊntn̩], meaning above and below, respectively) were presented in sequences of varying length, leading to a classification of the first stimuions using the same physical stimuli were implemented, so that the roving oddball stimuli were (1) unaware, (2) aware but task-irrelevant, (3) task-relevant but target-irrelevant and (4) target-relevant. The order of the conditions was pseudo-randomized, with the exception of the unaware condition being the first condition for every participant. Behavioral data showed that participants were able to easily differentiate presented words from not presented words in all aware conditions, but not in the unaware condition. We compared ERPs in response to deviant versus standard speech stimuli in all four conditions and found early fronto-central negativities and late positivities that varied with awareness and task relevance. Results have important implications concerning theories of unconscious and conscious deviance processing.

Cross-Subject EEG-Based Emotion Recognition through Neural Networks with Stratified Normalization

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Poster Session 3, Thursday July 4th, Ito International Research Center, 10:00AM-11:00AM

Recently, a good deal of effort has been made in creating machine learning models that can recognize evoked emotions from one's physiological recordings due to its large number of potential applications. In particular, researchers are investigating the use of EEG signals due to its advantages compared to other methods. However, the poor generalization of the EEG signals between-participants hinders the implementation of any system without a time consuming calibration stage. Hence, based on the reduction of the inter-participant variability when implementing participant-based feature normalization, we propose a neural network with stratified normalization to improve current cross-subject emotion classification results. To deepen the assessment of the stratified normalization's performance, we also present the results for the neural network with batch normalization. The analysis is carried out using the SEED dataset, which contains 62-channel EEG data collected from 15 participants. Results demonstrate that the neural network with stratified normalization outperforms the neural network with batch normalization and subtracts the inter-participant variability while maintaining the emotion information in the data. In particular, the highest emotion recognition accuracies were achieved when extracting the features with the multitaper method, performing with an accuracy of 91.6% and 79.6% for two categories and three emotion categories, respectively. This work's results provide us with a great insight into the potential benefits that feature normalization, stratified in particular, can have in developing any cross-subject model via EEG signals.

Developing sensory-evoked complexity as a possible marker of consciousness in infants and fetuses

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Poster Session 3, Thursday July 4th, Ito International Research Center, 10:00AM-11:00AM

Inferring consciousness in infants, and especially fetuses, is highly challenging due to undeveloped motor skills. Nonetheless, some of us have recently proposed a “cluster-based” approach (Bayne et al. 2023) in which a sufficiently large cluster of neural and/or behavioral markers associated with consciousness in adults might collectively provide persuasive evidence of consciousness when applied in infants, even if no one marker per se is sufficient evidence. While prior studies have examined a number of such markers (e.g., attention, P3b response), a consensus on infant consciousness is unlikely until additional measures can be added to this cluster. One of the most successful markers of consciousness in adults, the perturbational complexity index (PCI; Casali et al. 2013), is attractive for this purpose, but it relies on transcranial magnetic stimulation or TMS (hence, its “zap-and-zip” moniker). As such, PCI cannot be ethically applied to infants, much less fetuses. We propose a more suitable measure based on sensory perturbations in infants and fetuses (Frohlich et al. 2023). Sensory PCI (sPCI) might plausibly contribute to a cluster of markers if the complexity of neural activity recorded in response to sensory perturbations is a surrogate measure of consciousness. The validation of sPCI should take place in stages. Stage 1 should compare the complexity of sensory evoked potentials in adults to that of TMS-evoked potentials using EEG from wakefulness versus slow-wave sleep and general anesthesia (the latter two states lacking consciousness). Visual, auditory, or somatosensory stimulation might all be suitable at this and later stages. Assuming that sensory and TMS perturbations work similarly well in adults, the next stage of validation, Stage 2, should compare the complexity of sensory-evoked perturbations between wakefulness and slow-wave sleep in children at an age where self-reports of phenomenology are obtainable. This could be done using EEG or MEG. If Stage 2 is successful, the final stage, Stage 3, should compare the complexity of sensory-evoked perturbations between wakefulness and NREM sleep in infants. Across all stages and modalities, we recommend using irregularities or “oddballs” to avoid habituation and to generate prediction errors that propagate as widespread corticocortical interactions. Besides auditory, visual, or somatosensory modalities, a “sniff-and-zip” using olfactory perturbations might be especially well-suited for newborns, given the salience of many odorants in the first weeks of life. If successfully validated using the three-stage approach we have outlined, this technique might bring the accuracy of PCI to the cluster-based approach for inferring perinatal consciousness. Estimates of when consciousness begins in human life, informed by this cluster-based approach, can be further constrained by knowledge of thalamocortical development (e.g., no earlier than 26 weeks gestation, see Bayne et al. 2023).

Increased self-related cognitive differentiation after a single dose of 5-MeO-DMT

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Background: Language and inner speech not only convey information but also generate and sustain self-consciousness (Skipper, 2022). Words are the building blocks of the narrative self which actively modulate our thought processes, with prior studies showing that vividness of inner speech predicts awareness of mind-wandering (Bastion et al, 2017). Psychedelics have been shown to induce temporary alterations to the sense of self, which are also reflected in disruptions across several language domains (e.g. pragmatics, structure, and syntax) (Tagliazucci, 2022). However, no prior studies investigated whether any of these changes continue beyond the drug experience. To address this gap, our research explores how a single dose of 5-MeO-DMT might influence self-referential language, reflecting possible changes in the structure of self-awareness. Methods: Healthy, adult participants (n=28) were instructed to use a custom chatbot to record and submit their daily thoughts via voice notes for 7 days before and after a 5-MeO-DMT retreat (1x12mg). Participants were asked to submit a recording once a day in the evening at a time of their choice, and they were also allowed to journal spontaneously at any moment they wished. The chatbot sent reminders, collected and automatically transcribed submitted voice notes. The transcripts were split into individual sentences and analysed with Linguistic Inquiry and Word Count (LIWC) software. Sentences without self-referential terms (score of 0 in the LIWC 'I' category, which includes words such as 'I', 'me', 'myself') were excluded. For each participant, two mean scores were computed, and adjusted for word count: one from entries before and another from after the retreat. We initially focused on the 11 LIWC high-level domains: Cognition, Affect, Social, Culture, Lifestyle, Physical, States, Motive, Perception, Time, and Conversation, using nonparametric Wilcoxon tests. For significant domains determined using Bonferroni-adjusted threshold, we conducted a follow-up examination of its subcategories. Results: A total of 308 voice notes were collected (10±6 per participant). Out of the total, 26 participants submitted at least one voice note both before and after the retreat, meeting the criteria for data analysis. Seven of the LIWC categories had a sufficient word count for analysis, averaging at least 1% of all words across participants. Analysis of the transcripts including self-referential terms from before to after the retreat showed a significant increase in the high-level 'Cognition' domain of +2.49% (p=0.006). Further examination revealed that this result was mainly driven by an increase in the 'cognitive differentiation' subcategory (e.g., 'but,' 'except,' and 'however') by +0.93% (p=0.009). Discussion: These findings demonstrate that psychedelic-induced 'altered states of consciousness' can produce changes in self-referential language structure that persist beyond the drug's active period. Cognitive differentiation, as defined by Kovářová and Filip (2015), refers to an enhanced capacity to perceive experiences from multiple perspectives. The noted linguistic shift towards greater use of cognitive differentiation words hints at a possibility of more sophisticated levels of thinking and a somewhat elevated understanding of self. Nonetheless, further research involving larger samples and a wider variety of psychedelics is needed to thoroughly unravel this intricate relationship.

Integrative sensory modulation: Engineering intensive VR experiences to address depression and anxiety

Joshua Clingo (University of Washington)

Poster Session 3, Thursday July 4th, Ito International Research Center, 10:00AM-11:00AM

Issues of pathological canalization—including depression, anxiety, addiction, and PTSD—have recently seen treatment inroads. Among the most effective treatments are psychedelic and dissociative-assisted psychotherapy as well as TMS/ultrasound neuromodulation. In these, it is proposed that the primary mechanism for acute changes that give way to enduring changes is "temperature or entropy Mediated plasticity" (TEMP) (Carhart-Harris et al., 2023). Given this hypothesis, we have developed a series of experiments that explore the possibility of inducing TEMP without the need for direct pharmacological or neural modulation, similarly to EMDR (which combines behavioral methods with sensorial triggers). In these, we present intensive visual, audio, and tactile stimulus in a VR context, to the end of reaching similar hyperplastic states that can lead to lasting positive behavioral change. This has been explored by others in psychedelic analogues (Kaup et al., 2023) as well as immersive group experiences (Glowaki et al., 2022). In a pilot study (MTurk, N=78), we examined a visual stimulus based on a psychedelic aid (called "Barry Martin's Hopalong orbits visualizer"), selected for its apparent dissociative qualities. There were three conditions: 1. Hopalong Orbits visualizer (N = 22) 2. Altered Hopalong Orbits visualizer (attempted control; N = 17) 3. No stimulus (baseline for population) (N = 39) We found that awe (AWE-S) and meaning (MIQ) significantly increased in the Hopalong condition relative to the measured baseline, though we saw similar positive results with the attempted control, which was found to acutely increase positive affect. The primary study (current N=9) involves intensive visual, auditory, and tactile stimulus in a VR context, measuring wellbeing, connectedness, depression, anxiety, divergent association, altered states/acute dissociation, as well as meaning and meaning-making. The control is another VR context—a factory experience—as a baseline for VR stimulus. We reproduced the pilot study Hopalong stimulus with VR-specific adjustments, complemented by music and tactile feedback. Current results indicate acute increases to each of these measures—besides depression and anxiety, which saw decreases—in the Hopalong condition relative to the factory condition. However, it is unclear whether these changes persist beyond the moments immediately following the stimulus or whether they will generalize to the intended clinical population (participants are gathered from a non-clinical undergraduate pool that has largely not been diagnosed as having depressive and/or anxious symptoms). Further work should be done to explore the limits of purely intensive sensory modulation as a means of inducing TEMP, as a contrast to current pharmacological and neuromodulatory approaches, which may carry increased risk and accessibility limitations.

Private self-consciousness and psychological health in Japanese university students: Moderating roles of self-compassion

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Poster Session 3, Thursday July 4th, Ito International Research Center, 10:00AM-11:00AM

Private self-consciousness refers to one's propensity for paying attention to the inner self. Private self-consciousness is deemed to involve rumination and reflection, each of which reflects a maladaptive and adaptive aspect of self-consciousness. Among these constructs, rumination refers to negative, repetitive, chronic, and highly sustainable patterns of thinking that is motivated by perceived threats, losses, and injustices to oneself. By contrast, reflection is considered as a psychological trait characterized by a propensity to direct attention to the inner self motivated by intellectual curiosity. Whereas reflection has been associated with desirable psychological health outcomes such as higher psychological well-being, rumination has been suggested to be related to psychological symptoms such as higher depression and/or anxiety. To date, little is known about the potential protective factors for individuals with high ruminative tendencies against psychological symptoms. The present study focused on moderating roles of self-compassion, which denotes a mental attitude of directing kindness toward oneself (self-kindness), nonjudgmentally accepting experience (mindfulness), and recognizing that such experience is shared by others (common humanity). According to the Self-Compassion Scale developed by Neff (2003) and Arimitsu (2014), self-compassion involves these 3 positive dimensions, and 3 negative dimensions opposite to each positive component, i.e., self-judgment, over-identification, and isolation. Specifically, we examined associations between rumination/reflection, self-compassion, and psychological health. We also investigated whether and how the associations between rumination and psychological health may be moderated by components of self-compassion. A questionnaire survey using a cross-sectional design was conducted on 340 Japanese university students by using both an online platform and a paper-based survey sheets. The survey included established Japanese versions of psychological scales on rumination/reflection, self-compassion, perceived stress, trait anxiety, and depression. Results revealed statistically significant positive correlations between rumination and negative dimensions of self-compassion, and between rumination and psychological symptoms. Positive dimensions of self-compassion were significantly negatively correlated with both rumination and psychological symptoms. Reflection was not significantly correlated with most psychological variables. Furthermore, hierarchical multiple regression analyses involving subscales of self-compassion and their interactions with rumination as predictors showed that interactions between rumination and multiple components of self-compassion including over-identification and mindfulness significantly predicted trait anxiety. Post-hoc simple slope analyses further revealed that higher rumination predicted higher anxiety when over-identification was high, but not when over-identification was low. Also, lower rumination predicted lower anxiety when mindfulness was high, but not when mindfulness was low. These results suggest significant associations between a maladaptive dimension of private self-consciousness, self-compassion, and psychological health in the studied population. Moreover, the results suggest that multiple components of self-compassion play moderating roles in the relationship between rumination and psychological health, thereby serving as aggravating/protective factors for psychological health outcomes. Future studies may involve both longitudinal studies and comparisons between different cultures, to examine generalizability of the present results to a wider population, and to explore whether and how self-compassion-based interventions may improve psychological health in individuals with a high ruminative tendency.

Altered emergent information dynamics in Alzheimer’s disease and cognitive impairment

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Poster Session 3, Thursday July 4th, Ito International Research Center, 10:00AM-11:00AM

Alzheimer’s Disease (AD), a degenerative disease of the central nervous system leading to dementia, results in roughly 3% of deaths worldwide. It is increasingly viewed as a disorder of consciousness (see, for example, Huntley et al., 2021). Given the close theoretical and empirical ties between information processing and consciousness, here we explore altered macroscale information dynamics in AD. Recent work by Luppi et al. in 2022 identified distinct information processing dynamics across brain regions in healthy individuals using resting-state fMRI from the Human Connectome Project (HCP). To do this, they used Partial Information Decomposition (PID) and an extension, Integrated Information Decomposition (Phi-ID). PID and Phi-ID both provide measures of redundancy (a form of shared information) and synergy, which can be thought of as representing emergence, reflecting information accessed by a system which is greater than the sum of its parts. This work revealed synergy-dominant information processing in higher-order brain networks (such as those recruited in emotional processing, memory, cognitive control and social cognition) and redundancy-dominant information processing in lower-order brain networks (primarily sensorimotor regions). In this work we discuss how this approach can be applied to resting-state fMRI from the Alzheimer’s Disease Neuroimaging Initiative (ADNI) to explore the altered information dynamics signature of AD progression. We hypothesized that disease progression would correlate positively with increased global information redundancy. However, provisional results appear to demonstrate the converse; a potential lean towards synergistic information signatures at the global level ($p = 0.03$, Cohen’s $d = 0.16$), with stronger and more specialized trends locally. This work shows that there are intriguing information-dynamic differences in AD vs controls, potentially reflecting an altered conscious state. Furthermore, these information signatures could be used as possible biomarkers for understanding AD progression, and how this relates to cognitive impairment.

Tactile detection and localisation in the greyzone of perception

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Poster Session 3, Thursday July 4th, Ito International Research Center, 10:00AM-11:00AM

Numbtouch and hemispatial neglect, two neurological conditions often following one-sided brain injury, can possibly give us insight into mechanisms of tactile detection and localisation. Patients with substantial damage to primary sensory areas were reportedly able to correctly localise unperceived tactile stimuli, a phenomenon that became known as 'numbtouch'. Neglect patients often have a perfectly intact somatosensory cortex, but are nonetheless unable to both detect and localise tactile stimuli that are presented to their neglected body side.
We aimed to establish a near-threshold stimulation paradigm that integrated tactile detection, skin-based localisation as well as manipulation of stimulus location in external space. Weak electrical stimuli of constant near-threshold intensity were applied to two fingers of the left hand. Participants completed a yes/no detection task (Y/N) and a 2-alternative-forced-choice localisation task (2AFC). Throughout the experiment, they changed the position of their stimulated hand several times between anatomical position (in homonymous hemispace, left of the body midline) and crossed (in opposite hemispace, across the body midline). In a young healthy sample, we aimed to replicate behavioural findings from a previous series of experiments that demonstrated above-chance correct localisation of undetected tactile stimuli. EEG data was recorded to investigate the electrophysiological underpinnings of this undetected tactile localisation. Furthermore, we explored the effect of hand position in external space on tactile detection and localisation within an intact somatosensory system.
Our results showed no influence of hand position on tactile localisation and a negligible effect on detection. We argue that above-chance correct localisation in trials that were reported as undetected does not reflect unconscious stimulus processing but rather demonstrates how binary response designs fail to capture nuanced degrees of perception. Our electrophysiological results contribute to the existing body of research about the role of SEP components and neural alpha oscillations in tactile detection and related processes. Previous findings of electrophysiological and behavioural correlates of mapping tactile stimuli into peri-personal space could only partially be replicated.
The presented study empathises the importance of rigorously ensuring stimulus unawareness when investigating unconscious sensory processing, and calls for careful consideration of the challenges posed by near-threshold paradigms.

Everything everywhere all at once? Exploring the richness of visual experience beyond words

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Subjectively, our visual experience seems rich and detailed. However, previous studies implies our experience is limited to 3~4 items at a glance.To bridge the gap between our impressions of rich experience and empirical findings, we challenge the traditional framework to understand visual experience, probing deeper into how we experience our environment. Previous studies focused on small details in the stimuli and how we describe them, such as noting "a red car" in a street scene. However, descriptions of this kind cannot exhaust all that we experience. Here, we broaden the scope by considering not just the semantic, descriptive labels that human participants can name, but also the rich perceptual qualities such as texture and colour that may have no appropriate words for. To achieve this, we designed two experiments. In Experiment 1 which we already completed, we investigated the semantic labelling of visual scenes. We generated 100 natural scene image pairs, with each pair nearly identical except for local texture differences. We asked 100 online participants to describe each image, and assessed their descriptions using large language models. Our findings indicated that a substantial number of image pairs (27 out of 100) share indistinguishable semantic labels. This implies any physical differences in local properties in the images did not affect how participants reported about their experiences. In (registered) Experiment 2, we will use these semantically-equated pairs for a perceptual discrimination task, to examine whether participants notice the perceptual differences between the images that are not captured by words. Upon provisional acceptance, we will run this task online with participants accessing the task on their laptops, allowing us to test as many participants as needed for sufficient statistical power. While online testing is convenient for statistical power, its display setup is similar to that of a standard psychophysics task, which presents the stimuli in a small, central area of the participants' visual field, probing only a limited portion of what they can experience at around central vision (fovea to +/- 10 degrees visual angle). Therefore, we will also run this task in-lab using an ultra-large (180-degree, immersive) display, to test whether or not our experience across the entire visual field can be richer beyond verbal description. Our study is being conducted as a registered report (supported by the Center for Open Science (COS) / Association for the Scientific Study of Consciousness (ASSC) Registered Report grant initiative).

Empathy in AI: Theory of mind with sophisticated inference and isomorphic goal oriented dynamics

Mahault Albarracin (University of Washington)

Poster Session 3, Thursday July 4th, Ito International Research Center, 10:00AM-11:00AM

The advancement of Artificial General Intelligence (AGI) necessitates a paradigm that ensures alignment with human values and ethics, where the integration of empathy within AI systems emerges as a critical frontier. This paper delves into the intricate role of empathy in surmounting challenges of AGI alignment, presenting an innovative approach that equips AI agents with the capacity for understanding, sharing, and responding to human emotions. This capacity is designed to cultivate a synergistic interaction landscape between AI and humans, characterized by mutual understanding and ethical congruence. At the heart of our methodological innovation is the integration of sophisticated inference mechanisms within the active inference framework, enriched by a profound engagement with the Theory of Mind (ToM), and goal-oriented isomorphism. Sophisticated inference is an advanced computational process that allows AI agents to understand and predict complex behaviors and states by incorporating layered models of cognition and interaction. This capability enables agents to take on different perspectives by simulating the mental states and decision-making processes, which can be extended to that of others, thereby facilitating a deeper understanding of and adaptation to the varied viewpoints and intentions within social interactions. These elements coalesce to endow AI with the unprecedented ability to attribute and process mental states—including beliefs, intentions, and emotions—both in relation to themselves and others. This capability is pivotal in fostering interactions that are contextually appropriate and are deeply aligned with ethical considerations and human values. Our approach is grounded in the neuroscience of empathy, drawing parallels between the biological substrates that facilitate empathic behavior in humans—such as mirror neurons and the processes of mental simulation—and their artificial counterparts. We propose a model of goal-oriented isomorphy, where AI systems identify aligned objectives with those of humans through the concept of shared protentions, thereby achieving a resonance of goals that enhances empathetic engagement. Shared protentions refer to the anticipatory processes through which individuals or agents collectively foresee and align their expectations about future states or events, based on a common understanding or framework. This concept allows for a synchronized approach to planning and decision-making, rooted in a shared context or goal. By fostering a common anticipatory stance, shared protentions naturally lend themselves to isomorphic experiences, as they create a unified framework within which agents can experience and react to events in a harmonized manner, deeply aligning their cognitive and emotional responses with those of others. Through detailed exploration of the mechanisms enabling AI agents to experience the affective states of others and align with shared goals, we illustrate how empathy in AI transcends mere functional mimicry, achieving a form of intrinsic isomorphism with the dynamic structures of human generative models. This deep empathetic process, facilitated by sophisticated inference and shared protentions, fosters a sense of ingroupness and pro-social behavior aligned with the completion of shared objectives. We articulate the technical and ethical challenges inherent in actualizing this empathetic paradigm in AI, advocating for a multidisciplinary approach to navigate these complexities. Our vision for the future of AI is predicated on the capacity for empathy, positioning it as a cornerstone for AGI systems that actively promote human flourishing.

Tracking neural correlates of conscious content with complexity

Marcin Koculak (University of Washington), Michał Wierzchoń (Jagiellonian University)

Poster Session 3, Thursday July 4th, Ito International Research Center, 10:00AM-11:00AM

Identifying the brain mechanisms that support consciousness is one of the most challenging tasks that science faces today. Many theories have been proposed to explain how neuronal activity gives rise to this phenomenon, focusing on its different aspects. In this project, we investigated whether currently available state of the art measures of consciousness can be used to study the variability of consciousness in healthy awake humans at rest. Rigorously examining these fluctuations that every person experiences on the daily basis, could give novel insight into what brain mechanisms are responsible for the way we experience everything that is around us. To achieve this goal, we created a suite of resting state conditions, from classical version where participants were not exposed to any stimulation and had either opened or closed eyes; through conditions with external stimulation including listening to music, watching city camera footage, or videos imitating walking through different landscapes, up to watching short fictional stories that included a plot. We designed them to vary both sensory as well as non-sensory informational content. We expected they will give rise to different subjective experiences that we could later try to discern from EEG recordings of brain activity during this passive exposition. Collected data created a unique database of more than six hundred participants and total number of individual recording sessions exceeding 1600. Taken together, it formed a extensive database of high-quality EEG resting state data that to our knowledge does not have a precedence in publicly available datasets. We analysed the data with most popular complexity measures (Lempel-Ziv complexity, multiscale entropy, and detrended fluctuation analysis) to verify their claimed potential in tracking conscious activity in brain signals. We found that Lempel-Ziv complexity was the best at separating experimental conditions as well as scoring higher in those that were designed as containing more content. This was true for both increased sensory (e.g. comparison between eyes opened and condition with additional audio stimulation) and conceptual information (e.g. comparison between static viewing of the footage from city camera looking over the city and first-person view of a walk through the streets). Additionally, we explored how these effects hold for more localized set of electrodes over regions most typically connected with conscious processing as well as impact of chosen time windows to calculate the complexity estimates. Both those analyses revealed significant changes in results, warranting caution while performing similar analyses on different data.

Why time flows: an account of temporal experience based on Integrated Information Theory (IIT)

Matteo Grasso (University of Wisconsin-Madison), Renzo Comolatti (University of Washington)

Poster Session 3, Thursday July 4th, Ito International Research Center, 10:00AM-11:00AM

Why does experience feel the way it does? A scientific theory of consciousness should account for all aspects of experience, including the feeling of the flow of time. We present an initial attempt to apply the formalism of Integrated Information Theory (IIT) (Tononi 2004, 2008; Oizumi et al. 2014; Albantakis et al. 2023) to account for why time feels flowing. IIT identifies the essential properties of experience and formulates them in physical terms. In doing so, IIT provides the tools to identify the physical substrate of consciousness (a complex) and to unfold its cause-effect power in full (the cause-effect structure it specifies, composed of causal distinctions and relations), which accounts for the quantity and qualitative content of experience. First, we characterize the phenomenology of time, defining the explanandum we aim to account for: a phenomenal structure of distinctions and relations between them that we call phenomenal flow. Then, we propose an account of phenomenal flow in scientific, physical terms, in a way that is principled and testable, linking time phenomenology to a particular physical substrate, namely directed 1D grids, and plausible circuits in the brain. IIT establishes an explanatory identity between the properties of experience and the properties of the cause-effect structure specified by its substrate. Applied to the experience of time, we show how moments, the way they feel directed, the way they relate with each other, the way they compose the present, and other properties of the phenomenal flow can be accounted for in physical terms by the cause-effect structure specified by directed grids: by the causal distinctions that compose the cause-effect structure and the specific ways they relate to compose a flow.

Cardiac responses to auditory information during sleep reveal the embodiment of sleep functions

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Poster Session 3, Thursday July 4th, Ito International Research Center, 10:00AM-11:00AM

Cardiac signals, despite being typically recorded in experiments investigating cognitive processes during sleep, are usually neglected from analyses. We advocate here that cardiac responses to auditory information contain meaningful information about sleep functions above and beyond that obtained from cerebral activity. To do so, we investigated how interbeat intervals were modulated by sound presentation during sleep across three previously published datasets. First, we investigated cardiac responses to auditory deviants in two datasets presenting during sleep an auditory local-global paradigm – a modified version of the classic oddball (https://doi.org/10.1073/pnas.1501026112 and https://doi.org/10.1093/sleep/zsac199). During wakefulness, we found that cardiac activity was not modulated by deviants (corrected Wilcoxon test for local: z=-0.06, p=0.58 and global: z=-0.07, p=0.32). However, during sleep, we observed that cardiac activity accelerated in response to local deviants in Non-Rapid Eye Movement (NREM) sleep (z=-0.27, corrected p=0.029) and decelerated in response to global deviants in Rapid Eye Movement (REM) sleep (z=0.26, corrected p=0.038). This double dissociation in cardiac responses between sleep stages and type of auditory deviants diverge from magnetoencephalographical and electroencephalographical findings and unravel the cardiac correlates of sensory mismatch detection at different levels of complexity during sleep. Second, we analyzed cardiac responses from a study that induced a deeper sleep and a better sleep quality by presenting relaxing words during NREM sleep (https://doi.org/10.1093/sleep/zsab148). We demonstrated here that cardiac activity slowed down during periods of presentation of relaxing words (100.8%, Wilcoxon signed rank test p=0.001), but not control words (100.0%, p=0.418, relaxing vs. control: z=0.33, p=0.022). We furthermore show that this deceleration was a response to word processing since the heartbeat coming after the presentation of relaxing words was delayed compared to the same words played in reverse (17.5ms, p=0.037), an effect once again absent for control words (-4.6ms, p=0.561; relaxing vs. control: z=0.29, p=0.040). We finally found that cardiac responses during NREM sleep explain an additional part of variance in the modulation of sleep as compared to cerebral markers alone (EEG:18% vs. ECG+EEG:28%, model comparison test: p=0.03), demonstrating that cardiac activity holds valuable and irreducible information about the modulation of sleep by word presentation. Overall, we provide in this presentation a new set of empirical evidence supporting the embodied nature of auditory processing during sleep. Moreover, our methodology and tools was made openly accessible via a Jupyter notebook (https://gitlab.uliege.be/Matthieu.Koroma/cardiac_relaxation_beck) with supporting data available at OSF (https://osf.io/jn7ar/) and published in Koroma et al., 2024 (https://doi.org/10.1111/jsr.14160) to foster the analysis of cardiac responses to sensory information in sleep. With this approach, we promote the relevance of studying cardiac signals for advancing our understanding of cognitive processes during sleep and their modulation by sensory information.

Against Explaining the Memory Color Effect with High-Level Properties

Mingyan Yang (University of Washington)

Poster Session 3, Thursday July 4th, Ito International Research Center, 10:00AM-11:00AM

What we believe, desire, and intend influences what we perceive. The memory color effect reports that an object's color looks differently when one knows its canonical color. For example, knowing that bananas are typically yellow makes even a grayscale banana look yellowish. An explanation for it is from cognitive permeation: cognition affects and thus alters the content of perception. Some scholars suspect that in the memory color effect, cognitive states only cause changes in the low-level properties of the perceptual content, such as color and shape. This mechanism is called the Low-Level Permeation Mechanism (LPM). Others think that cognitive states also enrich the perceptual content, causing high-level properties, especially kind properties like the property of being lips and being bananas, to be represented in perceptual experience. Low-level contents are altered through high-level representation. This is called the High-Level Permeation Mechanism (HPM). I aim to refute HPM and then defend LPM in this paper. My main thesis is that in the memory color effect, it's unlikely for high-level properties to be represented in perception because of cognitive permeation. I will argue that LPM is the better explanation of the memory color effect. The paper is organized as follows. Section 2 begins by explicating the memory color effect and how cognitive permeation can account for it. Specifically, I focus on Delk and Fillenbaum's (1965) classic experiment on the memory color effect. Section 3 presents the HPM. The mechanism consists of two stages: (1) the belief state permeates the perception, resulting in high-level properties' representation; (2) intra-perceptual influences between high-level perception and low-level perception alter the low-level content. I argue against the plausibility of the first stage. Section 4 provides support for the Low-level Permeation Mechanism and addresses a potential objection. Finally, in Section 5, I discuss the philosophical implications of my defense of LPM.

What is it Like to Infer? Active Inference as a Minimal Model of Consciousness

Moritz F.Kriegleder (University of Washington)

Poster Session 3, Thursday July 4th, Ito International Research Center, 10:00AM-11:00AM

Active inference is a recent approach in Bayesian cognitive science, which claims to provide a unified model of action and perception in all types of self-organizing systems (Parr et al., 2022). Recently, it has been proposed as a model of phenomenal consciousness, especially considering introspective reports and subjective experience (Sandved-Smith et al., 2021). With this development, active inference enters the arena of theories of consciousness, alongside related approaches such as re-entry theories and predictive processing. Separate theories of consciousness need to enter a productive discourse by making their philosophical assumptions explicit and establishing a common foundation in the form of a minimal model. Here, I utilize the concept of minimal model explanations (Batterman & Rice, 2014) to identify the requirements for such a minimal model of consciousness. Wiese (2021) proposes that information generation under the free energy principle could serve as such a minimal model. However, I discuss how the free energy principle and active inference fall short of providing a satisfactory minimal explanation for consciousness. I argue that active inference provides a promising model of cognitive functions associated with access consciousness. However, to describe phenomenal consciousness, it is necessary to incorporate the first-person perspective of conscious agents. As emphasized by neurophenomenology, the explanatory gap between neuroscientific data and phenomenal consciousness can only be bridged by acknowledging subjective experience as a fundamental component of cognitive modeling (Varela, 1996). Therefore, I discuss the recently proposed 'inner screen hypothesis,' which seeks to encompass phenomenal consciousness within the active inference framework (Fields et al., 2021). The inner screen hypothesis posits that conscious systems consist of two or more layers that make inferences about each other. According to this model, the innermost layer of a cognitive hierarchy is the locus of phenomenal experience. The main points of connection of active inference, GWT, and IIT are the message passing algorithm, which identifies the inner screen as the global workspace in mental action, and the integration of lower-level information on higher levels in the active inference hierarchy as fundamental to subjective experience. My analysis compares the philosophical underpinnings of active inference to other theories of consciousness to elucidate areas of convergence and tension. Batterman, R. W., & Rice, C. C. (2014). Minimal model explanations. Philosophy of Science, 81(3), 349–376. Fields, C., Glazebrook, J. F., & Levin, M. (2021). Minimal physicalism as a scale-free substrate for cognition and consciousness. Neuroscience of Consciousness, 2021(2). Parr, T., Pezzulo, G., & Friston, K. J. (2022). Active inference: The free energy principle in mind, brain, and behavior. The MIT Press. Sandved-Smith, L., Hesp, C., Mattout, J., Friston, K., Lutz, A., & Ramstead, M. J. D. (2021). Towards a computational phenomenology of mental action: Modelling meta-awareness and attentional control with deep parametric active inference. Neuroscience of Consciousness, 2021(1). Varela, F. J. (1996). Neurophenomenology: A methodological remedy for the hard problem. Journal of Consciousness Studies, 3(4), 330–349. Wiese, W. (2020). The science of consciousness does not need another theory, it needs a minimal unifying model. Neuroscience of Consciousness, 2020(1).

Exploring how the geometry of the representation space influences curiosity-based exploration

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Poster Session 3, Thursday July 4th, Ito International Research Center, 10:00AM-11:00AM

In human spatial awareness, information appears to be represented according to 3-D projective geometry. It structures information integration and action planning within an internal representation space. In previous work it has been shown that geometrically constrained active inference can be used as a framework for understanding and modeling central aspects of human spatial consciousness (see the Projective Consciousness Model, PCM). We aim to investigate how the structure of the representation space influences exploration behaviors. The way different perspectives are related and transform a world model defines a specific perception and imagination scheme. In mathematics, such collections of transformations correspond to a 'group', whose 'actions' characterize the geometry of space. Imbuing world models with a group structure may capture different agents' spatial awareness and affordance schemes. We used group action as a special class of policies for perspective-dependent control. We explored how such a geometric structure impacts agents' behavior, comparing how Euclidean and projective groups act on epistemic value in active inference and drive curiosity and exploration behaviors. We formally demonstrate and simulate how the groups induce distinct behaviors in a simple search task, in which the agent is driven solely by curiosity and information gain. The projective group's nonlinear magnification of information transformed epistemic value according to the choice of frame, generating behaviors of approach toward an object of interest. The projective group structure within the agent's world model contains the Projective Consciousness Model, which captures key features of consciousness. On the other hand, the Euclidean group had no effect on epistemic value : no action was better than the initial idle state. In structuring a priori an agent's internal representation space, we show how geometry may in itself induce motion through curiosity, and can play a key role in information integration and action planning.

The Self-Modeling Paradox: Toward a Neurobiologically Plausible Mechanistic Explanation of Subjectivity

Nick M.Heinz (University of Washington), Aramis D. M. Valverde (New York University)

Poster Session 3, Thursday July 4th, Ito International Research Center, 10:00AM-11:00AM

The subjective nature of conscious experience – how it feels to be something – poses a central challenge for any scientific account of consciousness. This talk introduces the 'self-modeling paradox' as key to understanding the subjective, ineffable, aspects of consciousness. Drawing on principles analogous to Gödel's incompleteness theorem, it posits that the brain's capacity to model complex external and internal states generates an inherent blind spot when it comes to representing and evaluating its own representational processes. This limitation, the talk argues, partially underlies the difficulty in explaining the 'what it's like' quality of experience. The proposed Prioritized Representation of the Illusory Self Model (PRISM) offers a potential explanation for how this paradox arises, and why it leads to the perception of consciousness as ineffable and subjective. PRISM theorizes that the prioritization of bodily representations, driven by their strong association with affective states, pain perception, and self-preservation [cite Venturella & Balconi], likely contributes to the emergence of the illusory "I". This prioritization, occurring prominently within the somatosensory and parietal cortices, leads to a functional isolation of the "I" representation, obscuring its inherently representational nature. This PRISM-predicted misrepresentation of the self, driven by the brain's representational limitations, may subsequently contribute to the difficulty of understanding subjective experience, leading us to mistakenly view consciousness as inherently separate from the processes it arises from. Disruptions within parietal regions, which play a key role in integrating somatosensory signals and spatial self-awareness, offer a potential way to probe this paradox experimentally. For example, previous research demonstrates that targeting the inferior parietal lobule with techniques like rTMS can disrupt self-other discrimination and modulate the perceived location of illusory tactile sensations, providing further support for PRISM's predictions. The PRISM model directly challenges the intuitive notion of a stable, observer 'self', proposing instead that it's an emergent property of inherently limited representational systems. The PRISM model suggests novel predictions for how disruptions in somatosensory processing might alter self-experience, potentially testable via TMS or in clinical populations. If correct, the PRISM model could necessitate a fundamental re-evaluation of the relationship between consciousness, selfhood, perception, and the brain's representational architecture.

Accounting for non-physicalist intuitions through a perspectival account of Physical Computation

Nicolas Loerbroks (University of Washington)

Poster Session 3, Thursday July 4th, Ito International Research Center, 10:00AM-11:00AM

Jackson (1986), Levine (1993) and Chalmers (1996) famously argued that cognitive science could never fully account for the qualia of our every day subjective experience and conclude that consciousness must thereby be outside the realm of the physical.

Other authors, in particular, Daniel Dennett, on the other hand, reject those aspects of phenomenal consciousness that seem to defy explanation through ordinary physical or scientific means. Dennett's position can be seen as a form of computationalism: Mental states can be fully accounted for in terms of medium-independent functionality. Dennett and Frankish argue that there is no mind-body-problem, that it is an illusion.

Rather than taking the illusionist route of appealing to computational explanations and arguing that consciousness is reducible to cognition, I would like to propose that the non-physicalist intuitions can be accounted for in the context of physical computation, i.e. what it means for a physical system like the brain to implement a computation. According to the elaborations of Piccinini's mechanistic account of physical computation brought forward in Dewhurst (2018a;b) it is not possible to uniquely determine an objective mapping between a physical system and an abstract description of its computational properties in ordinary or scientific language. Instead such a mapping always depends on the cognitive explanation one seeks (the correspondence between the physical states and the computational explanations is, nevertheless, constrained by the underlying physical causal structure such that unlimited pancomputationalism can be avoided).

I want to argue that the resulting perspectivist anti-realism about neural computation may solve the dispute between the computationalist account of consciousness and the arguments against physicalism. For instance, Mary the neuro-scientist cannot know everything there is to know about color vision because she would have to know an infinite amount of facts: For any given set of computational processes that she may know about, investigating the matter in a new way could always give rise to another process which is not part of the set. This means that Jackson's argument may be valid, but not sound.

Put otherwise, associating the problematic aspects of qualia (e.g. ineffability) with precognitive mechanisms not fully describable by computational cognitive explanations would account for the intuitions brought forward by Chalmers and others without having to reject physicalism.

Furthermore, (Piccinini, 2019) proposes "noncomputational functionalism about consciousness" combing type/token-identity theory and functionalism. I want to argue that perspectivist anti-realism about computational processes in the brain can shed light on how the contribution of the physical substrate for consciousness is constituted: The substrate grounds the processes that could be identified or interpreted as serving a functional role at the present moment or in the future. The dialectic between identity theory and functionalism thus becomes coherent without having to appeal to the "phenomenal character" of experience as in (Piccinini, 2019).

Lastly, I would argue that anti-realism about neural computation does not imply dependence on the scientists' mental states. Already predispositioned functionality can also "come to the surface" through environmental changes.

Children's sense of bodily self in distorted virtual avatars

Oscar J.Sill (University of Washington), Robert W. Kentridge (Durham University), Dorothy A. Cowie (Durham University)

Poster Session 3, Thursday July 4th, Ito International Research Center, 10:00AM-11:00AM

The sense of bodily self-consciousness is critical to how we understand and interact with ourselves and our external world, and likely arises from comparing bottom-up sensory inputs with hierarchically weighted top-down expectations of the body. For instance, in adults, expectations of the body's structural form (e.g. limb dimensions) may be more important to embodied selfhood than expectations of its material form (e.g. texture). However, as a child's body grows, many particularly structural features are constantly shifting. Thus, how do children use structural and material form cues to experience a coherent sense of the embodied self? We address this by presenting children (n=38, 5-10 years) with four motion-tracked virtual reality avatars with varying appearances, including non-human structural and material distortions. Typically, immersive virtual experiences elicit strong senses of embodied ownership and agency over avatars that sufficiently match core own-body expectations, meaning the limits of this system can be identified by testing when the illusion breaks. We measure children's subjective embodiment and embodied motor behaviour, and test whether these link to the accuracy of children's lower-order cognitive body representations using a body pointing task with motion capture. In questionnaire ratings, children report equivalent ownership for the structural and material distortions, indicating both types of form are similarly important to children's definition of the bodily self. Interestingly, these both elicit selectively lower ownership than the human avatar, and higher ownership than a fourth avatar with 'extreme' combined material *and* structural distortions. Thus, children have a nuanced response to distorted avatars, modulating ownership by *how severely* a body violates expectations of material and structural form. For body agency, we instead find equivalent ratings for the human avatar and material distortion, with selectively lower agency for the structural distortion. Also, despite all avatars possessing identical motor functionality, children perceive the human and material distortion as more functionally useful than the structural distortion. Thus, children selectively up-weight structural form cues, and down-weight material form cues, for experiencing the sense of embodied control: a process that may be underpinned by using form information alone to infer a body's functionality. Additionally, we find that children use body form cues to inform their embodied motor behaviours: exploring their VR worlds in distinct ways when using a structurally versus a materially distorted avatar. Lastly, we find that children have strikingly inaccurate cognitive whole-body 'maps', but that this does not contribute to explaining ownership or agency ratings in any distorted avatars. Thus, this particular cognitive representation may not be an underlying mechanism for using form cues to sense embodiment. Overall, we demonstrate that information about the body's structural and material form is of clear importance to children in defining their sense of the embodied self: playing distinct roles in embodied ownership, agency, and movement. We also demonstrate the usefulness of immersive virtual reality for systematically investigating the components of children's bodily self-consciousness.

Reporting confidence decreases response and change-of-mind accuracy in a perceptual decision task

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Poster Session 3, Thursday July 4th, Ito International Research Center, 10:00AM-11:00AM

Self-monitoring seems to be crucial for regulatory behavior, but it is not clear how it influences performance in simple cognitive tasks. Some studies suggest that increased monitoring improves metacognitive regulation and enhances performance, while others suggest it impairs learning, problem-solving or perceptual processes. We investigated whether the requirement to report confidence in perceptual decisions affects metacognitive regulation and response accuracy. Participants performed a visual discrimination task in which they provided two responses: initial and final. Depending on the condition, participants reported their confidence (either together with or after the initial perceptual decision), performed an additional visual search task, or were asked to look at a blank screen between two responses. We expected that reporting decision confidence would induce more efficient regulatory activity, which would benefit final accuracy. In two experiments, we did not find any evidence that rating confidence improves regulatory processing or performance in perceptual tasks. Rather, when confidence ratings were retrospective, final response improvement was smaller compared to the condition with no additional task, and changes of mind were less frequent and less corrective. Confidence ratings given jointly with the initial response generally decreased accuracy. The results suggest that deliberate monitoring might put additional strain on cognitive resources and impair lower-order task processing.

Changes in brain hierarchy following acute and chronic use of DMT and cannabis

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Poster Session 3, Thursday July 4th, Ito International Research Center, 10:00AM-11:00AM

Background: Psychedelics are thought to flatten the brain’s hierarchy, resulting in increased flexibility of brain states through disintegration of the default mode network. Perhaps counter-intuitively, disintegration is consistent with increased reversibility of information flow. Limited yet compelling evidence suggests that this is the mechanism behind the action of psychedelics, but changes in the hierarchy of the brain under psychedelics are not yet well understood. Furthermore, it is not known what the effects of chronic use are on the acute psychedelic experience. Aims & Objectives: The present work examined changes in the functional hierarchical organization of the brain during the acute DMT experience in occasional users of psychedelics and ayahuasca in chronic users. We distinguished effects from cannabis in chronic and occasional users to identify key drivers of alterations in brain hierarchy under psychedelics. Methods: 24 long-term users of ayahuasca, 20 psychedelic naïve users of DMT, and 26 infrequent or frequent users of cannabis, defined as less or more than four times a week, respectively, were imaged at baseline/placebo and after administration of ayahuasca, DMT, or cannabis. Entropy production across the brain was estimated via non-reversibility through pairwise time-shifted correlation of the forward and reversed timeseries. Application of a Hopf whole-brain model yielded the effective connectivity for each participant. A graph-theoretic measure of hierarchy, trophic coherence, was evaluated, providing the directedness of the brain’s functional hierarchy and regional changes in hierarchical level, thereby giving access to the functional hierarchical organization of the brain at baseline and under the influence of ayahuasca, DMT, and cannabis. Results: Irreversibility was found to decrease significantly under ayahuasca and cannabis in chronic users, but not in DMT or cannabis in occasional users. Directedness was significantly decreased under both ayahuasca and DMT, signifying a relaxation of the brain’s functional hierarchy, while an increase was found for cannabis in occasional users. Regional hierarchy broadly and significantly decreased during ayahuasca and cannabis in chronic users, but not for DMT and cannabis in occasional users. Under DMT, this was reflected in greater variation in regional hierarchy. Discussion & Conclusion: We establish different signatures of acute and chronic use of psychedelics and cannabis with regard to alterations in irreversibility, directedness, and regional hierarchy during the acute drug experience. These findings are broadly consistent with previous theories of psychedelic action, namely the Relaxed Beliefs Under Psychedelics (REBUS) model, lending support to the theory that psychedelics work principally by relaxing the brain’s hierarchy. Given the heterogeneity of data acquisition techniques, it is not possible to make firm claims regarding differences in drugs. Future research should more specifically focus on the effect of chronicity in the use of psychedelics.

Task Confidence, Intentional Binding, and Explicit Sense of Agency

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Poster Session 3, Thursday July 4th, Ito International Research Center, 10:00AM-11:00AM

Intentional binding refers to the compression of the subjective time delay between a voluntary action and its sensory effect. This phenomenon has been used as an implicit measure of sense of agency, although the nature of its relationship with explicit sense of agency remains an open question. The present study examines how implicit and explicit sense of agency relate to task confidence, which has not previously been studied in the context of intentional binding. Additionally, we assess dispositional traits tied to sense of agency, including embodiment and self-control. In this study, participants completed an intentional binding task with two conditions. In the experimental condition, participants were instructed to estimate the time interval between their voluntary keypress and the appearance of a circle on a computer screen, rate their confidence in this estimate, and indicate the degree of control they felt over the appearance of the circle. Participants also completed a control condition in which they estimated the temporal interval between the appearance of two circles and rated their confidence in this estimate. Finally, participants completed a survey, which included the Embodied Sense of Self Scale (Asai et al., 2016) and Metacognition in Self-Control Scale (Burgler et al., 2022). Because more accurate confidence ratings suggest more precise awareness of sensorimotor information, we hypothesize that greater accuracy of task confidence will result in decreased intentional binding, thereby decreasing explicit sense of agency. In short, we aim to connect implicit and explicit sense of agency to task confidence and survey-based trait measures.

Semantically congruent sounds selectively enhance visual sensitivity of biological motion in the absence of visual awareness.

Stefano Ioannucci (University of Washington), Petra Vetter (University of Fribourg)

Poster Session 3, Thursday July 4th, Ito International Research Center, 10:00AM-11:00AM

On which level of awareness do semantically congruent sounds give an advantage in visual perception? This study investigates the dynamic interplay between visual ambiguity, audiovisual semantic congruence, and conscious perception of biological motion. We used Continuous Flash Suppression to suppress visual stimuli from awareness to differing extents by manipulating stimulus contrast subject-wise. Our findings reveal a significant modulation of access to conscious perception based on the quantity of visual ambiguity. During full suppression from visual awareness, visual sensitivity increased by co-occurring semantically congruent sounds. These results suggest that during conscious perception, implying ambiguous/noisy but visible visual stimulation, subjects relied mainly on visual information and preferred biological motion but sounds did not have a strong effect. In the absence of visual awareness, subjects relied more on auditory information which specifically boosted the perception of biological motion in the presence of semantically congruent sounds. This interaction highlights the nuanced relationship between visual ambiguity, audiovisual congruence, and the conscious perception of biological motion. The results underscore the importance of considering both visual clarity and multisensory congruency in understanding the mechanisms governing access to awareness for complex visual stimuli. We conclude that multisensory integration can happen in the absence of visual awareness and shows its advantage in the case of meaningful visual stimuli being fully suppressed/fully ambiguous.

Neural representation underlying textural quality in perception: Evidence from EEG-based image reconstruction

Taiki Orima (University of Washington), Suguru Wakita (The University of Tokyo), Isamu Motoyoshi (The University of Tokyo)

Poster Session 3, Thursday July 4th, Ito International Research Center, 10:00AM-11:00AM

The richness and reality of our visual perception largely depend upon 'textural qualia' in the image. Where and how do they come from? Long lasting investigations on the perception of texture images suggest that the visual system rapidly encodes texture information as the global and statistical features of the image region (e.g., Zipser et al., 1996; Okazawa et al., 2015; Orima & Motoyoshi, 2021 etc.), then utilizes them to recognize objects, scenes, and surface materials. Recent computational models successfully predict and even synthesize the visual appearance of a texture image only by using statistical features (Portilla & Simoncelli, 2000; Gatyes et al., 2015). Given that spatially global and statistical information are independent of precise retinotopy, their neural representations may be captured even by EEG that have low spatial resolution by its nature. Based on this idea, here we examined if the rich visual appearance of a texture image can be reconstructed from visual-evoked potentials (VEPs) as measured for the original texture image. Using VEP data (15 observers) for 191 natural textures (500 ms duration), we developed multi-modal variational autoencoder (MVAE) models inputting target images and the VEPs, setting the unique loss function i.e., sum of the style error of images and reconstruction error of VEPs, instead of the pure reconstruction errors. The image modal consisted of a series of 2 dimensional convolutional layers, the EEG modal was composed of a series of 1 dimensional convolutional layers, and the latent variable was set to be 256 dimensional vector. As a result, the MVAE models successfully reconstructed texture images only from the VEPs in the testing set for texture images, some of which were almost indistinguishable from the original images. These reconstructed images were psychophysically confirmed to have phenomenologically similar textural quality. If the inputting VEP data was limited to 200 ms after the stimulus onset, the quality of reconstructed textures was significantly degraded. These results suggest that the rich textural quality of visual perception is largely determined by the representation of statistical image features in the early visual cortex.

Analogical Modeling of Psychological Self Structure

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Poster Session 3, Thursday July 4th, Ito International Research Center, 10:00AM-11:00AM

The physical boundary for the self component of consciousness remains unclear. An obstacle to defining this physical boundary lies in a lack of concrete physical analogy informing conceptualization. Here, we integrated structural biology, artificial intelligence, and psychology/psychiatry to adopt molecular interactions as analogical models for self vs. world consciousness boundary. We found that language models are beginning to encode information that predict psychological factor groupings and identified top performers in a large screen. Utilizing the models' semantic representation of language, we exploited common data patterns between molecular structures and psychological surveys to develop and visualize psychological self structures. These psychological self structures are functionally relevant. They revealed intuitive explanations for patterns in psychological and psychiatric survey data, such as factor loadings, and the structural properties could be used to provide improved prediction of survey data patterns. We overlaid human self-report response patterns from diverse psychological and psychiatric surveys on personality and altered states of consciousness onto these self structures. We were able to identify diverse patterns of hotspot responses, suggesting interaction of self with world consciousness analogous to molecule-to-molecule interfaces. Further extending this analogy, we developed a model for self-to-world consciousness boundary topology that is physically validated with analogous systems. Our study establishes a concrete approach to map topological organization of self-to-world consciousness boundary in a physically relevant way, providing an entry point to investigate the linkage between self-consciousness boundary and physical substrates underlying it.

The LAG of consciousness as a novel quantitative measure of the temporal aspect of conscious perception

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Poster Session 3, Thursday July 4th, Ito International Research Center, 10:00AM-11:00AM

One of the challenges of exploring conscious perception stems from the fact that currently, there is no widely recognized measure comparing individuals' subjective perception with their objective task processing within the same performance domain. Past research has primarily relied on objective task outcomes (such as accuracy or reaction times) contrasted with subjective judgments (like confidence ratings or the Perceptual Awareness Scale). However, those measures do not capture the same aspects of the task. This work seeks to tackle this issue by introducing a novel measure of conscious perception, enabling both objective and subjective evaluations within a single task domain, specifically time. In the new type of task, participants are presented with a stimulus whose state is continuously changing. Their goal is to report the state of the stimulus when they first saw it appearing on the screen. The task was completed by a total number of 300 subjects who participated in two different behavioral experiments. Four distinct, but functionally equivalent setups, are included in the task: firstly, a line task, where participants are presented with a line that continuously changes its length (either elongating or shortening). Secondly, a circle that changes its size (either expanding or shrinking). Thirdly, a bar task, in which the distance between the bars is changing (either moving apart or drawing closer). Finally, a memory task serving as a control, wherein participants must accurately memorize the initial state of the stimulus before it undergoes any changes, thus assessing their ability to report precisely the stimulus state from memory. Behavioral results show that across all of those tasks, participants systematically overestimate the starting point of the stimulus. A comparison of the reported (subjective) and actual (objective) initial state of the stimulus indicates that participants saw it appearing with an average of 136 ms delay. We interpret this discrepancy in estimation as a sign of a delay in becoming aware of the stimulus, which we term the "LAG of consciousness." The LAG measure demonstrates a notable dissociation from objective outcomes, such as reaction times. Hence, alongside behavioral findings, we also intend to present preliminary EEG results from two distinct experiments involving 44 participants. Our goal is to investigate neural markers pertinent to the temporal dimension of perceptual processing associated with the LAG. Specifically, we aim to establish correlations at a single-trial basis between the LAG measure and the VAN and P3 components, identified as potential EEG markers of the neural correlates of consciousness.

Attentional integration into visual consciousness in the human neocortex

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Poster Session 3, Thursday July 4th, Ito International Research Center, 10:00AM-11:00AM

How subjective consciousness arises in the brain is a puzzle, of which attention lies in the core. Given long lasting debates whether consciousness prerequires attention, mechanisms through which top-down attention gets integrated into consciousness were poorly investigated. By discriminating supplied attention from integrated attention via a psychophysical experiment, we first built a specific link between integrated attention and consciousness. Then, combining psychophysics with intracranial electroencephalography (iEEG) from 21 epilepsy patients, we investigated consciousness-related (visible versus invisible) neural activity when attention was either poorly or sufficiently integrated into consciousness, respectively. In the former scenario, we found sustained and homogenous neural representations in the posterior brain though it was functionally disconnected with the frontal brain, justifying the proposal of a 'preconscious' buffer state inter-between unconscious and conscious. In the latter scenario, even before frontal-posterior coupling was established (thus still preconscious) supplied attention prepared the whole brain for later attentional integration, selecting signals-to-be-perceived at the posterior brain and stabilizing attentional direction at the frontal brain, respectively. Thereafter, functional coupling between the frontal and posterior brain allowed frontal attention to be integrated with posterior contents via the frontal-posterior loop. Importantly, what were continuously broadcasted within this loop were not fine-grained contents but coarse-grained binary (1/0) signals of consciousness emergence. Collectively, findings above call for a major revision for current theories of consciousness and we propose an attentional integration model of consciousness (AIM) aiming to reconcile sharp discrepancies in this field.

Oneshot Heartbeat Detection: A Novel Task For Measuring Interoceptive Accuracy

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Poster Session 3, Thursday July 4th, Ito International Research Center, 10:00AM-11:00AM

In the quest to assess individual differences in interoceptive accuracy, the ability to correctly detect internal bodily sensations, the scientific community has encountered significant methodological limitations, particularly within the cardiac domain. Traditional tasks such as heartbeat counting and heartbeat discrimination have been the bedrock of interoceptive accuracy but are not without their flaws. Heartbeat counting often suffers from estimation bias, artificially inflating scores, while heartbeat discrimination tasks challenge participants with the daunting requirement of dividing their attention between internal sensations and external stimuli—resulting in only about a quarter of individuals performing above chance. These limitations underscore the need for more solid approaches that can assess interoceptive accuracy without the confounding effects of estimation or divided attention. Recent endeavors in the field have led to the proposal of alternative methodologies, including heart rate discrimination and heartbeat tapping tasks. While these alternatives mark an improvement, they still fall short in ensuring participant's focused attention on internal sensations and actual heartbeat perception. Recognizing these shortcomings, our research introduces a novel "oneshot heartbeat detection" task, meticulously designed around synchronicity judgment paradigms. This task, distinct from heartbeat discrimination—a representation of synchronicity judgment—requires participants to judge the synchronization between a single heartbeat and an external signal, thereby maintaining concentrated focus on their internal physiological state. Our approach reduces the influence of estimation and external distractions, facilitating a direct and accurate assessment of an individual's perceptual capacity regarding their heartbeats. This task not only promises a refined measurement of interoceptive accuracy but also offers the potential to unravel temporal aspects of heartbeat perception, shedding light on the overall perceptual processes underpinning interoception. In the oneshot detection task, participants are instructed to press a button when they perceive their first heartbeat following a cue, while maintaining focus on internal sensations. Subsequently, between two to six heartbeats later, a word color change lasting 200 milliseconds is presented, timed either with their systole (300 milliseconds post-R-wave peak) or diastole (500 milliseconds post R-peak). Participants then answer a forced-choice question regarding the synchronicity of the heartbeat and color change. This approach allows for the collection of valuable data on the initial attentional focus to heartbeat detection timing, the variance in the timing window for detecting the first heartbeat relative to actual heartbeat timing, and the perceptual sensitivity to one's heartbeats, calculated through signal detection theory. A preliminary study with 22 participants showed that over 60% performed above chance, significantly improving upon traditional methods where three-quarters failed to do so. This task also provides timing insights on heartbeat detection, aiding in the assessment of individual interoceptive accuracy. Our research introduces a novel approach for interoceptive accuracy measurement in the cardiac domain, overcoming the limitations of prior methods. By focusing on the detection of individual heartbeats and internal sensations, this task could emerge as a superior metric for evaluating interoceptive accuracy. Our findings not only advance the measurement of interoceptive accuracy but also deepen our understanding of the link between consciousness and bodily awareness through temporal insights into heartbeat perception.

Partner's predictability in building a sense of joint-agency

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Poster Session 4, Thursday July 4th, Ito International Research Center, 3:30PM-4:30PM

The sense of agency (SoA) refers to the experience of controlling one's actions and their effects. While the sense of agency has been widely explored in the context of individual action, it is only very recently that studies have focused on its development in the context of joint action. Notably, recent research suggests we can have a SoA for a partner's actions during coordinated joint actions. As the sense of agency is regularly considered a prerequisite for the attribution of individual responsibility, understanding the mechanisms underlying its development when we are involved in collective actions seems paramount from a moral and legal point of view. In this paper, we hypothesized that the ability to predict co-agents' behaviours influences the SoA for oneself and the partner during joint action. To test this hypothesis, we devised a musical task where two co-agents had an equal role in co-constructing a melody. Each melody comprised 4 notes. Co-agents alternated notes, playing the first and third notes (P1) or the second and fourth notes (P2). We manipulated participants' predictive abilities by presenting videos of their partner's hand in 3 modes, which differed according to the matching between co-agents of action-note mapping. To produce any given note, the partner's action was either the same as that of the participant (SAME), flipped with regard to the participant's action-note mapping (REVERSED), or had no discernable pattern (RANDOM). Participants had to estimate the time interval between the last note and a validating tone to measure Intentional Binding (IB), which denotes a perceived temporal compression between action and outcome and is typically used to assess SoA. Those estimations were compared with a baseline estimation of between-tone intervals involving no action. Lastly, participants were asked explicit questions regarding their control over the melody. Results (n=46) revealed higher judgments of control when the partner's mapping was the same as that of the participant. Indicative of an IB effect, time estimations differed significantly from the baseline in all conditions. However, IB was greater when the participant produced the last tone (P2) than when the last tone resulted from the partner's action (P1). These results indicated that IB differed between who initiated or ended the melody even though control over the melody was equaly shared. Hence, although one may experience IB for a partner in joint action, IB for oneself appears to be stronger. Moreover, time estimation increased in SAME compared to the other mappings only in P2. This suggests that the ability to predict co-agents' behaviours when engaged in joint action impacts SoA for oneself, but does not so for the partners' action as far as IB is concerned. Those results challenge the conception that IB for other's actions relies on sensorimotor prediction and raises concerns about its reliability as a marker of SoA for others.

Neural information across the brain distinguishes the phenomenology of advanced concentrative absorption meditation known as jhana

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Poster Session 4, Thursday July 4th, Ito International Research Center, 3:30PM-4:30PM

We present a neurophenomenological case study investigating distinct dynamical regimes of neural connectivity during advanced meditation and specifically advanced concentrative absorption meditation (ACAM) known as jhanas. The jhanas are non-ordinary states of consciousness characterised by profound qualities of bliss, clarity, and spaciousness that can be experienced through deep-concentration meditation, usually as a culmination of long-term, intensive practice [1,2]. Using EEG recordings and phenomenological ratings (29 sessions) in a practitioner with over 23,000 hours of meditation practice, we evaluated connectivity metrics that capture distinct modes of neural communication: information theoretical metrics (WSMI and Directed Information), which capture neural dynamics associated with information integration and transfer, and spectral connectivity metrics based on neural synchrony (WPLI) which captures rhythmic neural regimes associated with more stationary, stable dynamics [3,4]. Our analyses showed that WSMI in a broad range of frequencies outperformed WPLI in distinguishing perceptually richer states (e.g. jhana states characterized by intensely pleasant bodily feelings ["bliss or joy"] compared to states reported as emotionally neutral [i.e. "equanimity"]), suggesting a decrease in information integration with decreased perceptual experience. Further, we investigated the dynamics of feedforward (back to front) and feedback (front to back) information connectivity across electrodes [5]. While feedforward information transfer dominated the initial concentration phase, feedback information transfer was increased in subsequent jhana states, suggesting a shift from externally to internally driven perceptual experiences. Interestingly, the last jhana states, characterized as "immaterial" or "formless" because they are achieved by surmounting all perceptions of material forms, showed no difference between feedforward and feedback information transfer, suggesting the emergence of a balance between externally and internally driven neural processing. Our results reveal distinct patterns of dynamics across the brain during deep concentration practices informed by first-person phenomenological methods. References: [1] Wright MJ, Sanguinetti JL, Young S, Sacchet MD (2023) Uniting contemplative theory and scientific investigation: Toward a comprehensive model of the mind. Mindfulness 14:1088-1101. [2] Yang WFZ, Chowdhury A, Bianciardi M, Van Lutterveld R, Sparby T, Sacchet MD. Intensive whole-brain 7T MRI case study of volitional control of brain activity in deep absorptive meditation states. Cerebral Cortex. Volume 34, Issue 1, January 2024 [3] Vinck M, Uran C, Spyropoulos G, Onorato I, Broggini AC, Schneider M, Canales-Johnson, A. Principles of large-scale neural interactions. Neuron 111: 987–1002 (2023). [4] Imperatori, L. S., Betta, M., Cecchetti, L., Canales-Johnson, A., Ricciardi, E., Pietrini, P., ... & Bernardi, G. EEG functional connectivity metrics wPLI and wSMI account for distinct types of brain functional interactions. Scientific Reports. 9(1):8894. [5] Canales-Johnson A, Beerendonk L, Chennu S, Davidson MJ, Ince RAA, van Gaal S. The human brain distinguishes perception from its consequences through feedback neural interactions. PLoS Biology 21:5, e3002120, 2023.

Internal Attention: from Underlying Mechanisms to a Revised Taxonomy

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Poster Session 4, Thursday July 4th, Ito International Research Center, 3:30PM-4:30PM

Human beings are constantly confronted with a multitude of information from the external world, as well as from their mental activity and internal bodily signals. Attention enables the selection, prioritization, and modulation of the most relevant information for decision-making and action. Mechanisms underlying external attention have been extensively studied. For example, it has been shown that the orientation of external visuospatial attention is associated with specific profiles in EEG, such as lateralization of evoked responses or posterior alpha activity. On the other hand, mechanisms underlying internal attention have been relatively unexplored. The definition of internal attention itself is heterogeneous in the literature, sometimes defined as directed towards mental contents, sometimes towards internal bodily signals, and occasionally towards the entirety of "internal" stimuli, bodily or mental, hypothesizing common mechanisms across these different domains. Studies on visual short-term working memory suggest that spatial attention directed towards mental contents shares characteristics with external spatial attention and involves similar mechanisms, such as lateralization of posterior alpha activity. Do these findings generalize to other mental contents, such as images derived from long-term memory? Similarly, internal attention directed towards internal cardiac signals modulates the amplitude of heartbeat evoked responses. Are there attentional mechanisms common to mental and internal bodily stimuli? We address these two questions here: 1) To what extent is the spatial attentional orientation within mental images derived from long-term memory similar to external visuospatial orientation? 2) Is the neuronal processing of internal bodily signals modulated depending on whether attention is directed towards a mental or an external image? To answer these questions, we developed a novel experimental attentional cueing paradigm (70% valid cues) in healthy humans allowing us to study attentional orientation within a mental image derived from long-term memory (the map of France) and, in different blocks, external visuospatial attention orientation. In addition to behavioral measures, we recorded EEG, as well as cardiac signals. Behavioral data reveal that despite spatial format differences, attentional orientation benefits both visual spatial discrimination and mental imagery tasks. However, attentional benefits are not correlated, suggesting different mechanisms. Scalp EEG indicates that at the onset of attentional orientation, similar mechanisms (lateralization of evoked responses and posterior alpha activity) are involved in both tasks. However, the two types of attentional orienting soon diverge: external visuospatial attention orientation is accompanied by sustained cue-dependent alpha lateralization, while lateralization of alpha activity in mental imagery is only transient. These data suggest that, unlike external visuospatial attention and spatial orientation in short-term memory, attentional orientation in mental images derived from long-term memory does not rely on sustained lateralization of posterior alpha activity. Finally, we will investigate whether the cerebral processing of interoceptive signals (responses evoked by heartbeats) is enhanced when attention is directed towards mental content (compared to an external stimulus), thereby refining the taxonomy of internal attention.

Profiling neural correlates of consciousness based on brain biological ontologies

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Poster Session 4, Thursday July 4th, Ito International Research Center, 3:30PM-4:30PM

Introduction Despite 25 years of neuroscientific research, the topography of the neural correlates of consciousness remains currently debated. Even less is known about the biological (e.g. molecular, microstructural) characteristics of the neural systems underlying consciousness. The present meta-analysis aims to shed light on the micro (molecular, microstructural) and macro (functional, evolutionary) biological ontologies of the neural correlates of consciousness, based on a quantitative synthesis of existing evidence on brain structural, functional and molecular alterations in patients with disorders of consciousness (DoC). Methods In June 2023, we used MEDLINE via Ovid, and Scopus and Embase via Elsevier databases to search for resting-state MRI and PET studies, published from 2000 to 2023, and involving predominantly adults (≥16 years old) with prolonged DoC (≥28 days) and a clinical diagnosis of DoC based on a validated behavioural scale. At least two referees independently screened abstracts and full texts of selected studies and extracted coordinates of whole-brain, voxel-based comparisons performed between DoC patients and controls. Coordinate-based meta-analysis was performed via activation likelihood estimation. The resulting statistical maps of voxel-wise likelihoods were compared to the topography of 24 molecular, microstructural, functional and evolutionary biological ontologies, using standard settings in the neuromaps toolbox. All maps included were surface-type maps, i.e. including cortical areas only. Spatial correlations were deemed significant at $p<0.05$ Bonferroni-corrected for multiple comparison within map-type. The full protocol, including search strategy using controlled vocabulary and keyword terms, is available on PROSPERO (CRD42022327151). Results As of June 2023, of the resulting 2798 MRI and PET studies, 24 studies including 35 experiments (4 structural, 13 functional and 18 molecular) met criteria for inclusion, for a total of 665 patients (338 UWS; 327 MCS) and 351 controls. Likelihood of consciousness-related alterations distributed following molecular, functional and evolutionary brain biological ontologies. No significant association was found with microstructural ontologies (T1w/T2w ratio and thickness). In details, likelihood of consciousness-related alterations spatially distributed following: - the degree of cerebral blood flow, with areas with higher cerebral blood flow most likely to be altered in disorders of consciousness - a unimodal-transmodal brain functional hierarchy, with higher-order associative areas (as opposed to sensory ones) most likely to be altered in disorders of consciousness - an evolutionary and allometric hierarchy, with areas that expanded the most in the evolution from macaque to human and that expand the most in the development from childhood to adulthood, most likely to be altered in disorders of consciousness Conclusions This meta-analysis provides the most extensive evidence to date on biological features of neural systems related to consciousness, where high-order cortical areas, that evolved the most in recent evolution and expand the most during development, and requiring higher cerebral perfusion, are most likely to be associated with the ability to express consciousness. Our findings should be independently confirmed based on evidence in other ordinary and non-ordinary states of consciousness (e.g. sleep, anesthesia).

Model-based planning as a function of consciousness

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Poster Session 4, Thursday July 4th, Ito International Research Center, 3:30PM-4:30PM

Conscious experiences are familiar to us all, yet the functional role that consciousness plays in cognition remains unknown. One appealing proposal arising from the literature on reinforcement learning is that consciousness supports “model-based” planning – a forward-looking computation that makes use of an internal model of the environment. This hypothesis is informed by psychophysical data indicating that short windows of unconscious processing precede a succession of integrated conscious experiences. One possibility is that these rapid and sequential phases of unconscious model-building occur throughout perception, with the ensuing (conscious) models enabling model-based planning in discrete phases. A central prediction of this account is that model-based planning should only make use of the information that is deemed reliable enough to be assimilated into the current world model, i.e., conscious information. We will present the theoretical and empirical motivations for this model together with a novel experimental paradigm that seeks to test the prediction that model-based planning is only available to conscious information. By combining a thresholded discrimination task with the well-known “two-step” reinforcement learning task, we aim to quantify the degree of model-based and model-free planning available to both conscious and unconscious information. This procedure has the potential to reveal a double dissociation in the effects of conscious awareness on model-based vs, model-free decision-making, going beyond the contrastive method in which one must interpret null results in unconscious conditions. We aim to motivate an empirical research program which connects the computational neuroscience of planning and decision-making with the science of consciousness, and ultimately shed light on the functional and evolutionary benefits of conscious experience.

No conscious seeing without attention: How redundancy masking and the compression of visual information limit conscious vision

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Poster Session 4, Thursday July 4th, Ito International Research Center, 3:30PM-4:30PM

A key question in current work on consciousness is whether we can consciously see without attention. Recently, it was proposed that 'identity crowding', where a peripherally presented target (e.g., a letter T) is flanked ('crowded') by identical items (TTT), is a case where an object is consciously seen despite the inability to attend to it (because of the flankers). A central premise of this debate was based on introspection: Observers can identify the central T better when it is flanked by Ts (TTT) compared to Xs (XTX). By contrast, we found in a number of studies that observers frequently do not even detect the central of three identical items, a phenomenon we termed 'redundancy masking' (RM): When presented with sets of identical items in the periphery, individual items, or subsets of items, do not reach conscious awareness, despite focused attention on the stimulus. Here, we investigated to what extent features of items in RM withstand or are lost in RM. We presented 3 to 5 radially arranged bars with varying widths (0.1°, 0.25°, 0.4°) for 150ms in the left or right hemifield (10° eccentricity). Observers reported the number of bars, and subsequently adjusted probe widths and spacings to match what they had perceived. We computed deviation scores as the difference between perceived and actual (1) numbers of bars, (2) bar widths, (3) spacings between the bars, and (4) overall widths of the arrays. There was strong RM: The number of bars reported was lower than the number of bars presented. Overall, the width of thin (thick) bars tended to be overestimated (underestimated). In RM trials, the reported width was slightly larger than in non-RM trials. Importantly, except for the thinnest width condition, the reported width was more accurate in RM trials than in correct trials. The reported spacing between bars was larger in RM compared to correct trials, showing lower perceived density in RM trials, while the reported overall extent of the arrays was smaller in RM trials, replicating previous results of visual space compression in RM. Our results suggest that the inability to consciously access all items in repeating patterns may go hand in hand with higher accuracy in reporting features of the redundant signal. Information compression in RM seems to be beneficial beyond the economical use of limited processing capacities by improving feature perception of redundant targets. Importantly, our findings show that 'Identity crowding' is not an example for conscious seeing without attention, and they highlight how experimental investigations of seemingly valid conclusions drawn from purely phenomenological observations are crucial for the investigation of consciousness.
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The Neural Correlates of Consciousness: A Systematic Review and Meta-Analysis Registered Report (Stage One) on the Visual Awareness Negativity and P3b

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Poster Session 4, Thursday July 4th, Ito International Research Center, 3:30PM-4:30PM

Isolating the neural correlates of consciousness (NCCs) is a paramount challenge within cognitive neuroscience. In electroencephalographic research, two event-related potentials (ERPs) have been identified as candidate markers of conscious visual awareness: the visual awareness negativity (“VAN”) and the P3b (or “late positivity”). We present stage one of a Registered Report, as part of the “Funding Consciousness Science with Registered Reports” initiative, that will deliver the first systematic review and meta-analysis of these ERPs as they relate to consciousness. We report detailed plans including research questions, hypotheses, and methodology. We will address whether these signals can be regarded as valid NCCs through estimating the magnitude and reliability of the relationship between each and conscious visual awareness. We will assess both their necessity and sufficiency through meta-analysis of effect sizes using both seen-unseen and unseen-unseen contrasts, and examine whether evidence is impacted by study quality, selective reporting, and/or publication bias, and assess for theoretical and methodological moderators. To demonstrate feasibility of our approach, we report a pilot meta-analysis where standardised mean differences (SMD) of the VAN and P3b from ten studies are synthesised using multivariate modelling with robust variance estimation. Within this sample, we estimate an SMD for the VAN at 0.36 (95% CI = 0.05 – 0.66) and P3b at 0.65 (95% CI = 0.38 – 0.91), from which we show our planned meta-analysis will be well powered to detect effects. Our meta-analysis will be critical to clarifying hypotheses and advancing important debates regarding the role of these neural signals as NCCs.

Electroencephalographic Biomarkers of Covert Cortical Processing in Critically Ill Comatose Children: A Multicenter Prospective Study

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Poster Session 4, Thursday July 4th, Ito International Research Center, 3:30PM-4:30PM

Introduction: We describe our prospective multicenter study to investigate for covert cortical processing in comatose children with acute brain injuries. Methods: This is a 3-year multicenter study investigating the utility of detecting covert cortical processing in critically ill comatose patients. Patients will be enrolled with Glasgow Coma Scores < 8 and no eye opening for 6 hours. They will undergo continuous electroencephalography in addition to daily testing with the local-global oddball paradigm and motor command paradigm to squeeze and relax each hand. When feasible, sedation will be lightened during the study session, and then resumed after paradigm testing. Patients will undergo daily testing with the Coma-Recovery Scale – FAST score. Patients will also undergo brain magnetic resonance imaging (MRI), including resting-state functional MRI and diffusion tensor imaging. Glasgow Outcome Scale-Extended scores will be collected at 6-months post-injury via telephonic questionnaire. Patients will be enrolled at Phoenix Children's Hospital, St. Louis Children's Hospital, Texas Children's Hospital, Children's Hospital of Wisconsin, and Children's National Hospital. The primary aims are to (1) evaluate the incidence of covert cortical processing across different pediatric brain injuries and (2) to evaluate the relationship of covert cortical processing with long-term functional recovery. Secondary analyses include the evaluation of covert cortical processing demonstrated on electroencephalography with functional and structural connectivity on MRI neuroimaging, in addition to evaluating how changes in anesthesia on electroencephalography predict coma recovery. Results: Central Institutional Review Board (IRB) approval was secured in September 2023 at Phoenix Children's Hospital. Enrollment began promptly following IRB approval, and as of the current date, three patients have been successfully enrolled. The initial cohort includes individuals who suffered from either cardiac arrest or toxic metabolic encephalopathy, reflecting the diverse etiologies of acute brain injuries. They include two female and one male patient. To date, one patient died, one patient recovered from coma and was discharged home, and one remains hospitalized. Conclusion: Our prospective multicenter study to assess covert cortical processing in critically ill children is underway, with the goal to address a critical gap in our understanding of recovery from coma and acute brain injuries in pediatric patients. By employing advanced neurophysiological measures, such as event related potentials and motor command following, and incorporating a multi-center approach, we aim to provide valuable insights that can inform clinical practices, guide treatment strategies, and improve prognostication for this vulnerable patient population.

Causal contributions of left prefrontal theta activity to subjective and objective mind wandering: preliminary results from an entrainment TMS-EEG study

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Poster Session 4, Thursday July 4th, Ito International Research Center, 3:30PM-4:30PM

Mind Wandering (MW) remains a complex and incompletely understood cognitive process characterized by a diversity of explanatory theories and disputed neural markers. Recent advancements have introduced measures of intentionality subtended by prefrontal executive systems as an important mediator to identify different types of MW. Here, we aimed to investigate the causal chain of MW dynamics linking prefrontal oscillatory activity, MW events and their level of intentionality. In addition, we explored their relations with the reported level of alertness. We recruited 16 healthy participants who received patterns of rhythmic transcranial magnetic stimulation (TMS) at a theta frequency to the left dorsolateral prefrontal cortex (DLPFC, MNI: x=-37, y=41, z= 22) during a Finger-Tapping Random-Sequence Generation Task (FT-RSGT). Each participant completed two TMS sessions, whereby they were exposed to the following conditions (in independent blocks): baseline, active/sham rhythmic TMS at theta frequency, and active/sham arrhythmic TMS, in counterbalanced order. Participants were asked to produce an unpredictable sequence of left and right index finger tapping following an auditory pacemaker (440 Hz, 75 ms long, every 750 ms), avoiding regularity. Objective behavioral measures, approximate entropy (AE) and behavioral variability (BV) served as proxies for executive control and behavioral performance. AE and BV were computed for each condition. Importantly, we also collected subjective reports on the participant's level of attention (MW rates or On/Off task rates), intentionality and alertness via thought probes using a 4-level scale (~10 probes per stimulation block). We hypothesized that during rhythmic theta TMS participants would report higher attentiveness (more 'on-task', hence lower MW) and increased intentionality compared to arrhythmic TMS patterns delivered to the left DLPFC. Furthermore, we expected these effects to be associated with increases in AE and decreases in BV, respectively. The hypotheses were partially

confirmed. Our results show that AE significantly increased when participants classified their state as 'on-task' and decreased when participants reported being 'off-task' ($p<0.001$); BV showed a reverse pattern ($p<0.001$), suggesting the validity of the task. At the group level, AE was higher in theta rhythmic TMS blocks compared to arrhythmic TMS blocks, suggesting the generation of more unpredictable tapping sequences, hence lower MW. However, according to our statistical analyses this difference proved only marginally significant ($p<0.06$). No statistically significant differences were found between these two conditions for BV or reports on attentional level (MW rates), intentionality, or alertness. Interestingly, more detailed analysis revealed group-level significant differences in MW, intentionality, and BV during the second of the two sessions ($p<0.05$). Specifically, lower MW and BV, and higher intentionality during rhythmic than arrhythmic TMS blocks were observed, aligning with our initial hypothesis. Our findings underscore the individual variability in subjective MW assessments, suggesting that conscious introspective reports of MW may not always accurately reflect the studied underlying cognitive processes. On this basis, we here emphasize the importance of individualized EEG biomarkers and objective behavioral measures of MW. Future analyses will investigate the EEG recordings performed along and the correlation between subjective and objective reports of MW across TMS conditions and the two sessions.

Directional information sharing differentiates binocular rivalry from bistable perceptual awareness

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Poster Session 4, Thursday July 4th, Ito International Research Center, 3:30PM-4:30PM

The mechanisms through which the neuronal assemblies give rise to the conscious perceptual awareness are still unclear, with several and somehow opposite theoretical attempts to explain the spatiotemporal dynamics of exogenous and endogenous perception. Nonlinear measures of brain connectivity have been shown to assess spatiotemporal dynamics of multistable alternations of endogenous percept in various perceptual modalities. Transfer Entropy (TE), for example, is an information-theoretic measure able to explore how brain connectivity unfolds over time and brain areas analyzing brain imaging data. In this study, we measured the directionality of the integrated EEG information (frontal ←→ posterior) before subjects indicate to experience a perceptual switch in two different bistable phenomena: Binocular Rivalry (BR) and bistable perception (the Necker cube; NK). We calculated feedforward (FF) and feedback (FB) TE for both endogenous (bistable conditions) and exogenous (control conditions) perceptual phenomena, finding that a) FB delayed shared information is present before and after button pression in bistable phenomena, while FF shared information is present only in the first milliseconds during the whole temporal window; b) FB TE of BR significantly differentiates between the endogenous and exogenous perception, while in the case of NK the difference is not significant, showing that TE measure can differentiate between the two perceptual phenomena; c) exogenously driven percept switch provokes much more FB information interchanged between the frontal and posterior areas than endogenous switches produced by both BR and NK alternations. We discuss our results in terms of predictive processing of perceptual information and delayed feedback reverberating information which might be able to produce the perceptual subjective experience.

Phenomenomics and Citizen Science: Mapping the Phenomenology of Altered States of Consciousness

Cyril Costines (University of Washington), Timo Torsten Schmidt (Freie Universität Berlin)

Poster Session 4, Thursday July 4th, Ito International Research Center, 3:30PM-4:30PM

Introduction Phenomenomics is a methodological strategy within consciousness research that focuses on the systematic description and analysis of the variety of altered states of consciousness (ASCs). These states, induced by various pharmacological and non-pharmacological consciousness-modifying techniques (CMTs), serve as a research tool to uncover invariant, etiology-independent phenomenological structures inherent to conscious experience. This approach aims to empirically identify fundamental dimensions of consciousness by mapping the phenomenological state-space (PSS) – a unified model of all types of phenomenal states. Through this rigorous phenomenological mapping, phenomenomics seeks to advance understanding of the phenomenological foundations of consciousness. Methods The Altered Xperience Project (AXP) is a feasibility study initiated in October 2022 in collaboration with El Gato y La Caya (Argentina) under the framework of phenomenomics. This project combines citizen science with big data methodologies to investigate the phenomenology of ASCs. The data were collected from participants who experienced ASCs induced by four distinct CMTs: alcohol, cannabis, MDMA, and psilocybin. For quantitative data collection, a revised 22-item Altered States of Consciousness Questionnaire (11-ASC) was used, supplemented by qualitative data in the form of open-ended reports. Results In an online survey, data were collected from approximately 10,000 participants over a period of 10 days, identifying distinct phenomenological effects associated with the use of alcohol, cannabis, MDMA and psilocybin, including their dose-dependent modulations. For alcohol and cannabis, a sense of impaired control and cognition was most pronounced, with alcohol additionally inducing a sense of unity and cannabis insight. MDMA and psilocybin induced a sense of bliss, insight and unity, with psilocybin also associated with altered perceptual meaning, complex imagery and elemental imagery. Discussion This pilot study assessed the psychometric characteristics of a 22-item adaptation of the 11-ASC questionnaire using citizen science crowdsourcing techniques. The results are consistent with existing meta-analytic data on drug-induced phenomenology and dose-response relationships observed in conventional laboratory settings. The use of citizen science to map the PSS and create a data-driven, systematically organized classification system for ASCs is feasible, economically efficient and information-rich. This classification system holds significant implications for both neuroscientific research and clinical practice.

Functional MRI reveals preserved unimodal-transmodal cortical differentiation in patients with blindsight

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Poster Session 4, Thursday July 4th, Ito International Research Center, 3:30PM-4:30PM

Introduction: Damage to the visual cortex leads to clinical blindness. Yet some patients retain visual functions and respond to stimuli they do not consciously perceive; a condition known as blindsight. Recent neuroimaging advancements suggest that variations in consciousness can alter functional connectivity across the brain's spectrum from unimodal/sensorimotor to transmodal/association areas, which putatively reflects the depth of the information-processing hierarchy. Here we explore whether changes in resting-state functional connectivity serves as biomarkers for distinguishing conscious and non-conscious visual processing using the largest cohort of blindsight patients to date.
Methods: We assessed blindsight using a two-interval detection task in individuals with visual cortex damage, dividing them into blindsight-positive (B+, n = 8) and blindsight-negative (B-, n = 8) groups. Resting-state functional MRI data were collected in all participants and in age-matched healthy controls (n = 17). We analyzed functional connectivity using joint entropy to quantify the shared information between pairs of regions from the Glasser atlas, covering the entire human cortex. Higher values indicate more complex interactions between the regions.
Results: B+ retained a preserved sensory-association organization of their cortical activity that differentiated brain areas along the unimodal/transmodal axis, unlike B- participants who showed altered hierarchical organization compared to controls. A significant correlation was found between patients' proficiency to detect stimuli non-consciously and preserved organization of functional connectivity along the sensory-to-association axis. This decline in hierarchical organization was determined by increased entropy within the somatosensory and visual networks, which is maximally expressed in the posterior thalamus; a region compatible with the location of the pulvinar.
Conclusion: Despite similar lesion sizes and locations, blindsight functions are associated with a preserved large-scale functional organization in intact brain areas, whereby primary sensory-motor and transmodal regions are situated at opposite endpoints of the spectrum. Differences in joint entropy of the posterior thalamus correlate with blindsight and preserved functional segregation in cortical areas. The resilience and adaptability of the brain's functional architecture in B+ suggest plastic changes that enable compensation for cortical damage and non-conscious processing capacity.

Is Auditory Awareness Graded or Dichotomous: Electrophysiological correlates of Consciousness at different depths of stimulus processing

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Poster Session 4, Thursday July 4th, Ito International Research Center, 3:30PM-4:30PM

A level-of-processing hypothesis postulates that transition from unaware to aware visual stimuli is either graded or dichotomous depending on the depth of stimulus processing. Humans can be progressively aware of the low-level features, such as colours or shapes, while the high-level features, such as semantic category, enter consciousness in an all-or none fashion. Unlike in vision, sounds always unfold in time, which might require mechanisms dissimilar to visual processing. We tested LoP hypothesis in hearing for the first time by presenting participants with words of different categories, spoken in different pitches near perceptual threshold. We also assessed whether different electrophysiological correlates of consciousness, the auditory awareness negativity (AAN) and late positivity (LP), were associated with LoP. Our findings indicate that LoP also occurs in the auditory modality. AAN is an early correlate of awareness independent of LoP, while LP was modulated by awareness, performance accuracy and a level of processing.

Towards the animal model for the development of the time domain of higher-order cognition and autonoetic consciousness

Eichi Toyoizumi (University of Washington), Thomas J McHugh (RIKEN CBS)

Poster Session 4, Thursday July 4th, Ito International Research Center, 3:30PM-4:30PM

For a comprehensive and systematic survey of higher-order cognition and consciousness, using an animal model is ideal. However, animal studies of consciousness suffer from a lack of consensus in definition, methods, and physiological signature. We propose that studies focusing on the developmental aspect of cognition and consciousness, the “how it’s built”, will provide valuable insights into “how it works” of the consciousness and to better interpret/organize the previous findings. Moreover, modeling the “how it’s built” of consciousness across animals is more suitable than directly modeling the “how it works” of consciousness when the qualitative content of consciousness likely differs across animal species. To this end, we looked for the possibility of a comprehensive and systematic screening paradigm for the development of higher-order cognition using mice. We have developed a novel variant of in-utero electroporation for bilateral delivery of genetic tools before birth. This allows neuronal manipulation of specific brain regions that span the entire periods of cognitive development. For a behavioral task that captures the development of complex cognition and the consequences of neuronal manipulations in mice, we focused on trace fear conditioning (TFC). The task itself is relatively simple: mice are required to associate the tone and the electric shock despite the temporal gap between the two, but TFC is highly cognitively demanding and employs mPFC, Retrosplenial cortex, Hippocampus, and Entorhinal cortex in addition to all the brain structures necessary for regular delay fear conditioning. TFC is suitable for measuring the capabilities of the time domain of higher-order cognitive processes and episodic memory which are deeply related to autonoetic consciousness. We established the ontogeny for trace fear conditioning in mice, with trace fear learning capacity emerging around postnatal day 27. We believe that the findings from this paradigm should help organize the findings in more complex tasks and lesion studies in monkeys and humans.

Towards an Embodied Approach to Memory

Elena R.Ostos (University of Washington)

Poster Session 4, Thursday July 4th, Ito International Research Center, 3:30PM-4:30PM

While memory has been a pervasive theme across various philosophical issues—personal identity, moral responsibility, knowledge acquisition, etc.—it wasn't until the 20th century that it crystallized into a standalone problem deserving its dedicated attention, thereby inaugurating an independent field of study. In the current landscape, two major perspectives predominate: the causal approach and the simulationist view of memory. The former posits a necessary condition for the existence of a causal link between the present representation of a memory and the past event experienced, while the simulationist perspective challenges this requirement, drawing on an extensive body of experimental cases. These cases emphasize that false, distorted, or imprecise memories often do not result from a malfunction of memory but, to the contrary, constitute the majority of its outcomes. According to this approach, a fundamental feature of memory is to imagine past situations that never actually occurred, suggesting that counterfactual thinking, alongside successful memories, emerges from the same cognitive faculty. Nevertheless, both theories, despite intending to provide a comprehensive explanation of memory, predominantly focus on episodic memory as a paradigmatic case. This methodological choice results in a challenge when accounting for certain types of memory not mediated by representations. On the contrary, re-situating memory in the place from which it emerges, the body, offers several explanatory advantages. Firstly, memory is commonly considered a key indicator of cognitive activity. Taking an embodied approach to this phenomenon allows us to account not only for instances of implicit and bodily memory in humans but also for the diverse range of memory-related responses in non-human organisms. Thus, a corporal perspective on memory would contribute to illuminating debates on minimal cognition. Secondly, reuniting memory with the body involves treating it as a phenomenon that primarily occurs in conjunction with perception. Within the theoretical framework proposed by 4E cognition, perception is defined as the ability to grasp affordances, which are opportunities for action. Portraying memory as a faculty that operates, at least initially, in harmony with perception transforms it into a faculty oriented towards shaping patterns of action based on past experiences. Hence, a post-cognitivist philosophy of the mental must not sideline the embodied role of memory, as doing so risks overlooking its significance in perception.

Conscious Confluence and Embodied Synchrony: Exploring Neurophysiological Synchrony and Self-Other Distinction in Dyadic Imitations during Body-Swap Illusions

George Fejer (University of Konstanz), Tzvetan Popov (University of Konstanz), Guillaume Dumas (University of Montreal / CHU Sainte-Justine research center.), Bigna Lenggenhager (Association for Independent Research)

Poster Session 4, Thursday July 4th, Ito International Research Center, 3:30PM-4:30PM

The presentation will feature first results from our recent study that investigated the effects of embodied perspective taking in virtual reality on neural synchronization during dyadic imitation with electroencephalography and posture tracking. Building on the work of Dumas, Nadel, et al. (2010), which established that spontaneous imitation induces alpha-mu phase-locking synchronization in the right temporoparietal junction (TPJ), our research examines these mechanisms during a full body-swap illusion (Petkova & Ehrsson, 2008). Our hypotheses incorporate findings from Rosso et al. (2023), who observed enhanced dyadic synchronization in finger-tapping behavior while participants embodied the hand of another person from the first-person perspective. Moreover, our study introduced two visual perspectives: a first-person perspective (1PP), where participants viewed the other person's body from a first-person perspective, separated by a curtain obscuring their view of themselves, and a third-person perspective (3PP), where participants additionally saw themselves while still experiencing events from the other person's viewpoint. In a separate control condition, participants synchronized their movements by mirroring one another as they sat across each other without body swapping. Through different conditions, participants were instructed to synchronize each other's movements while acting as a leader, follower, or in an unconstrained manner. We hypothesize that the unconstrained interactions in the first-person perspective will yield the greatest synchronization in the TPJ, reflecting its crucial role in self-other distinction and perspective-taking (Blanke et al., 2005; Hughes, 2018; Martin et al., 2020; Santiesteban et al., 2012; van Elk et al., 2017). Furthermore, our research aims to understand how behavioral and physiological synchronization parameters affect participant's subjective sense of identity fusion, body-ownership, and agency, thus offering valuable contributions to consciousness research by elucidating the neural and experiential aspects of perspective-taking and selfhood in social interactions. References:
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Neural Synchronization in Embodied Perspective-Taking: Investigating Neural Entrainment during Dyadic Imitations in Body-Swap Illusions

George Fejer (University of Washington), Bigna Lenggenhager (Association for Independent Research), Guillaume Dumas (University of Montreal)

Poster Session 4, Thursday July 4th, Ito International Research Center, 3:30PM-4:30PM

Our study investigates the effects of embodied perspective taking on neural synchronization during dyadic imitation. Building on the work of Dumas, Nadel, et al. (2010), which established that spontaneous imitation induces alpha-mu phase-locking synchronization in the right temporoparietal junction (TPJ), our research examines these mechanisms during body-swap illusion. We incorporate findings from Rosso et al. (2023), who observed enhanced dyadic synchronization in finger-tapping behavior while participants embodied the hand of another person from the first-person perspective. Our study introduced two visual perspectives: a first-person perspective (1PP), where participants viewed their body from the other's perspective, separated by a curtain obscuring their view of themselves, and a third-person perspective (3PP), where participants additionally saw themselves while experiencing events from another's viewpoint. Through different conditions participants were instructed to imitate each other's movements while acting as a leader, follower, or in an unconstrained manner. We hypothesize that the unconstrained interactions in the first-person perspective will yield the greatest synchronization in the TPJ, reflecting its crucial role in self-other distinction and perspective-taking (Blanke et al., 2005; Hughes, 2018; Martin et al., 2020; Santiesteban et al., 2012; van Elk et al., 2017). Furthermore, our research aims to understand how these behavioral and physiological parameters affect participant's subjective sense of identity fusion, body-ownership, and agency. References: Blanke, O., Mohr, C., Michel, C. M., Pascual-Leone, A., Brugger, P., Seeck, M., Landis, T., & Thut, G. (2005). Linking out-of-body experience and self processing to mental own-body imagery at the temporoparietal junction. Journal of Neuroscience, 25(3), 550-557. Hughes, G. (2018). The role of the temporoparietal junction in implicit and explicit sense of agency. Neuropsychologia, 113, 1-5. https://doi.org/https://doi.org/10.1016/j.neuropsychologia.2018.03.020 Martin, A. K., Kessler, K., Cooke, S., Huang, J., & Meinzer, M. (2020). The right temporoparietal junction is causally associated with embodied perspective-taking. Journal of Neuroscience, 40(15), 3089-3095. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7141886/pdf/zns3089.pdf Rosso, M., Van Kerrebroeck, B., Maes, P.-J., & Leman, M. (2023). Embodied perspective-taking enhances interpersonal synchronization: A body-swap study. Iscience, 26(11). Santiesteban, I., Banissy, Michael J., Catmur, C., & Bird, G. (2012). Enhancing Social Ability by Stimulating Right Temporoparietal Junction. Current Biology, 22(23), 2274-2277. https://doi.org/https://doi.org/10.1016/j.cub.2012.10.018 van Elk, M., Duizer, M., Sligte, I., & van Schie, H. (2017). Transcranial direct current stimulation of the right temporoparietal junction impairs third-person perspective taking. Cognitive, Affective, & Behavioral Neuroscience, 17, 9-23.

Mesocircuit-based predictions of EEG validated in a large cohort of patients with Disorders of Consciousness

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Poster Session 4, Thursday July 4th, Ito International Research Center, 3:30PM-4:30PM

The brain supports consciousness through intricate connections between the thalamus, basal ganglia and the cortex. The mesocircuit hypothesis provides a testable framework about these regional interactions. This generates predictions on the shape of the EEG power spectrum based on the severity of brain damage and the ability to sustain consciousness in patients with Disorders of Consciousness (DoC). In order of reduced ability to sustain consciousness at the bedside, these patients can be divided into unresponsive wakefulness syndrome (UWS), minimally conscious state (MCS) and emerged MCS (EMCS). The ABCD model distinguishes four EEG power spectral categories: A-, B-, C-, and D-type patterns representing the extent of thalamocortical deafferentiation. It is posed that a fully functioning, conscious brain normally exhibits alpha oscillations around 10Hz and faster oscillation in the beta range (15-25 Hz), called a D-pattern. Different extends of thalamocortical deafferentation can cause general slowing of alpha to the theta range (4-8 Hz) with present higher frequencies (pattern C), this slowing can be concurrent with the absence of higher frequencies (pattern B), or there can only be delta (1-4 Hz) in the spectral power (pattern A). This easily implementable classification has been shown to be clinically relevant, for both diagnosis and prognosis in the acute (< 28 days) stages of a DoC, and has been associated with diagnosis and the patients' brain's metabolic capacity in a small population in the prolonged stages. The aim of this study is to validate the ABCD classification in a large (n=176) sample of participants, including patients with a prolonged DoC (n=143). Moreover, in a subsample of the population the classification was associated to regional glucose metabolism in the thalamus using FDG-PET (n=87), whose clinical value has been extensively proven in this patient population. There were 2 raters that performed the ABCD rating twice, half a year apart, blinded to behavioral diagnosis, previous scoring and each other's scoring. We found substantial inter-rater agreement (Cohen's kappa = [first assessment: 0.63, second assessment: 0.57]) and excellent intra-rater agreement (Cohen's kappa = [first assessment: 0.8, second assessment: 0.8]). The classification was significantly associated with diagnosis, increasing consciousness was associated with better patterns, independent of the rater ($\chi^2(12, n=176) = 84.843$, $p<.001$, $\chi^2(12, n=176) = 78.24$, $p<.001$, $\chi^2(12, n=176) = 84.981$, $p<.001$, $\chi^2(12, n=176) = 121.861$, $p<.001$). Glucose metabolism in the thalamus was significantly associated with the classification ($F(3, 84)=8.023$, $p<.001$; $F(3, 84)=4.219$, $p=.008$; $F(3, 84)=4.886$, $p=.004$; $F(3, 84)=5.776$, $p=.001$). Post hoc comparisons using Tukey HSD revealed these differences were mainly due to the contrast between the thalamic glucose metabolism for patients with

pattern D or B compared to those with pattern A. These results support that simple, visual EEG spectral power inspection can provide powerful clinical information. Moreover, it is based on theoretical predictions made from the mesocircuit hypothesis, showing the importance of these brain areas and their interaction for consciousness. Future research includes validation of the scoring with additional scorers and more in-depth analysis of the glucose metabolism in the entire mesocircuit, including the cortical areas.

Linking psilocybin's pro-hedonic properties to complex network dynamics and altered states of consciousness

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Poster Session 4, Thursday July 4th, Ito International Research Center, 3:30PM-4:30PM

The lack of hedonic experiences, referred to as anhedonia and a key symptom across a broad spectrum of mental disorders including depression, has become a huge burden to modern society. Since 2020, the prevalence rate of depression itself as well as anhedonic symptoms in the non-clinical population has been skyrocketing with 4-7 times the rate it used to be. Intriguingly, hedonic experiences in response to psychedelics such as psilocybin show long-lasting effects, even altering an individual's own perspective and identity through profound transformative experiences. These transformative experiences are linked to the generation of an altered state of consciousness, leading to a neuronal rewiring by breaking up engrained thought patterns and enhancing complex brain network dynamics – a brain state that may be indicative for heightened information integration. However, widespread therapeutic use of psychedelics is currently constrained by the immense resources necessary for supervision. Establishing the therapeutic potential of psychedelics for broader application necessitates a deeper understanding of the underlying mechanisms that go beyond simple dosage and duration of effect, most specifically mechanisms of action and interindividual differences in responsiveness. There is an ongoing debate whether the transformative experience is responsible for the positive effects of psychedelics. Despite preclinical evidence challenging this assumption, a thorough, systematic examination in humans is lacking. Thus, the aim of this project is to address these specifics by probing the following hypotheses: (i) Is the increase of the hedonic response and wellbeing/resilience in neurotypical as well as anhedonic patients a consequence of the conscious transformative experience? (ii) If yes, is there a positive or negative relationship between the intensity of the experience and the effects? (iii) Is there a positive or negative relationship between the hedonic experience and complexity of brain dynamics? (iv) If yes, is the transformative experience affecting this relationship? (v) Does this relationship interact with specific personality traits such as openness? (vi) Does the psychedelic experience influence longitudinal effects? Here we implement a full within-subject, randomized trial with psilocybin and risperidone in 40 neurotypical subjects and 40 patients with anhedonia. The 5-HT2A/D2 antagonist risperidone abolishes the psychedelic experience when given together with psilocybin. In 6 different sessions (baseline; psilocybin with or without risperidone; 1-day post-assessment; psilocybin with or without risperidone; 1-day post-assessment; behavioral 6-weeks follow-up), we will assess changes in the complexity of brain dynamics using functional magnetic resonance imaging, as well as the hedonic response to complex stimuli (self-selected music), wellbeing, resilience, cognitive flexibility, severity of anhedonic and depressive symptoms, personality traits, and the conscious psychedelic experience as output measures using a broad range of established questionnaires and tasks. Findings shed light on the role of altered states of consciousness for brain information integration and the hedonic response which are crucial for the mental health of both the diseased and the neurotypical population.

Audiovisual Speech Perception in Japanese L2 and Multilingual Gaze Behavior

Katarina Woodman (University of Washington), Emmanuel Manalo (Kyoto University)

Poster Session 4, Thursday July 4th, Ito International Research Center, 3:30PM-4:30PM

Multilingual education has become increasingly common, with a push for introducing foreign languages, especially English, at an early age and an additional third language at later educational levels. This is uniquely true in Japanese language education, as many classrooms are mixed with students from countries such as Vietnam, Korea, France, and Taiwan. Often, JSL students are required to use English as the lingua franca when studying and living in Japan, leading to an environment where third language acquisition (TLA) occurs alongside second language learning (2LL), a distinction that remains underexplored in research. This study focuses on how individuals speaking multiple languages perceive and process spoken language using auditory and visual cues. We hypothesized that multilingualism would mediate the relationship between gaze bias towards the mouth and phonetic distinction task performance and that gaze bias might vary depending on what language is being perceived, reflecting the integrated linguistic systems of multilinguals. To test these hypotheses, we employed WebGazer extension via jsPsych for eye-tracking to measure gaze bias among 54 participants, categorized into 1) English monolinguals, 2) English-Japanese bilinguals, and 3) trilinguals with high proficiency in English, Japanese, and a third language. Participants engaged with a novel phonetic distinction task in both English and Japanese, assessing the impact of multilingualism and language of the stimuli on gaze behavior and task performance. Contrary to our hypotheses, the results indicated no significant mediation of task performance by gaze behavior due to multilingualism, nor did the language of stimuli significantly alter the impact of gaze behavior on performance. These findings suggest a reevaluation of the assumed direct relationship between gaze behavior and speech perception in multilingual contexts, implying a more complex model than originally proposed. However, post hoc analyses further explored the nuances of gaze behavior among native and non-native English speakers and the potential influences of cultural background on gaze perception. Native English speakers exhibit distinct gaze patterns when processing English and Japanese, differing significantly from native Asian and European language speakers. Additionally, significant variations were observed in mouth fixation durations while engaging with English content. Although less pronounced, trends in gaze behavior were also observed in the processing of Japanese, suggesting potential differences in visual attention among the groups, albeit not reaching statistical significance.

Supporting the cognitive challenges of dementia patients with visual data analysis by Visual Language Model (VLM)

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Poster Session 4, Thursday July 4th, Ito International Research Center, 3:30PM-4:30PM

The utilization of Internet of Things (IoT) technologies for supporting the daily lives of dementia patients is a crucial theme in the medical field. In particular, Artificial Intelligence (AI) assistance based on visual data through wearable IoT devices such as Augmented Reality (AR) glasses, Virtual Reality (VR) devices, and Brain-Machine Interfaces (BMI) requires the contribution of consciousness research to address the cognitive level and consciousness state of dementia patients. Among AI solutions, employing the Visual Language Model (VLM), which has evolved multi-modally based on the Large Language Model (LLM), emerged as a promising approach. Through this multimodal evolution, VLM can respond to combinations of images and text. In the context of dementia support, since the capacity of VLM is influenced by the interaction between the environment and the patient's condition, it is necessary to examine the capacity of VLM in the context of the environmental image and the patient's dementia condition. In this study, we investigate the ability of VLM to identify potential concerns and generate relevant alerts for dementia patients from a variety of visual scene images. In the experiments, we presented images from the SUN dataset, an open dataset of scene images that includes categories of indoor, outdoor natural, and outdoor man-made environments, to LLaVA (LLaVA-v1.6-34b model), an open-source VLM, with the "This is the view of a person with dementia. Is there anything to watch out for?" prompt. We conducted 45 experiments using a total of 45 images, comprising 15 indoor images, 15 outdoor natural environment images, and 15 outdoor man-made environment images. We analyzed LLaVA's responses to the 45 images to identify alerts that occurred frequently and to examine how alert percentages varied across indoor, outdoor natural, and outdoor man-made environments. As a result, a warning to check the presence of supporters was given by 95.6% (43 out of 45) of responses, and a warning not to lose orientation was given by 82.2% (37 out of 45) of responses. For indoor environmental images, the alert to confirm the presence of the supporter was 86.7% (13 out of 15) and the alert not to lose orientation was 80.0% (12 out of 15); for outdoor natural environmental images, the alert to confirm the presence of the supporter was 100% (15 out of 15) and the alert not to lose orientation was 93.3% (14 out of 15); for outdoor man-made environmental images, the alert to confirm the presence of the supporter was 100% (15 out of 15) and the alert not to lose orientation was 86.7% (13 out of 15). Namely, outdoor environments generally elicited a higher rate of alerts than indoor environments for these alerts. Our research provides foundational insights for supporting dementia patients through VLM utilizing visual data.

Investigating the Neural Correlates of Becoming Aware of Human Values Represented by Generative AI

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Poster Session 4, Thursday July 4th, Ito International Research Center, 3:30PM-4:30PM

Artificial intelligence is becoming more ubiquitous in our everyday lives. The key challenge is to understand whether and how people perceive AI as value-aware. Moreover, it is pivotal to understand humans' expectations of AI abiding by human values. While we can objectively evaluate the operations of machines, it is equally important to understand the neural basis for assigning value-awareness and intentionality to them. It is particularly challenging given that we still lack a sufficient understanding of the brain correlates of becoming aware of values in humans. Thus the translation of becoming aware of moral decisions made by AI remains unexplored. Our research employs generative AI to create visually captivating representations of human values. These generated images serve as stimuli for an in-depth investigation into the neural basis of becoming aware of values, as measured by event-related potentials (ERPs). In our experiment, images generated using generative AI were presented where the prompt consisted of two parts: a noun (the name of the value) and a definition taken from the Oxford Dictionary. A set of 3 stimuli for each value was used in each trial. The participants' task was to find one word that described all three pictures. Then, the participants were asked to make ratings on scales classically used to study the so-called 'Aha effect' - the suddenness, restructuring, and confidence. After answering these questions, the correct word was presented on the screen. After its presentation, participants had to additionally indicate whether, when they saw this word, they felt an 'aha' (they suddenly understood the meaning of this word) or not. Adapting scales from research on the classic eureka effect gave us measures to classify trials into those in which the subjects suddenly understood a given value and those in which they did not. ERPs analysis showed that the trials where, after seeing a correct response, participants suddenly understood the meaning of a given value elicited more negative ERP deflections in N2 (around 200 ms) and N3 (around 250 ms) time windows, and more positive amplitudes of P2 (around 200 ms) and LPP (around 400 ms) components in frontal, central and parietal scalp regions, than did the trials where the do not understood the value. The results indicate that the early N2 and N3 components may reflect cognitive conflict, and the later P2 and LPP components may be related to the generation of novel associations, all crucial to becoming aware of a value. Our results also indicate that the fronto-cental and parietal cortex areas might play a crucial role in processes involved in moral cognition. These results provide novel information about the neural basis of how people become aware of moral values. These neural correlates will lay the ground for subsequent experiments to explore whether people become aware of the moral decisions made by a humanoid robot and other artificial agents. This will help to further develop humans' attribution of morality and value-awareness towards artificial agents.

Artificial intelligence is equipped with the space-valence metaphor

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Poster Session 4, Thursday July 4th, Ito International Research Center, 3:30PM-4:30PM

The concept of emotional valence's association with vertical space in our cognition (i.e., the space-valence metaphor): Positive and negative emotions are metaphorically linked to upward and downward directions, respectively. Previous studies (e.g., Marmolejo-Ramos et al., 2013) found that human participants rated the word "up" more positively than "down." Furthermore, these studies employed a cursor-positioning task, demonstrating a tendency to associate positive words (e.g., "joy") with higher vertical positions and negative words (e.g., "sadness") with lower ones, while neutral words (e.g., "surprise") were placed in between. The present study investigated whether a similar metaphorical link would be present in the artificial intelligence ChatGPT-4. In Experiment 1, ChatGPT-4 rated "up" and "down" using a 7-point scale (1: very unpleasant, 7: very pleasant), with "up" receiving a significantly higher rating score than "down." Experiment 2 tasked ChatGPT-4 with positioning the words "joy", "surprise", and "sadness" within an XY coordinate plane (X: -10 = left, 10 = right; Y: -10 = down, 10 = up). It was found that "joy" and "surprise" received significantly higher Y coordinates than "sadness", with no significant difference in the Y coordinate for "surprise" compared to "up". These results nearly mirror the human cognitive phenomena related to the space-valence metaphor. Our findings suggest that the space-valence metaphor have developed spontaneously as a byproduct of training on extensive text data, demonstrating an emergent property of language processing in ChatGPT-4.

Visual Awareness is not required for the Virtual Hand Illusion: a combined protocol of Virtual Reality and Continuous Flash Suppression

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Poster Session 4, Thursday July 4th, Ito International Research Center, 3:30PM-4:30PM

Bodily self-consciousness arises from the spatiotemporal congruency of integrated sensory signals. In the Rubber Hand Illusion paradigm, the feeling of owning a fake hand is induced when the external object is perceived in first- (1PP), as compared to third- (3PP), person perspective, and when synchronous (synch), as compared to asynchronous (asynch), visuo-tactile stimulation is delivered over the fake and real hands. Despite multisensory integration is known to occur even if one modality is unconsciously perceived, the role of visual awareness on the illusion has never been tested. Capitalizing on immersive virtual reality and continuous flash suppression, we investigated whether or not awareness is necessary to induce the illusory feeling of ownership. We hypothesized that body ownership measured by the proprioceptive drift (i.e., the extent to which the real hand is mislocalized towards the fake hand) would still occur in the absence of visual awareness. 36 subjects were administered a binocular rivalry task and a virtual hand illusion procedure to assess, respectively, ocular dominance and illusory ownership (embodiment questionnaire and proprioceptive drift). Then, participants susceptible to the illusion underwent a virtual hand illusion task where we manipulated spatial perspective (1PP vs 3PP), temporal congruency of the stimulation (synch vs async), and awareness of the virtual hand (conscious vs unconscious) through Continuous Flash Suppression i.e., showing a dynamic high contrast mondrian pattern to the dominant eye). At the end of each trial, proprioceptive drift and stimulus visibility were measured. CFS-masked trials in which participants reported awareness of the virtual body were excluded. The results showed that, in the conscious condition, proprioceptive drift was significantly ($p < .01$) higher in the 1PP synch condition as compared to async or 3PP conditions, indicating the efficacy of the procedure. Crucially, proprioceptive drift in the 1PP unconscious condition was comparable to the drift in 1PP synch conscious condition, regardless of tactile stimulation (synch, $p = .94$; async, $p = .67$). However, a significant difference in proprioceptive drift was found between the unconscious 1PP and 3PP conditions, being higher in 1PP ($p < .05$). This suggests that proprioceptive drift was induced without visual awareness only when the virtual hand was unconsciously perceived in 1PP. Our findings demonstrate that objective ownership responses are modulated by unconscious processing of bodily perspective, having similar magnitudes as when the visual modality is consciously perceived. Synchronicity of tactile stimulation affected conscious, but not unconscious, 1PP condition. This is in line with the idea that 1PP is sufficient to induce the illusion, whereas synch stimulation enhances its strength, and async stimulation reduces it. Moreover, to reduce the illusion strength by administering async tactile stimulation, conscious awareness of the multisensory conflict is necessary. Overall, this work suggests that body ownership can be triggered in the absence of visual awareness, highlighting a complex interplay between consciousness and bodily-self-perception.

Emotional responses evoked by auditory stimuli are influenced by personal traits and hierarchical structure

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Poster Session 4, Thursday July 4th, Ito International Research Center, 3:30PM-4:30PM

Humans are continuously exposed to a wide variety of sensory inputs. While certain types of sensory input evoke positive responses such as a comfortable feeling from relaxing music or soothing texture, others evoke negative responses including distress caused by unsettling sounds or shocking images. Such emotional responses can sometimes be intense enough to inhibit an individual's functioning in daily life. Previous research has revealed that the acoustic features of auditory stimuli influence emotional responses. However, many emotional responses cannot be explained solely by the stimuli's acoustic features. Previous research has also revealed that the individual's personal traits influence the emotional response to auditory stimuli. However, the relationship between such personal traits and emotional responses remains unclear. Therefore, in our study, we examined how the hierarchical structure of auditory stimuli influences emotion, and how personal traits including autistic traits modulate emotional responses. We hypothesized that the global/local structure of auditory stimuli and the individual's uncertainty of the global/local structure affect the emotional responses to stimuli. We conducted an online experiment with 500 participants without psychiatric or hearing disorders. The participants completed a questionnaire about their autistic traits, sensory sensitivity, and intolerance of uncertainty scale (IUS). Next, participants were presented with 26 sequential auditory stimuli with different global/local structures. Subsequently, they were asked to report their emotional responses to each stimulus by providing ratings for valence, arousal, and emotion-related questions. Results showed the relationship between the individuals' emotional response to auditory stimuli and their intolerance of uncertainty regarding the stimuli's global/local structure ($p<0.05$). Furthermore, results showed the relationship between the individual's autistic traits and emotional responses to auditory stimuli. Our findings suggest the possibility of developing personalized strategies to manage auditory stimuli that impede the individual's daily activities by analyzing the global/local structure of the stimuli and predicting the individual's emotional response to them. Further, previous research suggests that individuals with autism spectrum disorder(ASD) have a heightened sensitivity to auditory stimuli, a preference for certain global/local structures, and an intolerance of uncertainty. Such traits are thought to be closely related to anxiety in ASD. By integrating our findings with such previous insights, we may also contribute to more effective anxiety treatments in ASD, particularly those arising from an intolerance of uncertainty related to auditory stimuli. In summary, our study enriches the current understanding of the intricate interplay between personal traits, global/local auditory structures, and emotional responses, offering valuable avenues for future research and applications in therapeutic contexts.

Predictive coding as a probabilistic bisimulation

Manuel Baltieri (University of Washington), Ryota Kanai (Araya Inc.)

Poster Session 4, Thursday July 4th, Ito International Research Center, 3:30PM-4:30PM

In the past few decades, Bayesian frameworks such predictive coding (processing) and active inference have emerged as a dominant paradigm for the study of cognition and consciousness. In recent years, parts of these frameworks have been recast in more abstract terms, providing principled accounts of Bayesian inference in the brain using constructions from (applied) category theory (St Clere Smithe, 2023), and an equational language in graphical form, string diagrams, to streamline and generalise current theories to a larger class of (dynamical) systems (Tull et al., 2023).

In this work, we follow the tracks of (St Clere Smithe, 2023, Tull et al., 2023) and further propose to characterise interactions between an agent and its environment in a categorical framework via structure preserving relations, i.e., bisimulations, between an agent and its environment. Bisimulations are a central construct in theoretical computer science, particularly in the field of concurrent systems for the definition of behavioural equivalence between automata, and are nowadays an integral part of the coalgebraic approach to the study of state transition and dynamical systems in (applied) category theory. Intuitively, bisimulations give us a notion of equivalence between the behaviours of two systems: when can two systems be said to behave in the same way (roughly, produce the same stream of outputs given the same stream of inputs)? In other words, they capture the idea that from an observer's, external perspective, two systems may appear to behave in the same way regardless of their particular internal (hidden) structures. Using this, we look at a typical setup of frameworks describing cognitive processes in terms of Bayesian inference, and cast generative process (environment) and generative model (agent's brain) as P-coalgebras for a probability monad P. We then define a P-bisimulation between them and exemplify its features for the special case of Set (the category of sets and functions) as the base category. This will give us a notion of "ideal" generative model (as a P-coalgebra) that is in a bisimulation relation with a generative process (also as a P-coalgebra), expressing an agent('s brain) that "models" its environment in a way that makes it behaviourally consistent with the very environment it's interacting with.

With this as a toy model for systems with discrete-state probabilities and discrete-time dynamics, we then characterise connections between this approach and recent developments of causal state representations for POMDPs in RL (Zhang et al., 2021a). Causal state representations are defined using probabilistic bisimulations, and are characterised in RL as "task-relevant" representations (Zhang et al., 2021b), i.e., representations that depend on task-relevant information, information that affects rewards, but that are invariant to task-irrelevant information, information that doesn't change rewards no matter what action is taken.

We will conclude by suggesting that an account of agent-environment interactions based on (probabilistic/P-) bisimulations may provide a principled background for "action-oriented" approaches to predictive coding (processing) and active inference, discussed in the literature of philosophy of mind by (Clark, 2013) and later implemented by (Baltieri & Buckley, 2017; Tschantz et al., 2020).

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Perceptual Quality spaces

Marco KWittmann (University of Washington), Cormac Dickson (University College London), Hakwan Lau (RIKEN center for brain science), Stephen M Fleming (University College London)

Poster Session 4, Thursday July 4th, Ito International Research Center, 3:30PM-4:30PM

A fundamental question in consciousness science concerns the neural and computational substrates of qualitative aspects of experience. Quality space (QS) theory proposes that sensory qualities are determined by relational distances between different perceptual attributes (Rosenthal, 2010). Roughly speaking, the reason red is experienced as phenomenologically red is because it is a bit like orange, and a bit like yellow, but different to blue and very different to the sound of a trumpet or the feeling of fear. The core idea is that an estimate of "what it is like" can be answered by consulting a QS - X is a bit like Y, but not like Z. However, the neural substrates supporting a perceptual QS remain unknown. We conducted a functional magnetic resonance imaging (fMRI) study (N=41) to investigate (1) how the brain represents multiple perceptual attributes in parallel and (2) whether the brain implicitly represents the similarity between successively presented stimuli. First, we constructed a 4 x 4 perceptual space using random dot motion kinematograms (RDKs). RDKs varied along dimensions of both colour (red to green) and motion (leftwards to rightwards). We constructed individual stimulus spaces tailored to each participant based on the results of a pre-scanning calibration procedure which ensured that stimuli were roughly perceptually equidistant along both dimensions and that both colour and motion dimensions were comparable in terms of their range. Next, we conducted a fMRI repetition suppression study. Participants observed pseudorandom sequences of individually calibrated RDK stimuli. We systematically varied the trajectory through the motion-colour space, which could change in one dimension (only motion, or only colour; 1D trials) or along both dimensions at the same time (2D trials). The fMRI experiment was followed by a behavioural experiment which elicited systematic similarity ratings across all pairs of stimuli presented in the experiment. Analyses of behavioural data confirmed that subjects were sensitive to both motion and colour dimensions when estimating pairwise similarity, but also revealed interesting idiosyncrasies in the construction of the perceptual space. For instance, we can capture the similarity data using multidimensional scaling and a feature space that is 1 dimension higher than the objective feature space used in the task (3 instead of 2 dimensions). This additional dimension is necessary to distort the space and to account for a logarithmic similarity structure in which similarity ratings tend to asymptote at greater objective stimulus distances. The analysis of the fMRI data is ongoing, and we expect to have results at the time of the conference.

Supramodal neural information supports stimulus-driven attention across cortical levels

Maria Niedernhuber (University of Washington)

Poster Session 4, Thursday July 4th, Ito International Research Center, 3:30PM-4:30PM

Sensory systems utilise stimulus-driven attention to survey the environment for significant features. The question arises: are the cortical networks that influence stimulus-driven attention supramodal or specific to each sensory modality? Here we employed a hierarchical target detection task (n=30), examining cortical responses linked to the detection of salient targets in the somatosensory and auditory modality. In a temporal decoding analysis, we reveal a transient early supramodal process activated by target detection. We also demonstrate that both common and unique modulations of salience-related cortical responses to somatosensory and auditory targets involve modality-specific and frontal regions using Parametric Empirical Bayes. Specifically, we found that the inferior frontal gyri share information across both sensory modalities, while recurrent information transfer between ipsilateral inferior frontal gyri and associative regions was modality-specific. Finally, we showed both supramodal and modality-specific attentional modulations of effective connectivity linking regions across hierarchical levels in the cortex. Our results provide evidence for an attention network which integrates information across inferior frontal cortices to detect salient targets irrespective of their specific sensory modality. Beyond the notion of a supramodal attention system, our findings support the role of modality-specific cortices in processing inputs from other sensory modalities, highlighting that attention can bias these processes at multiple stages of the cortical hierarchy.

Is poor metacognition in psychosis an artefact of criterion instability?

Marianne Broeker (University of Washington)

Poster Session 4, Thursday July 4th, Ito International Research Center, 3:30PM-4:30PM

Metacognition reflects the ability to assign high-confidence ratings to a correct, and low confidence ratings an incorrect response (Fleming and Lau, 2014). Thereby, it reflects a person's evaluation of their own cognitive processes (e.g. perception, memory). In psychosis, investigations into alterations, impairments of metacognition have shown mixed results (review: Rouy et al, 2021), but were often calculated on top of type-I responses of a YesNo task, which isn't bias free, but can be affected by response bias (Azzopardi and Cowey, 2001). Generally, there is the question if d' (type-I) and meta d' (type-II) are measuring distinct phenomena, and how differentiating between metacognition on top of a YesNo (type-I) decision, which is affected by response bias vs. 2AFC (type-I) decision, which isn't affected by response bias, might help answering this question. In a clinical sample (psychosis), which is hypothesised to show instability in criterion setting and maintenance processes, I am testing whether type-I decisions, or/and type-II decisions are altered, and how both might or might not be affected by criterion setting and instability, if they turn out to be distinction phenomena. In other words, if criterion instability is evident in the type-I decision, it would be hypotheses that it transfers onto the type-II decisions as well, in which case poor metacognition reflects overall instable criterion setting processes. Confidence responses were used to calculate meta d' and explore the relationship between criterion setting (instable criterion setting) and the computation of the confidence variable (metacognition) in a contour integration task. As d' in the YesNo and meta d' (YesNo and 2AFC) entail the setting of a criterion, a strong association of meta d' and d' would be expected in YesNo task, in comparison to a weaker correlation of meta d' (criterion) and d' (no criterion) in 2AFC tasks – especially when criterion instability is evident. In other words, since d' in 2AFC has no criterion, criterion instability should not factor in 2AFC type-I but in the 2AFC type-II decisions, which does rely on a criterion. If a dissociation of 2AFC type-I and type-II is evident, that might point to the role of criterion setting in the computation of meta d'. In this study, I show that meta d' is influenced by criterion setting processes of the type-1 decision in YesNo tasks, whereas the confidence variable (type -II) is computed differently in the 2AFC task, where the type-I decision does not require a criterion. Thus, not setting a criterion in the type-I decisions influences setting a criterion in the type-II decision, and makes the criterion in the type-II decisions less biased. In other words, the confidence ratings in the 2AFC task might be tapping on a different source of information than the 2afc decision - in fact that is very likely because there is no criterion in the 2afc decision, but there are criteria in the rating scales; whereas yn decisions and yn confidence ratings draw on the same information (i.e. the criterion could be related).

Spatiotemporal pattern of cortical activity predicts spontaneous fixation shifts

Masakazu Inoue (University of Washington), Shuntaro Sasai (Araya, Inc.)

Poster Session 4, Thursday July 4th, Ito International Research Center, 3:30PM-4:30PM

Introduction

In daily life, we encounter abundant environmental stimuli, yet naturally direct our fixation only a subset thereof. With controlled experimental settings, visual, parietal, and frontal cortices were found to play an important role in fixation shifts [1]. However, neural mechanisms for fixation shifts in natural settings remain unclear. Using fMRI data obtained during movie-watching, we examine whether fMRI signals predict spontaneous changes of fixated locations. We localize brain regions contributing to the prediction and characterize the spatiotemporal neural dynamics underlying the spontaneous fixation shifts in natural settings.

Methods

dataset

We used a publicly available, StudyForrest dataset [2] consisting of simultaneous fMRI (TR=2) and eye tracking data during movie watching. Twenty two ROIs were extracted according to Glasser et al. [3].

fMRI-based prediction of fixated locations

We newly developed fMRI-based prediction of fixated locations as follows.

Visual features of entire image and fixated location. We resampled the movie clips at 0.5Hz and generated masks to black out non-fixated locations. Using the image encoder (ViT), we constructed visual features from whole and masked images. Features of the masked images underwent average pooling across the spatial dimension. Thus, patched eatures of the entire image (5x16x16x1408) and pooled features of the masked image (5x1x1x1408) were obtained at each time point.

Visual feature decoding from fMRI signal. We constructed linear models to predict the feature of fixated locations from BOLD signals of each ROI after voxel selection.

Prediction of fixation and evaluation. Pearson correlation between predicted feature vectors and those of each image patch was calculated. Patches with top-k correlation were chosen as predicted fixated areas. We used Intersection over Union (IoU) between these predicted patches and the true fixated patches as metrics for evaluation.

Results

We examined whether fMRI signals in each ROI can predict spontaneous shifts of fixated locations. To do so, we focused time points where large eye movements occurred. We found that posterior, parietal ROIs can significantly predict the fixated locations before the eye movements. In addition to these ROIs, paracentral, middle cingulate, posterior cingulate, and dorsolateral prefrontal ROIs can predict the fixated locations after the eye movements. Interestingly, paracentral and middle cingulate ROIs decoded the fixated areas earlier than other cortices.

Conclusion

We confirmed that the fixation with voluntary eye movements could be significantly decoded from the BOLD signals of multiple time points. We also found that the neural activity in Paracentral lobular and mid cingulate can decode earlier than visual cortex, suggesting the ROI may be involved with generation or processing of voluntary attention.

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Music-related Bodily Sensation Map in Individuals with Depressive Tendencies

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Poster Session 4, Thursday July 4th, Ito International Research Center, 3:30PM-4:30PM

Music shapes the human embodied emotional experience. In particular, interoception and bodily sensations during listening to music have been suggested to be crucial for generating musical emotion. Recent studies have suggested that individuals with emotional disorders, such as depressive tendencies alter musical emotions. However, it remains unclear how depressive tendencies modulate bodily perception including interoception when listening to music. The present study aims to investigate music-related bodily sensations in individuals with depressive tendencies. This was achieved through an online survey employing body mapping tests and subsequent emotional judgments for each of the eight types of 4-chord progressions (N=527, female=257). Eight type of 4-chord progressions are originally used in the body map study of uncertainty and surprise in music by Daikoku et al (2024) .In the 4- chords, two groups of cases where the first to the third have both uncertainty and surprise low as well as high. And the fourth chord has four patterns where both uncertainty and surprise are low, high and combinations where one of them is high and one of them is low. Participants were exposed to these eight types of chord progressions in random order. Following each listening session, they were asked to respond within 10 seconds with clicks to the position in the body where they felt from the chords, using the body image presented on the screen. We found that individuals with depressive tendencies experienced more unpleasant sensations, especially those related to low valence and low aesthetics, and reported that bodily sensations were stronger in the head region. The ANOVA for types of chord progressions in depressive tendencies revealed that the clicks at the head region showed significant main effects (χ^2 = 18.0, df = 7, p = .012). The Durbin-Conover post hoc test detected that the head sensation was stronger in the sHuH-sLuH sequence than in the sLuL-sLuL sequence (p < .001) , the sLuL-sHuL sequence (p = .017) , the sHuH-sHuL sequence (p = .05) , the sHuH-sHuH sequence (p = .007). Further, the head sensation was stronger in the sHuH-sHuH sequence than in the sLuL-sLuL sequence (p < .005).Further, the Spearman correlation analysis revealed that significant positive correlations of anxiety with the number of clicks to the head region in the sHuH-sHuH chord progressions (rs = 0.178, p = <.01). These findings may imply that within the whole body, sensations in the head, rather than heart-related sensations of interoception, are associated with negative emotions. Furthermore, such sensations may be amplified in emotional disorders like depression. Our study suggests that not only interoception involved in bottom-up activities , such as heart-related sensations, but also whole-body sensations, including those in the head involved in top-down activities such as consciousness, play an important role in generating musical emotion.

Higher-order phenomena and the limits of reductionism in the science of consciousness

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Poster Session 4, Thursday July 4th, Ito International Research Center, 3:30PM-4:30PM

The study of consciousness presents a classical example of the complexities inherent in bridging reductionist and integrative methodologies in scientific research. Reductionism, with its emphasis on dissecting phenomena to their foundational elements and interactions, has significantly advanced our understanding of the neurological correlates of consciousness, seeking to explain states of awareness and cognitive functions through the lens of fundamental neurobiological processes. Despite its successes, this approach often falls short in comprehensively addressing the intricacies of consciousness, as it may overlook the emergent properties and the integral dynamics that characterize the conscious experience. On the other hand, integrative approaches, which embrace the complexity and multifaceted nature of brain activity, may offer a broader perspective, crucial for consciousness studies [1]. Our work investigates these two methodologies through recent developments in information theory and complex systems physics. Specifically, we explore the potential in overcoming the limits of reductionistic perspectives, offered by recent advances in the study of higher-order interactions [2, 3]. We present case studies from neuroscience and physics where an overemphasis on reductionism and the quest for causal claims led to miss crucial aspects of the subject's complexity. Then, we show how integrative approaches focusing on higher-order phenomena can facilitate us with new elements to describe and represent human brain complexity [4]. Finally, we propose a new line of research in which quantitative approaches to emergence are combined with mechanistic modeling to enhance methodological depth in the examination of these topics [3, 5]. This integrative proposal aims to deepen our methodological approaches and foster a more comprehensive understanding of consciousness, pushing the boundaries of how we investigate and interpret the complexities of the conscious mind. 1. Petri, Giovanni, et al. "Homological scaffolds of brain functional networks." Journal of The Royal Society Interface 11.101 (2014) 2. Battiston, Federico, et al. "The physics of higher-order interactions in complex systems." Nature Physics 17.10 (2021) 3. Rosas, Fernando E., et al. "Disentangling high-order mechanisms and high-order behaviours in complex systems." Nature Physics 18.5 (2022) 4. Luppi, Andrea I., et al. "Information decomposition and the informational architecture of the brain." Trends in Cognitive Sciences (2024) 5. Rosas, Fernando E., et al. "Reconciling emergences: An information-theoretic approach to identify causal emergence in multivariate data." PLoS computational biology 16.12 (2020)

Peak hedonic experiences are states of increased information integration

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Poster Session 4, Thursday July 4th, Ito International Research Center, 3:30PM-4:30PM

Despite ketamine's well-known rapidly acting pro-hedonic properties, its precise mechanism of action still remains elusive. Yet, mounting evidence suggests ketamine's therapeutic effect might be linked to its neuroplastic properties - changing both the functional and structural neuronal network which in turn seems to be related to the induced strength of an altered state of consciousness (ASC). At subanesthetic dose, ketamine increases complex network dynamics, enabling the brain to explore a broader range of possible states. We hypothesize that this expansion of the neuronal repertoire is indicative of an increased capacity for neuronal information integration. This surge in global information integration might underlie ketamine's pro-hedonic properties as even hedonic experiences elicited by simple rewards such as food depend on cross-modal information integration of primary sensory areas. Moreover, the intensity of hedonic experiences evoked by more complex stimuli such as music additionally relies on various contextual factors and cognitive processes, indicating that peak hedonic experiences might be states of heightened information integration. Leveraging recent advancements in information theory, we employ partial information decomposition to examine whether 1) peak hedonic experiences are states of increased information integration, 2) ketamine increases information integration, 3) this increase is associated with ketamine's pro-hedonic properties, and 4) the strength of the ASC influences the above-stated relationship. Using ketamine, we altered the hedonic experiences in response to music in 38 neurotypical subjects. The placebo-controlled, cross-over design consisted of 2 main sessions (ketamine & placebo). To assess the subacute state in which the beneficial effects start to emerge, participants completed the 5-Dimensional Altered States of Consciousness questionnaire and underwent fMRI scanning (resting-state and a hedonic task) four hours after administration. The hedonic task consisted of self-selected highly moving and neutral music. Participants rated the induced experiences based on 3 dimensions: moving, chills, and valence.

The ordinal Bayesian mixed-effects models for the behavioral data with the within-subject factors of Treatment (ketamine & placebo), Music (positive & neutral), and Session (1 & 2) indicate that ketamine has a small positive effect on the strength of experienced chills [β: 0.34; CI: 0.54-0.13], being moved [β: 0.21; CI: 0.40-0.02], and valence [β: 0.22; CI: 0.41-0.04]. Contrary to prior psychoplastogen studies, we do not find that the strength of the induced altered state of consciousness affects the hedonic experience. The linear mixed-effects model (LME) for the resting state data with the within-subject factors of Treatment (ketamine & placebo) and Session (1 & 2) revealed that ketamine increases information integration [β:

3.89; $p < 0.05$]. Furthermore, the LME of the hedonic task with the additional factor of Experience (high & low), indicates that peak hedonic experiences are associated with increased information integration [β: 32.26; $p < 0.05$]. Interestingly, we did not find a main effect of Treatment during the hedonic task. This may be due to a ceiling effect of complex stimulation such as music. In line with our hypotheses, hedonic experiences are indeed states of increased information integration; and ketamine – if not overshadowed by complex stimulation – increases (baseline) information integration.

Limits of unconscious reasoning: To what extent can subliminal stimuli influence our decisions?

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Poster Session 4, Thursday July 4th, Ito International Research Center, 3:30PM-4:30PM

We often assume that our interactions with the world are primarily driven by conscious experiences. However, according to numerous experimental and medical reports, stimuli that are not consciously perceived can exert an influence on behaviour. One of the open questions in the field of consciousness research is to what extent unconscious perception can affect our actions. A seemingly good strategy to approach this problem is to compare the complexity of tasks in existing experiments involving subliminal stimuli presentation, and determine the point at which the effects of unconscious perception vanish. However, various methodologies are used to investigate unconscious perception (e.g., different methods of rendering stimuli subliminal), which makes it difficult to draw conclusions from such comparisons. The purpose of our study was to address this issue and investigate the limits of unconscious perception. To achieve this, we conducted an experiment in which participants (n=40) made decisions which accuracy depended on the content of subliminal stimuli. The experiment had three conditions in which the same stimulus presentation parameters were used, but which differed in the complexity of the decisions (simple decisions without a context, medium decisions with a context, and complex decisions with a context and logical inference). Essentially, the study compared the impact of unconscious perception across varying levels of decisions complexity while keeping the stimulus presentation parameters and stimuli presentation settings constant. We observed a decrease in the decision accuracy with the increase of complexity of decisions. Simple decisions had the highest accuracy rate (58%), which was significantly above the random response level (50%). The Bayes factor indicated extreme evidence for the difference between the random level and the obtained accuracy. A lower accuracy was observed in the medium condition (54%; yet the Bayes factor suggested substantial evidence for the difference between the obtained accuracy and the random response level). We found no evidence for a difference between random response level and the accuracy in the complex condition, and anecdotal evidence for the opposite hypothesis. In a separate procedure, all the participants performed the objective test of awareness. The average visibility score was 50.08%. The Bayesian factor indicated substantial evidence that the score did not differ from the random response level (50%), suggesting that the participants were not aware of subliminal stimuli. Our results provide evidence that subliminal stimuli may influence decision making, but not when the task requires logical inference. Thus, our research protocol allowed us to manipulate the complexity of decisions and to delineate the limits of unconscious perception influence on behaviour (which is a logical inference). The results may contribute to the discussion about the functional roles of conscious and unconscious processing.

Reorganization of cortical and subcortical motion-selective brain regions in cortical visual impairment

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Poster Session 4, Thursday July 4th, Ito International Research Center, 3:30PM-4:30PM

Damage to the primary visual cortex results in visual field loss. How this damage affects motion-selective pathways and its relation to residual motion processing abilities remains debated. In this study, we investigate the neural correlates underlying residual vision or conscious/nonconscious processing of diverse motion stimuli, including looming and biological motion, following an occipital cortex injury, by collecting whole brain coverage and high-resolution fMRI data from participants with cortical visual impairment (CVI) (n = 8) and a neurotypical control group (n = 25). Automatic lesion mapping enabled to reliably quantify the extent of brain damage, and participants were classified based on residual visual ability determined from a separate motion direction discrimination threshold task. We employed targeted regions of interest analyses for both cortical and subcortical areas, in addition to conducting whole brain analyses, to examine neural responses following intact and impaired visual field presentation. We observed that despite the absence of intact primary visual areas, the brain can still process and represent visual motion-selective information with the participation of both cortical and subcortical structures, which may be linked to residual visual functions. Whole brain analyses revealed that participants with CVI exhibit a broader distribution of activated brain regions extending from occipital to parietal and temporal regions in response to motion stimuli compared to neurotypical controls. In the hemisphere with the lesion, the middle temporal area still responds to motion stimuli, although the response is weaker. Interestingly, this response does not vary whether the stimuli are presented in the intact or impaired visual field. Conversely, in the unaffected hemisphere, the middle temporal area appears to broaden its response to motion stimuli presented in the ipsilateral, impaired visual field. Moreover, upregulated responsiveness in the lateral occipital complex within the intact hemisphere suggests its involvement in facilitating residual visual abilities. High-resolution fMRI targeting subcortical structures revealed an adaptive response in the thalamus and pulvinar, particularly in high performers with CVI, indicating a strengthened response to contralateral impaired visual field looming motion. These results suggest that subcortical structures support residual visual abilities in the impaired visual field of high-performing participants with CVI, with individual differences possibly linked to retained visual function and the severity of visual cortex damage. The nature of the visual motion information processed in the impaired visual field leads to differential activation, with looming motion inducing a more robust sense of visual flow and leading to more prominent modulations in visual processing regions. The findings highlight cortical and subcortical structures, including the middle temporal area, lateral occipital complex, thalamus and pulvinar, in facilitating spared visual motion perception and nonconscious processing of information in the absence of the primary visual cortex.

I think therefore I am unique: Studying qualia as an idiosyncratic phenomenon through numerosity

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Poster Session 4, Thursday July 4th, Ito International Research Center, 3:30PM-4:30PM

‘Is the red you see, the red I see?’ is a question that is deemed impenetrable in the study of consciousness. In color perception there is an unexplainable gap between the electromagnetic radiation and visual experience. This gap does not exist between quantity and its subjective experience, numerosity, that are measured on the same scale. We used numerosity to demonstrate a first mapping of qualia. Participants were exposed to dot arrays and were asked to report their quantity. Quantity the physical properties of each array were recorded, and a transfer-function (TF) between the actual quantity and its representation was fitted individually. TFs were unique predicting the subjective reports of individual observers, based on idiosyncratic weighting of physical properties, better than the prediction by group TF. We show that ‘the twelve you see, is not the twelve I see’, supporting the idiosyncrasy principle, putting forward a new framework for studying consciousness.

Characteristics of interoceptive belief in alexithymia and its relationship with abstraction ability and emotional granularity

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Poster Session 4, Thursday July 4th, Ito International Research Center, 3:30PM-4:30PM

Introduction: Alexithymia is the tendency that have difficulties realizing and describing their own emotions. Alexithymia has been considered that stems from the inaccurate perception of interoception (e.g., Brewer et al., 2015), but solely explaining emotion generation through interoception is challenging. Therefore, it has also been said that language functions effect the degree of alexithymia, linking interoception and actual emotional experiences (e.g., Hobson et al., 2019). However, the specific aspects of language function involved have not been identified, and there has been little research that examine the relationship between interoception. Hence, this study aimed to examine them. Methods: We analyzed data from 23 participants (14 female, mean age = 20.8, SD =1.79). Participants first completed the following questionnaires: MAIA (Mehling et al., 2012), AQ (Baron-Cohen et al., 2001), SDS (Zung, 1965), STAI (Spielberger et al., 1970), and BVAQ (Vorst et al., 2001). Subsequently, they performed the Heart Rate Discrimination task (HRD task; Legrand et al., 2022). And then their language abilities were evaluated by WAIS (VCI) (Wechsler, 2018a; 2018b), some items from the Standardized Comprehension Test of Abstract Words (SCTAW) (numbers 32 to 45; Haruhara et al., 2002) and the emotion concept interview (Wotschack et al., 2013). We analyzed the interoceptive belief, abstraction ability, and participants' emotional granularity by means of natural language processing. Results: A significant negative correlation between alexithymia and interoceptive belief, indicating that higher alexithymia was associated with higher uncertainty of interoception. A significant positive correlation was found between exteroception belief and alexithymia. Moreover, while no significant relationship was observed between alexithymia and semantic knowledge such as vocabulary richness, there was a significant negative correlation between alexithymia and abstraction ability. This suggests that individuals with higher alexithymia find it challenging to conceptualize abstract ideas. Conclusions: These results suggest that alexithymia may be associated with inappropriate interoceptive belief and lower abstraction ability. Future research should focus on elucidating the mechanisms about how interoception and information of external environment are abstracted and conceptualized to generate emotion experiences.

The Relativistic Theory of Consciousness – a new testable solution for the hard problem

Nir Lahav (University of Washington)

Poster Session 4, Thursday July 4th, Ito International Research Center, 3:30PM-4:30PM

Consciousness poses one of the biggest puzzles in science. Despite critical development in our understanding of the functional side of consciousness, we still lack a fundamental theory regarding its phenomenal aspect. There is an explanatory gap between our scientific knowledge of functional consciousness and its essential part - the subjective, phenomenal aspects, referred to as the hard problem of consciousness. To date there is no theory of consciousness that solves the hard problem in a satisfactory manner. Recently, however, a new physical approach, named the Relativistic Theory of Consciousness, offers to dissolve the hard problem using the principle of relativity (the principle that guided Galileo and Einstein developing their theories). A common thread connecting most theories of consciousness is that consciousness is an absolute phenomenon. In contrast, the relativistic theory of consciousness proposes a novel relativistic approach in which consciousness is not an absolute property but a relative one, in which a system can either have phenomenal consciousness with respect to some observer or not. By changing this assumption, the theory shows how the explanatory gap can be bridged in a natural way using different cognitive frames of reference. The theory has a couple of testable predictions. One of its intriguing predictions is that cognitive maps should serve as neural correlates of consciousness. Another one is that consciousness is not private and in principle, with the right technology, we can change one cognitive frame of reference to another and experience what it is like to be someone else.

Ameliorating Anthropocentrism: A Relative Perspective on Consciousness

Renee Ye (Ruhr-Universität Bochum)

Poster Session 4, Thursday July 4th, Ito International Research Center, 3:30PM-4:30PM

Anthropocentrism constitutes the intimate and inherent cognitive framework of human consciousness, shaping our understanding of the world around the human experience. Influenced by distinct biological, psychological, and cultural factors, this framework predisposes our perception, interpretation, and comprehension toward a human point-of-view, guiding how we navigate and understand the world. While often considered harmful, I argue that anthropocentrism can serve as a benign and necessary feature of comparative consciousness research. To achieve this, I distinguish between Pernicious Anthropocentrism and Benign Anthropocentrism; I suggest that researchers exercise extreme caution to avoid falling into the pernicious type and instead aim to maximize the application of benign anthropocentrism. First, there is 'pernicious anthropocentrism': Pernicious Anthropocentrism: When a researcher is being perniciously anthropocentric, she uses human consciousness to identify very specific features of conscious experience (often only realized in humans) in order to define consciousness in general. Pernicious anthropocentrism colours our epistemic access to other forms of consciousness in a distinctly human light and inherently neglects evidence for or against consciousness that is not human-like, especially artificial consciousness. Within pernicious anthropocentrism, there are two subtypes: Explicit Pernicious Anthropocentrism: A researcher is explicitly deploying pernicious anthropocentrism when she deliberately endorses the false presupposition that human consciousness is the gold standard for consciousness or, at least, the most expedient model. Implicit Pernicious Anthropocentrism: A researcher is implicitly deploying pernicious anthropocentrism when she non-consciously prioritises features of human consciousness in consciousness research, for example, those features based on biological and brain-based models. With explicit pernicious anthropocentrism, researchers actively disregard the possibility of other forms of consciousness and fail to acknowledge the limitations and biases inherent in using human consciousness as the sole reference point. With implicit pernicious anthropocentrism, however, researchers simply give preference to features of human consciousness in consciousness research, a preference which is not justified. I propose to distinguish yet another kind of anthropocentrism, 'benign anthropocentrism': Benign Anthropocentrism: A researcher can be said to be benignly anthropocentric when their starting point for investigating consciousness is a rich cognitive and behavioural account of human cognition, which is then used to partially guide investigation into human and non-human conscious experiences. Importantly, human consciousness is not used to define consciousness as such, rather, it gives us an open-ended framework that allows us to understand human and non-human consciousness on their own terms. Benign anthropocentrism is importantly different from pernicious anthropocentrism because it uses human experience as a valuable starting point for studying consciousness, rather than claiming the superiority of models of human consciousness. Through benign anthropocentrism, it is possible to leverage our understanding of human consciousness to develop a framework that allows us to systematically investigate the profiles of human and non-human conscious experiences by providing a basis for comparison, highlighting the similarities and differences between human and non-human consciousness.

Brain-Computer Interfaces and (Free) Action: Disappearing or Extended Agent?

Robyn RepkoWaller (University of Washington)

Poster Session 4, Thursday July 4th, Ito International Research Center, 3:30PM-4:30PM

Nature Electronics has named brain-computer interfaces (BCI) as the technology of year (2023). BCI technology promises to enhance our agency by decoding intentions, even if the agent lacks the capacity for intentional bodily movement. Users have been documented as experiencing a sense of agency (operationalized as intentional binding) over their BCI actions and outcomes, akin to the sense of agency experienced in the embodied case (e.g., Caspar et al. 2021). In contrast, experimental decoding of intentions — such as the Libet-inspired paradigm — has been taken to threaten agency, even if the agent has a full range of intentional bodily movement. Intriguingly, both projects rely on the same neurotechnology and brain activity. Both BCI and neuroscience of agency utilize neuroimaging and measurement such as EEG, intracortical electrodes, and functional magnetic resonance imaging to record and algorithmically decode motor-task-related significance of brain activity in areas like the primary motor cortex, premotor cortex, posterior parietal cortex, and the supplementary motor area. BCI is heralded as enabling the disembodied agent to consciously command her interaction with the world, whereas research on the reading of motor intentions is often said to expose the illusion of conscious agency. Do decoding algorithms and neurotechnology hold promise to expand our agency or, on the contrary, threaten to eliminate it? How do BCI-enabled actions fit with our philosophical accounts of agential control in terms of intentional and free action? I review the case for BCI actions and outcomes as intentional and as attributable to the (free) agent. I focus on active BCI in contrast to passive BCI. That is, I address those instances in which users intentionally bring about effects in their environment (typing, painting, computer-generated speech, prosthetic limb movement) via directed thought — intentionally modulating their neural activity (for instance, motor imagery). To assess agential control over BCI actions and outcomes, I re-visit classic armchair thought experiments in action theory and emerging lab experiments on agency. The standard causalist story of action should, one would think, cohere well with BCI action under the umbrella of intentional action given its compatibility with physical realizers and causal mechanisms. However, the standard causalist response to thought experiments such as Davidson (1973; 2001)'s climber and Mele (2003)'s Norm and the Martians suggests that the fit of causalism with BCI is less than straightforward. Rather, to assess whether BCI actions and outcomes are intentional, free, and attributable to the human agent, I argue that we need to look at the full range of functions of practical intention and at movement/outcome execution in dynamic outcome conditions. The fact that BCI actions are causally initiated from decoded motor representations and that users experience themselves as the source of outcome is a start, but requires a fuller account to be classed as intentional and free action. I thereby outline three characterizations of BCI-action, as basic mental action, as non-basic action, and as basic extended action. Finally, I conclude by arguing that we should understand BCI-enabled action as basic extended action akin to neurotypical bodily action.

Exploring Variability in Therapeutic Outcomes and Subjective Experiences in Psilocybin-Assisted Psychotherapy: Insights from a Pilot Clinical Trial

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Poster Session 4, Thursday July 4th, Ito International Research Center, 3:30PM-4:30PM

Within the interdisciplinary study of altered states, there has been significant investigation into the use of psychedelics as tools for understanding consciousness, as well as clinical uses in addressing mental health disorders. Although a robust understanding of the pharmacological mechanism of psychedelics has been established, there remains a gap in understanding individual responses to these substances. This study addresses this gap through insights from a pilot trial (n=7) examining the safety and efficacy of psilocybin-assisted psychotherapy for treatment-resistant depression, as well as individual responses to the treatment. The trial protocol employed two 25mg doses of psilocybin accompanied by psychotherapeutic support over a 12-week period. A range of clinical outcomes were assessed at multiple points throughout the treatment and at a long-term follow-up conducted at 20 weeks post-dose 2. Additionally, acute subjective effects and expectancy effects were assessed, and qualitative data from interviews were analysed to capture individual experiences and perceptions of the therapy. The findings reveal significant variability in both therapeutic outcomes and subjective experiences among a relatively uniform sample undergoing a standardised treatment protocol. Significant variability was observed in treatment trajectories, which included sustained treatment response, initial response followed by relapse, non-response, and novel treatment trajectories. Further, between participants with similar trajectories, and across participants with different trajectories, subjective experiences of the treatment varied widely. These findings highlight the need for further research to understand the sources of this variability, as well as the use of personalized approaches to maximize therapeutic benefits and minimize risks in psychedelic therapy. Further, such variability in responses underscores the challenges in utilizing these substances as reliable tools for investigation in broader areas of research.

Disruption of consciousness depends on insight in obsessive-compulsive disorder and on positive symptoms in schizophrenia

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Poster Session 4, Thursday July 4th, Ito International Research Center, 3:30PM-4:30PM

Disruption of conscious access contributes to the advent of psychotic symptoms in schizophrenia but could also explain lack of insight in other psychiatric disorders. In this study, we explored how insight and psychotic symptoms related to disruption of consciousness in obsessive-compulsive disorder (OCD) and schizophrenia respectively. Patients with schizophrenia, patients with OCD with good vs. poor insight and matched controls underwent clinical assessments and performed a visual masking task. We used a principal component analysis to reduce symptom dimensionality and found that clinical dimensions could be well summarized by principal components which correlated with the extent of consciousness disruption. More specifically, positive symptoms were associated with impaired conscious access in patients with schizophrenia whereas the level of insight delineated two subtypes of OCD patients, those with poor insight who had consciousness impairments similar to patients with schizophrenia, and those with good insight who resemble healthy controls. Our study provides new insights about consciousness disruption in psychiatric disorders, showing that it relates to positive symptoms in schizophrenia and with insight in OCD. In OCD, it revealed a distinct subgroup sharing neuropathological features with schizophrenia. Our findings refine the mapping between symptoms and cognition, paving the way for a better treatment selection.

Integrated information theory (IIT) and the testability of the silent neuron predictions

Sergio Ponce de Leon (University of California, Merced), Jeff Yoshimi (University of California, Merced)

Poster Session 4, Thursday July 4th, Ito International Research Center, 3:30PM-4:30PM

Integrated information theory (IIT) makes 2 predictions about the role of inactive neurons in consciousness. Both predictions are variants of the idea that a neuron's potential to fire makes a difference for consciousness, even if the neuron has no actual spiking activity (is "silent"). According to the silent brain prediction, rendering all active neurons silent in the physical substrate of consciousness (the "main complex") does not eliminate the presence of consciousness. According to the disabled neuron prediction, rendering a population of silent neurons in the main complex no longer able to fire can impact the qualitative character of experiences not conventionally associated with those neurons. For example, disabling silent neurons in auditory cortex could impact visual experience, and vice versa. Bartlett (2022) argues that both silent neuron predictions are untestable, because any positive evidence (a report of consciousness in the silent brain case, or a change in experience in the disabled neuron case) would imply that the testing conditions were not met (the brain was not silent, or the silent neurons were not disabled). In this paper, we provide a detailed analysis of both silent neuron predictions, showing how they can be tested. For the silent brain case, we clarify how a mechanism outside of the main complex can yield the requisite report of consciousness while maintaining the silent brain state. For the disabled neuron case, we show how such a mechanism "pinging" disabled neurons can yield the requisite report of a change in experience, and we distinguish between two ways of explaining the change. According to the canonical IIT "dispositionalist" explanation, the quality of consciousness can change (and be reported) even when the actual state of the main complex has not changed, analogous to how the trajectory of a planet can change (and be measured) as the result of nearby neutron stars merging into a black hole, even if there is no "actual" change in the planet. According to a more conventional "actualist" explanation, the factor that yields the change in experience is an actual change that results from disabling the silent neurons (other than the activity initially assumed to be relevant for consciousness). We conclude with a discussion of how the distinction between the two explanations further supports the testability of IIT's disabled neuron prediction, and how our analysis can be used in future work.

Tracking probability implicitly: the inconsequential role of explicit knowledge

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Poster Session 4, Thursday July 4th, Ito International Research Center, 3:30PM-4:30PM

The implicit nature of learning the statistical structure in the sensory environment has been repeatedly demonstrated. On the other hand, we seem to be able to explicitly track the co-occurrences of sensory objects and utilize such information for survival. Here we adopted an exogenous cueing paradigm and examined the role of implicit and explicit probability tracking. Both the cue (a disc) and the target (a Gabor patch) were clearly visible, however, how well the cue predicted the target location (cue validity) was initially unbeknown to the observer. A canonical cueing effect was found: target reaction time decreased when the target appeared in the cued location, as compared to when it did not. This cueing effect scaled with the actual validity, but subjective awareness of the validity did not alter the effect. This was shown both with ascending and descending validity changes. We further directly examined the role of explicit knowledge in this cueing effect. While keeping the validity constant (70%), we asked the participants to estimate the validity or gave them an explicit prime of the validity. In both experiments, the cueing effect persisted but was irrelevant to the reported or primed validity, suggesting that the effect was immune to the explicit perception of validity. These results further lend support to the dominant role of implicit gathering of the probabilistic structure of the sensory objects. Research funds: Templeton World Charity Foundation (TWCF: 0495). JSPS KAKENHI 22H00090. JST Moonshot Research and Development JPMJMS2012.

Beyond Pixels: How the Sense of Bodily Ownership Transforms Virtual Harm into Real Harm

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Poster Session 4, Thursday July 4th, Ito International Research Center, 3:30PM-4:30PM

Abstract This paper discusses how virtual harm inflicted on avatars in virtual reality can cause real harm to users. It argues that this is grounded in the user's sense of bodily ownership towards their avatar. When developing this sense of ownership, the user incorporates the avatar into their protective body map, feeling affection and the need to defend it like their real body. Thus, according to the bodyguard hypothesis, users actively avoid virtual harm, perceiving it as similar to real harm. However, the paper argues that within this framework, a distinction should be made between harm from the environment versus harm from other users. The latter retains more features of real harm, based on intuition, legal principles, and affective phenomenology. In particular, harm from others elicits complex social emotions and seems directed at one's personhood. To explain this, the paper proposes that sense of bodily ownership contains an intersubjectivity component, arising from interacting subjects. This shapes the protective body map to also defend against emotional and social harms. In virtual reality, real intersubjective relationships remain between users. The avatar allows users to extend their protective body map and self-image. Thus, harm from other users, reflecting harm intentions, causes real trauma. In conclusion, the intersubjectivity component of the sense of bodily ownership means virtual harm can constitute real harm, despite happening in virtual reality. The paper provides an analysis of how virtual embodiment impacts users' experience and cognition.
Keywords: the sense of bodily ownership, bodyguard hypothesis, virtual reality, virtual harm, avatar, intersubjectivity

Experimental studies of emotional crying

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Poster Session 4, Thursday July 4th, Ito International Research Center, 3:30PM-4:30PM

Emotional crying is a uniquely human behaviour. It has hardly been studied experimentally. Some professional actors can cry at will (or "on cue"), providing a convenient experimental model of crying. We report a multi-method study investigating the control and communicative value of emotional crying. Fourteen actors were video-recorded while trying to make themselves cry. Multi-rater judgements confirmed that most successfully produced tears. Machine vision analyses identified specific facial expressions associated with crying, but found substantial individual differences between actors. We developed a questionnaire investigating how actors consciously control emotional crying. Analysis of 110 actors' responses identified distinct factors corresponding to cognitive, emotional, somatic and cultural aspects of crying. Interestingly, the results do not strongly support James-Lange theory predictions that crying behaviours should precede feelings of sadness. Next, paired 5s segments from these videos were shown to a sample of 36 naïve observers. Participants indicated which video of the pair communicated greater emotional intensity. The perceivers' judgements were analysed to identify the factors that made for more successful emotion communication through crying. The actor's mental focus and their sensitivity to the situational context were associated with successful emotion communication through crying. In contrast, the actor's self-reported cognitive control and metacognition seemed irrelevant to their ability to communicate emotion through crying. We use the results to investigate the possibilities of studying crying as a socio-communicative behaviour.

Closing the eyes may shift intrinsic quasi-periodic activity patterns towards an internally-oriented state

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Poster Session 4, Thursday July 4th, Ito International Research Center, 3:30PM-4:30PM

The brain appears to show infra-slow (<0.1 Hz) waves of activity that pass systematically through it. These quasi-periodic patterns (QPPs) have been consistently seen in humans and non-human animals, during both rest and task states. It has been suggested that QPPs play a role in coordinating interactions between different brain networks, with their potential functional relevance highlighted by their modulation by, for example, consciousness level and psychiatric conditions. A question of interest is how the brain integrates the body and the environment to produce conscious experience. One avenue for studying this is to manipulate the contribution of the environment by studying the difference between eyes-open and eyes-closed states. This change has been previously reported to cause widespread changes in brain activity properties. We therefore sought to investigate how changing between and eyes-open and eyes-closed state influences QPPs. In particular, we sought to identify what changes may occur in the interoception-related insula. To do this, we took resting-state fMRI data from 48 healthy participants who were scanned with their eyes open and closed. The primary QPP was calculated following global-signal regression, with the general properties of this compared between conditions. A specific analysis of QPP properties within the insula was then conducted. Based on this analysis, it was found that closing the eyes altered the flow of QPP activity through most brain networks. This was true of both sensory (e.g., visual and auditory networks) and of higher-order networks (e.g., dorsal attention and language networks). The time between QPPs was shorter in the eyes-open condition, meaning that the patterns occurred somewhat more frequently in that state. In the insula, a clear increase in QPP amplitude was observed during the eyes-closed condition. Interestingly, no difference was seen in the somatosensory cortex, suggesting that the change may be related to an interoceptive shift specifically rather than one towards body perception overall. These preliminary results suggest that the closing of the eyes shifts the brain to a more internally-oriented state. Follow-up work is required to investigate how this may influence the integration awareness of the body with that of the environment and how this may change in different behavioural contexts.

Confidence Prediction Error Predicts Learning and Insight during Problem-Solving

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Poster Session 4, Thursday July 4th, Ito International Research Center, 3:30PM-4:30PM

In cognitive computational neuroscience, a growing interest lies in understanding the relationship between metacognition and reinforcement learning, but the extent to which metacognition facilitates learning in a sparse reward setting needs to be better understood. This study examines this relationship in an abstract reasoning task. During problem-solving, metacognition monitors the likelihood of solving the problem correctly during different stages of the process (Ackerman and Thompson, 2017). We focus on both prospective (i.e., initial solvability judgments) and retrospective (i.e., final confidence) metacognitions. We hypothesized that the confidence prediction error (CPE), the difference between initial solvability and final confidence, would predict problem-solving accuracy. Additionally, we posited a link between CPE and feelings of insight. We designed a novel visual abstract reasoning task where participants learned the rules of the problems through rewarded correct responses. Results confirmed that CPE predicted problem-solving accuracy. Greater accuracy was associated with positive changes from a lower initial solvability to higher final confidence. This effect was stronger in the unrewarded blocks and was replicated even after early reward removal in the following experiment. Interestingly, a smaller magnitude of CPE correlated with stronger feelings of insight, suggesting that insight is associated with minimal changes in the metacognitive ratings before and after solving a problem. Overall, our findings highlight the role of metacognitive signals in guiding learning, even without explicit rewards, while suggesting a link between insight and minimal metacognitive adjustment during problem-solving.
Keywords: confidence prediction error; insight; problem-solving; reinforcement learning
Ackerman, R., & Thompson, V. A. (2017) . Meta-reasoning: Monitoring and control of thinking and reasoning. Trends in Cognitive Sciences, 21 (8), 607–617. https://doi.org/10.1016/j.tics.2017.05.004

Swinging, Fast and Slow: Multiscale Synchronisation Dynamics Reveals the Impact of an Improvisatory Approach to Music Performance on Collective Experience

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Poster Session 4, Thursday July 4th, Ito International Research Center, 3:30PM-4:30PM

Collective activities involving shared experiences are ubiquitous in human culture, and are believed to play crucial roles for strengthening social bonds, sense of group belonging, and social cohesion. Yet due to their phenomenological and collective nature, these experiences are particularly hard to quantify or capture in the lab, making their scientific scrutiny extremely challenging. In our work [1], we investigate the experience of 42 audience members during a naturalistic concert-experiment, by analysing the audience's psychological absorption and subjective reports, as well as the movement synchrony patterns (as quantified by the multiscale wavelet coherence [2]) between musicians and audience members and within the audience, in response to improvisational attitudes to performance. Our results show that music performances with improvisational elements affect synchronisation dynamics between performers and audience members differently at different timescales, which are predictive of changes in the subjective perception of music. Higher synchrony as well as higher temporal variability at larger timescales appears to be strongly linked to an improvisatory, innovative and risk-taking experience, suggesting an adaptive, dynamical relationship between performers and audiences. Amongst audiences, the temporal variability in long-term synchrony, as well as the entropy rate of breathing patterns, appears indicative of an improvisational performance, while higher breathing phase synchrony in the shorter term characterises a more familiar performance without improvisatory elements. These results provide a step towards the quantification of some of the fundamental aspects of collective artistic experiences and improvisational state of mind [3]. Moreover, the reported findings shed new light on the relevance of the often-neglected multiscale coordination between audiences and performers, and explains how this rich tapestry of physical behaviour is connected with the quality of the collective subjective social experience [4]. [1] Nozawa, T., Sas, M. I. et al. (2023) Swinging, Fast and Slow: Multiscale Synchronisation Dynamics Reveals the Impact of an Improvisatory Approach to Performance on Music Experience. DOI: 10.31234/osf.io/cqxya [2] Nozawa, T. et al. (2019) Prior physical synchrony enhances rapport and inter-brain synchronization during subsequent educational communication. Sci. Reports 9, 12747, DOI: 10.1038/s41598-019-49257-z [3] Dolan, D. et al. (2018) The improvisational state of mind: A multidisciplinary study of an improvisatory approach to classical music repertoire performance. Front. Psychol. 9, 21, DOI: 10.3389/fpsyg.2018.01341. [4] Rennung, M. & Goritz, A. S. Prosocial consequences of interpersonal synchrony: A meta-analysis. Zeitschrift fur Psychol. 460 224, 168–189, DOI: 10.1027/2151-2604/a000252 (2016).

Self-face perception modulates the Visual Awareness Negativity amplitude

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Poster Session 4, Thursday July 4th, Ito International Research Center, 3:30PM-4:30PM

Even if we do not consciously perceive a face, we are still able to extract a variety of information from it that can be prioritized in visual awareness. For instance, our own face enjoys privileged cognitive processing, both in conditions of visual awareness (Tong & Nakayama, 1999) and unawareness, as shown in electroencephalography (EEG) studies (Bola et al., 2021; Geng et al., 2012). It is, however, still unknown whether self-face perception (and, more generally, stimulus content; Dembsky, Koch & Pitts, 2021) can modulate the Visual Awareness Negativity (VAN) ERP component. The VAN has been hypothesized to be the earliest electrophysiological correlate of visual awareness, peaking between 100-300ms post-stimulus in the posterior-occipital cortices. The aim of our study was to explore whether self-faces, which are known to enjoy prioritization in visual awareness, might also modulate VAN amplitude or latency in comparison to other-faces. Furthermore, we examined whether a differential lateralized effect can be observed, considering that the right hemisphere is more tuned to self-face processing (Molnar-Szakacs & Uddin, 2023). We recruited 30 participants (15 pairs of close friends, same age and gender) and pre-processed photos of their respective faces to be comparable in low-level features. Participants performed a backward-masking task in which we manipulated face-stimulus identity (self/familiar), location in visual field (left/right), and awareness (masked/unmasked), while recording their EEG signals (64-channels). They were instructed to localize the stimulus, discriminate its identity, and report stimulus visibility through the Perceptual Awareness Scale (PAS), as accurately as possible and guessing if necessary. Presentation timings in the masked condition were assessed by a backward masking staircase procedure before the experiment in order to select the subjective presentation time in which identity discrimination performance was at chance level (i.e. objective unawareness, mostly at 17ms). We used the d' (Signal Detection Theory) to evaluate discrimination and localization task accuracy as a function of the awareness condition (masked/unmasked) and subjective visibility (PAS score). VAN, at bilateral posterior electrodes in the 100-300ms time window, was calculated by subtracting the EEG signals between consciously and unconsciously perceived trials (through both masking/unmasking awareness conditions and subjective visibility responses) as a function of face-stimulus identity. The results showed that, at the behavioural level, unconscious discrimination d' was extremely low (d'=0.5 in masking, d'=0.2 in unaware PAS scores), and no effect of stimulus identity was found on discrimination and localization performance. However, at the electrophysiological level, greater negativity amplitude of the VAN in its peak (≈250ms) was found in the self as compared to the familiar condition, both between masked/unmasked trials ($p < .01$) and between subjective awareness vs. unawareness PAS scores ($p<.05$; Bonferroni- corrected). Moreover, this effect was stronger in the right hemisphere ($p<.05$). No effect was found on VAN latency. These results support our hypothesis that self-face perception modulates the amplitude of the VAN, thereby suggesting that self-related stimuli enjoy enhanced processing at perceptual stages (Tacikowski & Ehrsson, 2016), and providing, in our knowledge, the first evidence for the effect of high-level stimulus content on the electrophysiological onset amplitude of visual consciousness.

Visual Entrainment Reveals Unconscious Rhythmic Information Processing

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Poster Session 4, Thursday July 4th, Ito International Research Center, 3:30PM-4:30PM

Intrinsic biological rhythms are central to the everyday operations of organisms. Previous studies have demonstrated that these rhythms can synchronize to external periodic events. Specifically, the observer's behavioral performance fluctuates with the different phases of the entrained periodic events. However, the unconscious aspect and the depth of information processing involved remained unclear. In our study, we aimed to uncover evidence of such unconscious entrainment by presenting periodic flashing gratings to observers unconsciously and probing their behavioral performance at different time points.

In Experiment One, during each trial, observers were entrained with frequencies selected from delta, alpha and gamma frequency bands. Following a few seconds of exposure to the entrainers, they were then asked to perform a speeded Gabor orientation discrimination task, allowing us to probe their performance at different points in time. Results from Experiment One revealed that accuracy rate increases when the temporal gap between the termination of entrainment and the initiation of Gabor orientation discrimination task was increased. This finding aligns well with the literature on readiness effect, but failed to provide sufficient evidence for the hypothesized unconscious entrainment.

Given that both microsaccade rates and pupil size dynamics have been correlated with different phases of temporal information processing, we conducted a second experiment. In this experiment, we employed binocular eye-tracking as auxiliary measure, and implemented the continuous flash suppression (CFS) technique to mitigate the readiness effect observed in Experiment One. After controlling for the readiness effect in Experiment Two, we did not uncover evidence for unconscious entrainment in the post-entrainment period; instead, it indicated potential during-entrainment unconscious information processing. In summary, our research provides positive evidence for unconscious rhythmic information processing during flicker entrainment utilizing both behavioral and eye-tracking methodologies.These findings suggest that consciousness might not be necessary for human rhythm perception.

Exploring the Links Between Consciousness, Dysphagia, and Spontaneous Swallowing Frequency in Patients with Severe Brain Injury

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Poster Session 5, Friday July 5th, Ito International Research Center, 10:00AM-11:00AM

Background: Following severe brain injuries, some patients may develop prolonged disorders of consciousness (DoC). Severe dysphagia (i.e., swallowing disorder) is almost invariably present in these patients, leading to significant functional consequences and comorbidities, such as a dependence on tracheostomy, pulmonary discomfort, infection, dehydration, and malnutrition. Although there seems to be an interconnected relationship between the level of consciousness, spontaneous swallowing frequency, and dysphagia severity, these relationships have not been previously characterized. We aim to explore the utility and feasibility of spontaneous swallowing frequency measurement in clinical practice in severely brain-injured patients with DoC and emerging from the minimally conscious state (eMCS). Additionally, we aim to characterize the relationship between the spontaneous swallowing frequency and the level of consciousness, as well as explore the stability of spontaneous swallowing frequency at two different time points within a short period of time.

Methods: This protocol was developed for patients with DoC and in eMCS. It is taking place within a maximum period of 5 days, divided into 3 sessions. During the initial session, the level of consciousness is assessed using the Coma Recovery Scale-Revised (CRS-R) as a baseline measure. The two subsequent sessions involve assessing the level of consciousness and evaluating swallowing function at least thirty minutes prior to the measurement of swallowing frequency. The level of consciousness is assessed with the Simplified Evaluation of Consciousness Disorders (SECONDs) that allows for a quick evaluation. Swallowing function is evaluated using two scales: the Swallowing Assessment in Disorders of Consciousness (SWADOC) and the modified Mann Assessment of Swallowing Ability (mMASA).The recordings of swallowing frequency are then conducted for thirty-five minutes on separate days, with one session scheduled in the morning and one in the afternoon. Swallowing frequency is measured using the Swallis DSA™, equipped with a microphone, an accelerometer, and a camera. The collar is specifically designed to detect swallowing sounds and movements.

Expected results: So far, a total of 10 patients with DoC and eMCS have been assessed with our protocol. We found an association between swallowing abilities and consciousness level: patients with higher consciousness levels displayed higher swallowing scores. We expect to observe a positive association between consciousness level and spontaneous swallowing frequency.

Conclusion: This study provides scientific evidence for a positive association between swallowing and consciousness. Spontaneous swallowing frequency may emerge as a novel indicator of the severity of swallowing impairments in patients with DoC that is also associated with the level of consciousness.

Implicit Learning in Socially-Relevant Contexts: Exploring the Influence of Surface Stimulus Characteristics in Virtual Reality

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Poster Session 5, Friday July 5th, Ito International Research Center, 10:00AM-11:00AM

Learning in the absence of awareness, also known as Implicit Learning (IL), is posited as a foundational process in social cognition. However, previous investigations have predominantly prioritized internal validity in their methodologies, potentially neglecting external validity. For instance, while tasks like the Artificial Grammar Learning (AGL) effectively induces IL and assess its role in language acquisition, their applicability to socially relevant contexts remain uncertain. This practice underscores a critical gap in the literature: the lack of experimental paradigms able to induce and assess IL in a socially-relevant context. In turn, this hinders the development of real-world applications grounded in IL research. To address this, we set to develop a task capable of inducing and assessing IL within socially relevant settings while maintaining robust internal validity. Our approach involved the creation of a dynamic systems control task implemented in Virtual Reality (VR). Participants were informed that the task aimed to explore the influence of colors on emotion regulation. Interacting with a holographic avatar capable of expressing varying degrees of joy, anger, and neutrality, participants were instructed to keep the avatar's facial expression as neutral as possible by presenting one of seven differently colored cubes to it. Unbeknownst to them, the relationship between the colors they presented and the avatar's facial expressions was governed by a complex rule. Subsequent to their interaction, participants engaged in a generation task accompanied by subjective measures of awareness to discern implicit from explicit knowledge of the underlying rule. Surprisingly, after we have collected data from 47 participants, we failed to confirm the presence of learning in the task. We conjectured that this might stem from the relatively implausible nature of regulating emotions through arbitrarily assigned colors. Consequently, we sought to enhance ecological validity by transitioning to a more familiar scenario wherein participants would attempt to regulate the avatar's facial expression by displaying their own chosen facial expressions. Crucially, by maintaining all the task's other features, this modification at the level of the response options design, yielded drastically different outcomes. The results (N=140) demonstrated strong evidence for the induction of both implicit and explicit learning. The present study provides some of the first evidence that adaptive responses in social interaction can be supported by unconscious knowledge. Conjointly, the two studies also underscore the important role of surface stimulus characteristics in influencing the quantity and the implicit-explicit character of learning: IL occurred only when the task mimicked closely a natural interaction (i.e., the faces condition) but not in an artificial setting (i.e., the color condition). However, given that these findings are exploratory, we invite further discussions to elucidate plausible mechanisms underlying this observed sensitivity.

Learning multisensory models for space perception

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Poster Session 5, Friday July 5th, Ito International Research Center, 10:00AM-11:00AM

During self-touch, spatial perception arises through the integration of motor and tactile signals from the touching and the touched body part. However, it remains unclear whether these signals are integrated by a single simple fusion process, or if, alternatively, the brain acquires and updates an internal model of space through self-touch. Here, we investigated spatial recalibration during self-touch using a robotic leader-follower setup and a sensorimotor adaptation paradigm. Participants moved the handle of the leader robot with their right hand which caused synchronised strokes on their left forearm from the follower robot. They were asked to report the spatial extent of either touch or movement, in different experiments. Each experiment involved a pre- and a post-adaptation phase where the motor:tactile gain between the two robots was fixed to 1, thus approximating ordinary self-touch. Next, during the adaptation phase, the gain between the two robots was manipulated to provide tactile feedback that was either systematically larger or smaller than the movement that caused it. By comparing participants' extent judgements in the pre- vs. post-adaptation phases, we calculated the after-effect produced by learning a new stable relationship between movement and touch. Across six experiments, we found that movement updated a model for tactile spatial perception, and vice versa. However, model-updating only occurred when the task-irrelevant stimulus was longer than the target stimulus. These results are consistent with the hypothesis that an internal model of sensorimotor space is updated through plastic remapping of motor and tactile signals.

Wow, this object is next to ME, so it is important! Processing of Information Related to the Self in 2-Year-Old Children

Arleta Remiszewska (Jagiellonian University; Applied Memory Research Laboratory), Michal Remiszewski (Jagiellonian University; Consciousness Lab) and Krystian Barzykowski (Jagiellonian University; Applied Memory Research Laboratory)

Poster Session 5, Friday July 5th, Ito International Research Center, 10:00AM-11:00AM

The conventional approach to studying the development of Self in early childhood mainly revolves around the mirror self-recognition test (Gallup, 1970). However, the mirror test primarily addresses the visual and immediate aspects of Self, which may not necessarily encapsulate the entirety of this phenomenon. We contend that Self is a dynamic and multifaceted construct, warranting examination beyond its visual dimension. Furthermore, we posit that the development of Self should be linked to processing of Self-related information. To investigate these issues we designed an experiment with the use of an eye-tracker to monitor the processing of Self-related information in 2-year-old children (19-25 months). Preceding the experiment, participants underwent three procedures assessing the development of various aspects of Self: visual (the mirror test), bodily (the body as an obstacle test; Moore et al., 2007), and temporal (the delayed self-recognition test; Povinelli et al., 1996). Throughout the experiment, children viewed objects presented alongside a photo of their own face and objects presented alongside a photo of an unfamiliar peer. During such stimuli presentation, an association between the face and the picture may be established (Cunningham et al. 2014). Subsequently, the objects were displayed without accompanying faces, allowing us to measure differences in gaze patterns between Self-related and non-Self-related stimuli. Our hypothesis was that 2-year-olds exhibit heightened attention toward Self-related stimuli. To date, we have tested 17 children (with plans to reach 70 children by June). A major finding from our research is that 2-year-olds exhibit a 12% longer fixation time on Self-related (vs peer-related) pictures and a 19% more first saccades toward Self-related pictures, which suggests a tendency to direct greater attention to stimuli related to Self. The eye-tracking method we introduce offers the potential for a supplementary approach to assessing self-awareness in children. The litmus test for self-awareness—the mirror test—involves interaction with one's own body, and its outcomes are contingent upon factors such as motivation and temperament. Our method, on the other hand, has the potential to capture more nuanced cues of self-awareness, particularly in scenarios where conventional behavioral assessments encounter challenges due to various constraints (e.g., in children with physical disabilities or those who are shy and withdrawn). Additionally, our current findings challenge research by Povinelli et al. (1996), in which none of the 2 year-olds passed the delayed self-recognition test (and only 25% of 3-year-olds). In our study, 36% of 2-year-olds passed the test, which is intriguing from a chronosystem perspective. We speculate that immersion in a culture that offers exposure to photographs and videos of self-images already in early childhood may have a significant impact on the development of Self in contemporary children.

Mechanisms of interoceptive-exteroceptive integration during cardio-audio synchrony

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Poster Session 5, Friday July 5th, Ito International Research Center, 10:00AM-11:00AM

Interoceptive-exteroceptive integration has been hypothesized to occur via different mechanisms, i.e., active inference (Banellis & Cruse, 2021), predictive processing (Banellis & Cruse, 2020; Pfeiffer & De Lucia, 2017) or dynamical coupling (Palmer et al., 2022). In this preregistered study (osf.io/6fvuw), we are testing which mechanisms support interoceptive-exteroceptive stimulus integration during cardio-audio synchrony. To do so, we ran two experiments using the same within-subject 2x2x2 factorial block design. We recorded reaction times (behavioral, n=10) and multi-modal physiological responses (physiological, n=38; ECG, EEG, EMG, EDA, respiration, pupil size) to auditory deviants that varied in terms of a) cardio-audio synchrony (synchronous or asynchronous with the heartbeat), b) type of deviation (rare tone or omission) and c) predictability (regular or random). We hypothesized that behavioral and physiological responses would reflect interoceptive-exteroceptive integration if they are sensitive to cardio-audio synchrony. Furthermore, we predicted that dynamic coupling would translate as a dependence of responses to deviants' types but not predictability, predictive processing to predictability but not deviants' types, and active inference to both predictability and deviants' types. The behavioral experiment revealed that reaction times depended on deviants' type (β=0.07, p<0.001) and regularity (β=0.22, p<0.001) with an interaction between both (β=0.05, p<0.001). No effect of synchrony was observed (β=0.00, p=0.83), nor any other types of interaction (p>0.05 for all other tests). Based on our preregistered hypotheses, we interpret behavioral results as evidence for active inference mechanisms that do not rely on interoceptive-exteroceptive integration. On the contrary, the physiological experiment revealed that cardiac responses depended on synchrony (β=0.07, p<0.001), showing that cardiac responses reflect interoceptive-exteroceptive integration. Cardiac activity slowed down after the presentation of deviants in the synchronous condition (z-value=-1.09, corrected p<0.001) but not in the asynchronous condition (z-value=-0.04, corrected p=0.80), replicating previous observations obtained in response to omission (Pelentritou et al., 2024) and extending them to rare tones. We indeed found that cardiac responses did but not depend on deviants' type (β=0.01, p=0.10), regularity (β=0.00, p=0.55), nor any other interactions (p>0.05 for all other tests). Since we did not preregister a hypothetical mechanism for such an effect, we propose here that cardiac deceleration to synchronized deviants might reflect an automatic parasympathetic action (Roelofs 2017), as for example during the freezing response (Livermore et al. 2021), that would occur only when stimuli are associated with internal variables like heartbeats and thus indexed as self-relevant (Sel et al., 2017). By testing how the body, the brain and the environment are integrated into behavior and physiological signals, we provide a better understanding of the mechanisms underlying cardio-audio synchrony in wakefulness. Evidence for a dissociation in interoceptive-exteroceptive integration in the behavioral and physiological responses is particularly informative for studies probing the preservation of self-related processes in states of reduced behavioral responsiveness, such as sleep and disorders of consciousness. Codes are openly available at https://gitlab.uliege.be/Kevin.Nguy/giga-crc-cardio-audio-expe/ and data at osf.io/6fvuw

Do Neuroscientific Theories of Consciousness still Stink?

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Poster Session 5, Friday July 5th, Ito International Research Center, 10:00AM-11:00AM

We may not always notice the world of odors enveloping us, yet olfaction provides a powerful source of conscious experience. Our sense of smell, the anatomical structure of the olfactory system, and its functional organization have profound consequences for the study of consciousness. Over a decade ago it was argued that the then contemporary neuroscientific theories of consciousness were either false or inadequate as general theories because of their visuocentric methods and neglect of olfaction (Young, 2012). The talk explores if this is still the case – are neuroscientific theories of conscious still disproportionally dominated by vision and insensitive to the need to relativize their experimental results to visual consciousness? An outstanding example that not much has changed is that the entire debate couched in terms of the question "is consciousness in the front or back of the brain?" (Koch et al, 2016; Boly et al, 2017; Odegaard et al 2017; Storm et al 2017) only makes sense if vision is assumed to be the default modality that universally generalizes. The mere starting tacit assumption of this exemplar debate will be used to document how scientific theories of consciousness exclude the nuances of olfactory processing regardless of the kind of consciousness under consideration. The focus of this talk is thusly to review the nuances of olfactory consciousness, how neglecting smell has negatively impacted neuroscientific theories of consciousness, and documenting how a large range of theories of consciousness are still either false or inadequate as general theories of consciousness. References: Boly M, Massimini M, Tsuchiya N., Postle, BR., Koch, C., and Tononi, G. (2017) Are the neural correlates of consciousness in the front or in the back of the cerebral cortex?Clinicalandneuroimagingevidence.JNeurosci;37-9603–13.DOI:10.1523/JNEUROSCI.3218-16.2017 Koch C, Massimini M, Boly M, Tononi G. (2016). Neural correlates of consciousness: progress and problems. Nat Rev Neurosci;17(5):307-21. doi: 10.1038/nrn.2016.22. Odegaard, B., Knight RT, Lau H (2017) Should a Few Null Findings Falsify Prefrontal Theories of Conscious Perception? The Journal of Neuroscience, 37(40)/9593–9602. DOI:10.1523/JNEUROSCI.3217-16.2017 Storm, JF., Boly, M., Casali, AG., Massimini, M., olcese, U., Pennartz, CMA., and Wilke, M., (2017) Consciousness Regained- Disentangling Mechanisms, Brain Systems, and Behavioral Responses. The Journal of Neuroscience, 37(45)/10882–10893. DOI:10.1523/JNEUROSCI.1838-17.2017 Young, B.D. (2012). Stinking Consciousness. Journal of Consciousness Studies. 19 (3-4):223-243

Improving Behavioral Assessment for Disorders of Consciousness through Machine Learning

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Poster Session 5, Friday July 5th, Ito International Research Center, 10:00AM-11:00AM

Behavioral assessment is a central clinical challenge in patients with a disorder of consciousness. In everyday clinical practice, non-reflexive behaviors are interpreted as signs of residual consciousness. Standardized scales, such as the Coma Recovery Scale-Revised (CRS-R), are used to assess these behaviors. Although these scales provide relevant information for clinicians, they have several shortcomings that compromise the reliability of diagnosis and prognosis: lack of evaluation objectivity, punctual assessment, and absence of assessment in naturalistic contexts (i.e., emotional and/or social situations of everyday life, such as family visits). In response to these issues, we propose the development of a new tool based on machine learning, specifically computer vision and classification algorithms, to enhance behavioral measures of patients with disorders of consciousness, thereby enabling us to better infer their residual consciousness. We recorded 2 patients in a unresponsive wakefulness syndrome (UWS), as well as 16 conscious participants, using a camera, in different naturalistic situations: listening to music or ambient noise, resting, and receiving visits from relatives or caregivers/experimenters. We analyzed the videos using a two-level machine learning method we have developed. A first level of computer vision allowed us to extract numerous behavioral characteristics (e.g., gaze, body and head movements, facial expressions). A second level of classifiers and artificial neural networks (e.g., XGBoost, LSTM, Transformers...) allowed us (a) to classify situations based on the extracted behavioral characteristics and (b) to highlight the specific characteristics that allowed the models to make their classifications, using AI explainability methods. The results showed that the algorithms efficiently extracted and classified situations with up to 90% accuracy among conscious patients. This classification primarily relied on positive valence facial expressions and eye/wrist movements, which were significantly different between the situations. In the case of the 2 UWS patients, we were also able to extract and highlight subtle behaviors, albeit in fewer instances and specifically during family visits. These behaviors included subtle facial expressions and movements of the eyes and face. These results are highly promising as they demonstrate the functionality of our methodology and its ability to objectively assess behaviors that may not be identified with the CRS-R (i.e., subtle facial expressions and movements) in naturalistic contexts where patients are typically not evaluated, such as during family visits. Building on these findings, we are expanding the patient cohort with disorders of consciousness and including patients at various stages of their recovery. We will also develop another axis facilitated by our methodology, which is multimodality, specifically focusing on studying brain-behavior-environment interactions and their importance along the trajectory of patients' recovery.

The relation between DNA markers and disorders of consciousness in patients with severe acquired brain injury: Preliminary data

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Poster Session 5, Friday July 5th, Ito International Research Center, 10:00AM-11:00AM

Background: Severe acquired brain injury (sABI) may result in substantial cognitive and physical impairments associated with disorders of consciousness (DoC). Prior research suggests that presence of DNA markers, such as brain-derived neurotrophic factor (BDNF), apolipoprotein E4 (ApoE4), and catecholO-methyltransferase (COMT), influence patients' recovery after sABI. However, the full extent of these DNA markers and their implications in the development of prolonged DoC are not understood. Specifically, it is not clear which genomic variations are associated with unfavorable outcome after sABI and resulting in prolonged DoC. Objective: to review the main genetic markers associated with recovery from sABI and to investigate the presence of these markers in a small population of prolonged DoC in order to gather preliminary information on polymorphisms associated with poor outcome following sABI Methods: Until now, fourteen patients (8 males, age: 40±16y) classified as being in MCS or VS based on the Coma Recovery Scale-Revised (CRS-R) have been included in this study. Etiologies included traumatic brain injuries (n = 6), anoxia (n = 7), and stroke (n=1). Time since injury range from one to six years. Salivary samples from 14 patients with were collected using 23andMe kits and raw genotype data were provided after analyses (i.e, DNA extraction and amplification using Polymerase Chain Reaction, and genotyping using Single Nucleotide Polymorphism microarray). Specifically, BDNF (rs6265), ApoE4 (rs7412 and rs429358), and COMT (rs4680) were investigated to determine the presence of specific alleles and their frequency in patients with DOC. Results: For COMT, 71% of patients had alleles associated with poor outcome (14% with alleles GG and 57% with AG). Additionally, for BDNF, 50% of the patients presented alleles associated with poor outcome (7% with alleles TT, 43% with alleles CT). Lastly, only 2 patients (14%) had a C allele at both rs7412 and rs429358, indicating presence of ApoE4. Almost half of the patients (n=6; 43%) had more than one marker (mostly, BDNF and COMT). A trend to significance was found for the CRS-R total scores [t=1.4 (df=12), p=0.09] as well as the motor subscores [U=33 (df=12), p=0.09]; scores being lower in patients with more than one marker. No differences were found regarding age, time since injury, etiology, or gender. Conclusion: These findings are preliminary; however, our current results indicate that COMT and BDNF seems the most frequently detected DNA markers in our patients with prolonged DOC. COMT polymorphism (rs4680; allele G) is associated with lower dopamine levels in the prefrontal cortex while BDNF polymorphism (rs6265; allele T) is associated with motor deficits (i.e., altered short-term plasticity and motor learning). A bigger sample size will be required to confirm these findings and to assess the potential link to the CRS-R, and more exactly, to the motor subscores.

Affect from metacognition and interoception: a computational proof of principle

Chatrin Suksasilp (University of Washington), Karl Friston (University College London), Sarah Garfinkel (University College London)

Poster Session 5, Friday July 5th, Ito International Research Center, 10:00AM-11:00AM

Emotional valence – feeling 'good' or 'bad' – is thought to inform decision-making in a domain-general manner (Lindquist et al., 2016). Interoception – how the brain monitors, integrates and regulates bodily changes – is increasingly recognised as a foundational aspect of emotional valence (Barrett & Bliss-Moreau, 2009) and an understudied facet in many mental health conditions (Khalsa et al., 2018). We present results from computational simulations, which illustrate how interoceptive (dys)function can bias emotional valence, leading to downstream consequences for learning and decision-making. This work extends an Active Inference formulation of emotional valence; namely, affective inference (Hesp et al., 2021), in which agents infer their valence state based on implicit metacognition concerning the suitability of their action model for bringing about desired outcomes. Interoception is incorporated as a state factor that informs affective inference, thereby influencing domain-general implicit metacognition. Numerical studies suggest that interoceptive lesions bias agents towards low confidence in their action models, engendering maladaptive behaviour in a reward learning behavioural paradigm. Overall, this work presents a precisely-specified hypothesis for interoceptive mechanisms underlying emotional and cognitive symptoms in mental health disorders, and provides a computational framework for empirically testing this hypothesis.

Temporal binding for auditory outcomes is attenuated when accompanied by visual components

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Poster Session 5, Friday July 5th, Ito International Research Center, 10:00AM-11:00AM

Temporal binding, also known as intentional binding, refers to the compression of subjective timing between a voluntary action and its outcome. Most studies on this phenomenon investigate the temporal binding of unimodal sensory outcomes, such as auditory, visual, or tactile events. In this study, we investigate the temporal binding for a sound stimulus when it is embedded in an audiovisual context. We employed a modified version of the Libet Clock to depict a physical collision event involving both auditory and visual modalities. The experiment aimed to compare the magnitude of temporal binding for auditory stimuli when presented alone versus in combination with a visual component. It employed a 2 x 3 repeated measures design: Action (Passive/Agency) and Event (Audio Only/Audiovisual Integrated/Audiovisual Irrelevant). The primary task for participants was to determine the onset time of a collision sound. During the Audiovisual conditions, participants were also required to report the trajectory of two colored discs displayed on the screen, ensuring that the visual component was being attended to. In the Audiovisual Integrated condition, the two discs moved towards the center fixation point and rebounded upon contact, accompanied by a collision sound, depicting an integrated audiovisual event. In the Audiovisual Irrelevant condition, two discs launched in pseudo-randomized directions, unrelated to the target sound. Planned contrasts show that the magnitude of temporal binding is significantly weaker in both Audiovisual Integrated and Audiovisual Irrelevant conditions compared to Audio Only, and there is no difference between the Integrated and Irrelevant conditions. This finding suggests that the event timing for the auditory stimuli, which is caused by the voluntary action, is less distorted when accompanied by the visual stimuli, regardless of the integration between the two modalities.

Commonalities and Differences between Synesthesia and Lucid Dreams: In Search of Boundary between Subjective and Doxastic Veridicality

Eiko Matsuda (University of Washington), Eiko Matsuda (Toyo University)

Poster Session 5, Friday July 5th, Ito International Research Center, 10:00AM-11:00AM

In consciousness studies, the veridicality of perceptual content, or the sense of its real existence, is essential. Veridicality can be divided into several stages, with synesthesia and lucid dreams being significant phenomena (Seth, 2014). "Subjective veridicality" refers to the experience of perceptual content as part of the real world. Synesthesia is unique in that while an evoked sensory experience is perceived, it is understood that the evoked sensation does not exist, thus having perceptual reality but lacking subjective veridicality. "Doxastic veridicality" refers to the property where the perceptual content is cognitively understood to reflect the properties of the real world. In lucid dreams, the perceptual content may appear continuous or confusable with the external world. Still, the individual understands at a doxastic (belief) level that the content is not part of the external reality, thus being unique as having subjective veridicality but lacking doxastic veridicality. Synesthesia and lucid dreams share some commonalities: the arousal of sensory experiences without real stimuli and the realization that the perceptual content is not real. Previous research suggests a high prevalence of lucid dreaming among individuals with synesthesia (Khallieva et al., 2022). While 80% of synesthetes have experienced lucid dreams, only 53.1% of non-synesthetes have, and the reason remains unclear. In different research contexts, it is known that personality traits influence both synesthesia and lucid dreams. Synesthesia is significantly associated with "neuroticism" and "openness" of the general personality traits known as the Big Five (Rouw et al., 2016), while lucid dreaming has a strong correlation with openness as well (Hess et al., 2016). Openness refers to a person's appreciation for new experiences, creativity, and openness to different ideas and values. This study explores the boundary between subjective and doxastic veridicality by clarifying the relationship between synesthesia and lucid dreams, focusing on personality traits (Big Five). As a result, synesthetes scored significantly higher on the Lucidity and Consciousness in Dreams scale (LuCiD; Voss et al., 2013) than non-synesthetes, consistent with previous research (Khallieva et al., 2022). A multivariate regression analysis was conducted to predict the total score of the LuCiD scale based on synesthesia ownership and the Big Five personality traits. The results of the AIC showed that the model was mainly influenced by the number of synesthesia types and the interaction between the number of synesthesia types and openness [Adjusted $R^2=0.14$, $F(17, 408) = 5.19$, $p < 0.001$]. This study attempted to link synesthesia and lucid dreaming through personality traits. With a low coefficient of determination, it only partially explained the relationship, indicating that personality traits alone are not the sole connection between them. The results indicating the importance of openness suggest that synesthesia and lucid dreaming are associated with a tendency to embrace new experiences, with the impact increasing alongside the number of synesthesia types. While synesthesia is said to be based on one-shot experiences in early childhood, dreams are related to the physiology of memory, suggesting that the process of memorizing experiences is a crucial perspective in understanding both phenomena.

Ontologically Challenging Experiences: Navigating Psychedelic-Induced Groundlessness

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Poster Session 5, Friday July 5th, Ito International Research Center, 10:00AM-11:00AM

Psychedelics act as a ‘pharmakon’, able to produce contrasting effects in different contexts. It is theorised that psychedelic substances act by amplifying the perception of meaning, which drives their therapeutic benefits against a range of mental health disorders. However, in our work exploring extended difficulties that follow psychedelic experiences, over 50% faced ontological difficulties, relating to their understanding of reality and existence. We interviewed 26 participants that described experiencing such challenges, and analysed their transcripts with Reflexive Thematic Analysis. We explored their acute experiences and difficulties that followed, as well as what they found helpful or unhelpful navigating them. Participants reported significant distress and disturbance to their daily functioning, relating to a loss of their prior ontological and therefore cognitive grounding. Embodiment practices, interpersonal connection, and cognitive framing were identified as crucial elements for recovery. Many saw integration of their psychedelic experiences as a continuous process and some recognised positive outcomes, a result of successfully overcoming their existential challenges. We draw insights from participants’ accounts of navigating experiences of existential groundlessness; the dissolution of their foundational cognitive structures due to challenging psychedelic trips. We discuss these findings in the context of building bridges between altered states of consciousness and normal waking consciousness, through their successful ontological integration.

The Neural Mechanisms and Subjective Experiences of Adults With ADHD and Without

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Poster Session 5, Friday July 5th, Ito International Research Center, 10:00AM-11:00AM

The human capacity to focus for extended periods of time is limited. Often, when attentional lapses occur, the subjective experience has been reported as either mind-wandering (MW; spontaneous, stimulus-independent thought) or mind-blanking (MB; a short-term absence of thought). These attentional failures are more prominent in individuals with conditions affecting their ability to concentrate, such as those with Attention Deficit Hyperactivity Disorder (ADHD). Although ADHD is a prevalent neurodevelopmental condition (Faraone et al., 2021), its underlying mechanisms have yet to be fully understood. ADHD symptoms involve difficulty in sustaining attention, increased impulsive tendencies, and hyperactive behaviour. Moreover, ADHD individuals have reported higher occurrences of MW and MB compared to neurotypicals (Van den Driessche et al., 2017). Interestingly, some ADHD adults also experience higher sleep disturbances and daytime sleepiness (Hvolby, 2015). This is intriguing as, in wake, the region slow waves (SW) occur is predictive of mental state and behaviour: SWs in frontal regions were predictive of MW and commission errors, whilst parietal region SWs were predictive of MB and omission errors (Andrillon et al. 2021). Here we will present 2 EEG studies aiming to identify attentional lapses in ADHD adults (compared to neurotypicals) and their neural underpinnings. We first conducted a visual sustained attention task (the Continuous Temporal Expectancy Task (CTET)): a go/nogo task wherein participants detected rare targets characterised by a longer presentation duration (1120ms) compared to standard stimuli (800ms). We tested adults with ADHD (n=51) and without (n=48) and found a global increase in SWs (delta and theta) in wakefulness in the ADHD cohort despite performing comparably to controls. This indicates that ADHD adults show different (and slower) neural dynamics than non-ADHD adults but these changes are not necessarily reflected in performance, suggesting compensatory mechanisms in ADHD adults. To further investigate this and explore how the subjective experience differs between ADHD and non-ADHD adults, we are conducting another study utilising a modified Sustained Attention to Response Task (SART), a task known to elicit differences in performance in these 2 groups (Bozhilova et al., 2020). During the SART, we sought to determine the participants current mental state by interspersing thought probes within. The task stops at random intervals to ask 4 questions (e.g. “Just before the interruption, where was your attention focused?’’). Participants then press the corresponding button in accordance with their mental state (1 if they were on-task, 2 if they were off-task, 3 if they were MB or 4 if they do not remember). With their mental state information along with their task performance, we will explore whether there is a relationship between mental states, the region SWs are occurring, and task performance (reaction time, commission errors and omission errors). We hypothesise that ADHD adults will have more SW intrusions, more MW and MB episodes, and poorer performance compared to controls. We will present here our preliminary SART findings along the CTET results. Overall, this research could provide new insights about the aetiology of ADHD and the dynamics of subjective experience in and beyond the ADHD population.

Self processing in different states of (un)consciousness

Fabien Perrin (University of Washington), Bruno Michelot (CAP Team - CRNL), Robin Duclermortier (CAP Team - CRNL), Fabrice Ferré (CAP Team - CRNL)

Poster Session 5, Friday July 5th, Ito International Research Center, 10:00AM-11:00AM

The relationship between self and consciousness remains poorly defined. Notably, it remains challenging to determine whether the ability to recognize a basic self-referential stimulus, such as one's own name, is dependent on the level of consciousness and/or the preservation of higher cognitive functions. Can unconscious individuals, whether due to physiological or pathological reasons, discriminate self-referential stimuli? Is this also the case for conscious individuals experiencing a global decline in higher cognitive functions, as seen in delirium (a state of confusion characterized by complete disorientation and hallucinations)? We conducted a meta-analysis of data obtained in several of our studies using the same paradigm in different states of consciousness or unconsciousness. We compared the brain response (event-related potentials) elicited by one's own name (presented within sequences containing other names) in: (a) unconscious states including sleep (n=10), coma (n=38), vegetative state (n=30), and minimally conscious state (n=44); and (b) conscious states including individuals without cognitive impairment (n=20) and those experiencing delirium (n=19). The discriminative brain response to one's own name was obtained in 30% of DOC patients, 60% of sleeping participants, and over 80% of conscious participants (without cognitive disorder). The results also revealed that the brain response to one's own name disappears in conscious patients experiencing delirium (less than 10%). Thus, this meta-analysis suggests that the discrimination of self-relevant stimuli, such as one's own name, is not abolished in unconscious states, whereas the decline of cognitive functions observed in delirium impairs the processing of the self.

Beyond Disagreement: Constructing a Paradigm for Consciousness Science

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Poster Session 5, Friday July 5th, Ito International Research Center, 10:00AM-11:00AM

Consciousness Science (CS) stands at a crucial crossroads, teetering between a pre-paradigmatic stage of exploratory inquiry and the pressures of evolving into "normal science". By adopting a Kuhnian perspective (Kuhn, 1962), this talk delves into the foundational questions concerning the current state of CS. We examine whether CS remains in a nascent, pre-paradigmatic stage or whether, instead, is transitioning towards a paradigmatic one dominated by functionalist and cognitive perspectives. We propose that consciousness science is currently pre-paradigmatic. Because of this, we introduce a plan to help the advancement and the maturation of CS into normal science. The success of this plan amounts to successfully addressing the challenges of incommensurability between competing theoretical frameworks. The current pre-paradigmatic stage in CS is characterized by significant disagreements over theoretical frameworks, research questions, methodologies, and metaphysical foundations, making it extremely difficult to find some common ground upon which different frameworks can be meaningfully compared. However, Kuhn's later specifications on incommensurability emphasize that the "failure of translation" affects only local sets of theoretical sentences. This offers a unique lens through which the potential for collaboration and empirical theory testing in CS can be evaluated: different theoretical frameworks can be compared and tested over the aspects that can be meaningfully translated into the vocabulary of rival frameworks. For this reason, we regard adversarial collaborations in CS to be a necessary and crucial component for the development of CS as a normal science (Melloni, Mudrik, Pitts et al. 2023), but they are not the whole story. Following Kuhn, we argue that, although the path to breakthroughs in CS must be empirically driven, other factors will play a role for the maturation of CS. This talk proposes a multi-faceted approach to navigate the complexities of incommensurability in CS and a 4-step plan to help the field mature into normal science. First, it advocates for the development of metatheoretical research to facilitate theory comparison from a conceptual standpoint. This involves clarifying the structure and central constructs of theoretical frameworks in consciousness science, and determining a metatheoretical measure of comparison. Second, it suggests that empirical testing, especially in adversarial form, should continue and target the common ground identified in the metatheoretical step. Third, the plan proposes the embedding of empirical testing within a confirmation-theoretic framework to score the evidential impact of experimental testing on the whole theoretical structure of the frameworks. Finally, the fourth step addresses the critical role of funding in supporting innovative research without diluting the progress of established programs. Through these strategies, this project aims to chart a course for progress in CS, ensuring it can evolve from its current state into a robust, "normal science".

Finite automata as a tool for modeling psychological phenomena

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Poster Session 5, Friday July 5th, Ito International Research Center, 10:00AM-11:00AM

Using computational frameworks to model cognition has been standard since the cognitive revolution in the 1950s. ACT-R (Anderson, 1976 - today) is an example of such cognitive architecture. More recently, Bloom (2021) modeled consciousness via a Conscious Turing Machine. In our research, we provide the use of a theoretical computer science tool which has the advantage of being simple and accessible for the modeling of psychological phenomena: Finite Automata. Turing machines are a fundamental concept in theoretical computer science used to describe and study formal languages and pattern recognition problems. They are abstract computational models that operate on sequential inputs according to predefined rules. Finite automata are a simpler subclass of Turing machines that can only read the tape but not write on it. They originate from the work of a neurophysiologist (McCulloch) and a logician (Pitts) modeling neural nets (McCulloch & Pitts, 1943). Their ideas were further developed by Kleene (1956) who laid the foundations of Finite Automata Theory. To exemplify the transdisciplinarity of such machines or automata, let us mention that Noam Chosky studied mathematically the parallel between them and classes of languages in linguistics (Chomsky's hierarchy, 1959). Our research leverages finite automata's capacity to represent complex theories in a simple and clear way, translating established psychological and consciousness theories into finite-state models. Some advantages of this methodology are listed below:

1. Educational utility: finite automata diagrams, thanks to their clarity and simplicity, are accessible to students, psychologists and various researchers without extensive background in mathematics or computer science.
2. Transdisciplinarity: these models may also serve as a bridge between researchers in psychology and researchers in theoretical computer science.
3. Mathematical formalization of theories: by formally representing psychological theories, this approach facilitates the identification of ambiguities within theories.
4. Comparative analysis: Different theories of the same psychological phenomenon may be easily compared by comparing the corresponding automata, which fosters understanding and integration between different theoretical perspectives.

As a proof of concept of this approach, we present an enriched finite automata model of Lazarus and Folkman's Transactional Theory of Stress (Lazarus & Folkman, 1984), focusing on key elements such as cognitive appraisal and coping. While an exhaustive model of the entire theory is beyond the scope of this study, we attempted to model some of its essential components, as slightly detailed below. In the transactional model of stress, cognitive appraisal is the process through which an individual deems an interaction with the environment to be stressful, positive, or irrelevant (primary appraisal), and identifies available strategies for coping (secondary appraisal). The finite automaton that we will present is enriched with two kinds of objects: Boolean vectors representing the state of the environment, the individual's beliefs and resources; and Boolean functions that represent the goals of the individual. The automaton is meant to depict as accurately as possible the subtle processes of primary and secondary appraisals and how they interact as described by Lazarus and Folkman.

Lazarus, R. S., and Folkman, S. (1984). Stress, Appraisal, and Coping. New York: Springer.

Investigating Visual Perception through Comparisons of Artificial and Biological Neural Networks during Face Recognition: Insights from MEG and CNNs

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Poster Session 5, Friday July 5th, Ito International Research Center, 10:00AM-11:00AM

Understanding the brain's workings and mechanisms is crucial to advance the study of conscious perception. The neural determinants of visual perception can be explored with a wide range of brain recording techniques, and are often combined with a variety of modeling techniques. In particular, artificial neural networks (ANNs), originally inspired by the structure and functionality of the brain, are increasingly used as a framework to model information processing in the primate brain. The underlying idea is that building ANNs that carry out the same tasks that humans do (e,g, visual categorization), and then comparing the activations across the layers of the ANN on one hand, and the neural activity in regions of the brains on the other hand, can reveal important insights into how information is processed and transformed and could thus shed insights into cognitive tasks such as perception. Indeed, comparing artificial and biological systems in visual categorization has yielded promising insights (Kubilius et al., 2019; Yamins et al., 2014). Face recognition, however, is less explored in this context. Do Convolutional Neural Networks (CNNs) trained for face recognition mimic the neural dynamics of face recognition in brain circuits? Would they behave in ways that might resemble the conscious processing of faces in humans? Here we compare human brain activity collected using Magnetoencephalography (MEG) during a face recognition task to activations across seven CNNs trained on the same task. Compared to previous work (Chang et al., 2021; Jiahui et al., 2023; Kathrina Dobes et al., 2023), we leverage the high temporal resolution of MEG and source reconstruction techniques to compare these models to the brain across time, frequency, and space. For source estimation, we use projected data to source space using "MNE" operator. We ended up with 1000ms of activity per voxel for 8092 voxel. Next for frequency analysis we applied Hilbert transform over the source signal. Out of the tested models, the model "FaceNet" emerged as the most brain-like model during face recognition. Crucially, training on face recognition, rather than on object recognition or both simultaneously, was necessary and sufficient for high model-brain similarity. In terms of temporal alignment, peak similarities were observed around 170 ms which corresponds to the M170-component linked with face perception. Examining the Fusiform Face Area (FFA), we observed that, compared to an untrained model, the similarity to FaceNet trained on face recognition significantly increased,in certain FFA regions. These results were obtained when presenting the Familiar stimuli to the models but not when presenting Unfamiliar or Scrambled stimuli. Generally speaking, this alignment between computational models and neural dynamics underscores the potential for ANNs to serve as effective tools in deciphering the mechanisms of conscious and possibly unconscious perception. Furthermore, our findings underscore the significance of considering the temporal dynamics and spatial distribution of these similarities across layers and brain regions. By dissecting the spatio-temporal congruencies between ANNs and the human brain, we reveal a nuanced understanding of the neural underpinnings of face recognition tasks.

The Second-Person Perspective and Consciousness Studies

Haoying Liu (University of Washington)

Poster Session 5, Friday July 5th, Ito International Research Center, 10:00AM-11:00AM

Studies of consciousness are typically thought to concern the first-personal, subjective phenomena of experiences, and the third-personal, objective physical correlates of consciousness. In this paper, I argue that consciousness and scientific studies of consciousness encompass a second-person perspective. First, I explain the second-person perspective as a distinctive view toward other (potential) conscious subjects. The second-person perspective provides an epistemic access to the mental states of others, which is associated with capacities of social cognition, such as the ability to appreciate others' experiences. But beyond the epistemic access, the second-person perspective also carries a practical dimension, in the sense that by assuming the second-person perspective to another, one treats the other as someone that can be "addressed" in some way, such that meaningful interaction or engagement is possible. Such practical significance in the recognition of other perspectives is observed in phenomenological traditions. Recently it is also reflected in empirical studies of social cognition. Application of the second-person perspective therefore goes beyond mere knowledge of consciousness; it brings in distinctive attitudes toward the entities recognized, and potential ethical commitments. Second, I point out the place of the second-person perspective in consciousness studies. While the scientific studies of consciousness seem to cross over the first- and the third-person perspectives, the second-person perspective is also present, because the phenomenon of consciousness includes both the first- and the second-person views. Empirical studies of consciousness involve the second-person view through the measurement of consciousness. Various scales for measuring consciousness in patients can be understood as identifying different levels of subject engagement. The neuroimaging method developed by Owen and colleagues on vegetative-state patients can be understood likewise, as it explicitly determines whether subjects can be addressed. Even in "no-report" paradigms where consciousness is measured without reports, validating such measures still requires subject engagement. Also, the practical dimension of the second-person perspective explains the significance (sometimes moral anxiety) related to consciousness attribution in e.g., anaesthesia, vegetative states, animal consciousness, and AI consciousness. Finally, I argue that the involvement of the second-person perspective explains some points of difficulty in consciousness studies. The difficulty in measuring consciousness and in validating such measures can be reconsidered as the difficulty of unambiguous application of the second-person perspective in certain cases. To the extent that attributing consciousness to infants, animals, robots, etc. seems questionable, it is because we may find ourselves engaging with these entities, but upon further reflection question whether we really address them.

Dynamicity of Object Perception

Heeyoon Choi (University of Washington)

Poster Session 5, Friday July 5th, Ito International Research Center, 10:00AM-11:00AM

This paper proposes distinctive temporal constraints for the dynamicity of object perception and examines its metaphysical and epistemological significance. Our visual system is dynamic in the sense that it needs to resolve the problem of "the unit of perception": how can our visual system determine necessary and sufficient information for a single perceptual unit, out of the ever-changing flux of information over time? Although the temporal nature of object perception has been partially discussed in reference to the spatio-temporal constraints of visual perception, the primary focus of understanding spatio-temporal constraints has been on the 'spatial' rather than the 'temporal.' However, there are three motivations for distributing equal weight to temporal dimensions of object perception: First, the relative neglect might hinder important understandings of real-world perception, in which we see non-static natural scenes and 3D entities. Second, various philosophical problems depend on the solution for the problem of unit determination across time. Third, there is a growing interest in pinpointing time series data or individuating temporal properties for different psychological phenomena. To establish relevant temporal constraints for object perception, I draw on both philosophical and psychological discussions. First, temporal constraints are parts of assumptions that visual system utilizes, rather than perception of time or duration per se. Second, although temporal constraints may work in a standalone manner, I suggest that there is a tight dependence relation between spatial and temporal constraints that invites fruitful discussions. Third, just like there are diverse levels of spatial constraints, temporal constraints or assumptions encompass varying degrees of temporal aspects, from the level of computation or subliminal processing to explicit expectations about the duration, motion, or event types. Empirical supports are driven from the studies of visual masking, oscillations and temporal structure of vision and attention, expectation of durations, and temporal integration and discrimination. A finer-grained account of spatial and temporal constraint of perception jointly enhances our understanding of object perception and relevant philosophical problems. First, focusing on temporal constraints may add a new angle to the debate of the perceptual attribution of object files or object representations: is object representation an empty medium for a bare causal-tracking or does it contain more information like basic spatiotemporal properties? Second, does perceptual imprecision or a momentary blurred experience of objects imply a metaphysical threat to naïve realism or certain views about "objects of perception"? Third, how should we understand the nature of object selection across time? Elucidating temporal constraints contributes to carving out the boundaries of psychological mechanisms or the content of perception, which in turn renders epistemological significance. First, pinpointing temporal constraints contributes to a better architectural understanding of borders and causal influences between mental processes. (e.g. time difference for low-level versus high-level adaptation, diachronic perceptual learning versus cognitive penetration) An enhanced understanding of temporal constraints contributes to a clearer distinction between object perception and other types of perception such as fact-seeing, event perception, or generally, seeing-that, each of which might function as a distinct epistemic source for perceptual knowledge.

A guide towards outside the body: A novel approach integrating meditation with visuo-vestibular stimulation to altering bodily self-consciousness

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Poster Session 5, Friday July 5th, Ito International Research Center, 10:00AM-11:00AM

This study introduces a novel approach aimed at inducing altered states of consciousness by integrating meditation-like practices with virtual reality (VR) technologies and visuo-vestibular stimulation. Meditation and contemplative practices are known to give rise to altered states of self-consciousness sharing some aspects with out-of-body experiences (OBEs; Millière et al., 2018). Recent work has investigated OBEs experimentally by using VR and multisensory stimulation (Wu et al., 2023). In light of the common objectives of these two approaches, the investigation into their synergistic potential through integration presents a promising avenue for inducing OBE-like phenomenological experiences. In our experiment, participants are engaged in guided sessions involving focused attention practices (on bodily awareness and breathing), conducted in immersive VR, while simultaneously experiencing controlled visuo-vestibular stimulations using a human motion platform. Participants go through three stages: (1) embodiment in a virtual body with synchronous visuo-vestibular stimulations, (2) visual dissociation from the virtual body to locate in a third-person perspective view, and (3) fuller detachment from the virtual body by visuo-vestibular and visuo-proprioceptive asynchrony. By orchestrating these elements, we aim to create a synergistic effect conducive to inducing an OBE-like state. We hypothesize that the integration of meditation guidance with VR and visuo-vestibular stimulation will be reflected in changes in bodily self-consciousness (full body illusion) as well as changes in heartbeat-evoked potentials, linked previously to bodily self-consciousness (Park et al., 2016). Additionally, we predict that participants will report heightened experiences of disembodiment, unity, and transcendence, along with changes in perceived body boundaries and sensitivity to bodily illusion compared to the control condition in which they remain embodied in the avatar. The investigation into the synergistic effects of bottom-up multisensory integration and top-down cognitive modulations (meditative practice) can help to better understand the underlying mechanisms of self-consciousness and its relations to the body, and further shed light on how bodily self-consciousness is linked to other altered experiences such as a dissolved sense of self or even nondual awareness.

Perceptual awareness negativity or late positivity? Correlates of awareness in a multimodal delayed-report paradigm

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Poster Session 5, Friday July 5th, Ito International Research Center, 10:00AM-11:00AM

In recent years, several ERP components have been discussed as neural correlates of consciousness (NCC), including early negativities (e.g., perceptual awareness negativity, PAN) and late positivities (e.g., P3). However, in many past experiments, awareness was confounded with reporting it, possibly overestimating the NCCs. Up until now, the 'report problem' has only been addressed in separate experiments for different sensory modalities. In order to address this gap, we presented the critical stimuli (spoken syllables and written letters) in the same sustained inattentional blindness and deafness delayed-report paradigm. Electrophysiological responses were obtained while participants experienced a physically identical multimodal presentation of critical stimuli that differed only with respect to the participants' instructions. Participants were either informed about an auditory or a visual stimulus and performed either an auditory or a visual demanding foreground task. After completion of the experiment, participants were queried regarding their awareness of the critical stimuli. Furthermore, they completed a short block of trials reacting to the letters. Informed participants reported awareness of the critical stimuli, while uninformed participants experienced inattentional deafness/blindness and reported not to have perceived them. We compared brain responses between aware and unaware participants and found that a PAN but no late positivity accompanied awareness of critical stimuli. Early negativities differed between auditory and visual perception in topography and timing. We did not recover evidence for an additional domain-general correlate of consciousness. Taken together, these results are in line with theories proposing that the NCCs are associated with sensory activity corresponding to the respective modality.

The Dimensionality of Color Perception

Javier Fdez (University of Washington), Oneris Rico (Cross Labs), Olaf Witkowski (Cross Labs)

Poster Session 5, Friday July 5th, Ito International Research Center, 10:00AM-11:00AM

Chromatics, or the science of color, not only studies the description of colors in terms of the physics of electromagnetic radiations, but also their perception through the human eye and cognitive apparatus. Although in purely physical terms colors may be described by as few as three dimensions – such as hue, saturation, and brightness – an open debate remains about how our cognition maps colors and in how many dimensions they encode the distinction between colors according to our perspective. In this work, we study the trade-off between finding an embedding for color perception with the minimal number of dimensions, while maximizing the discrimination between colors. To do so, we designed an experiment where thirteen subjects reported the similarity between twenty colors randomly generated using the Munsell color system. For each subject, we mapped perceived colors in an n-dimensional space, where distances between two colors reflect how different they are according to the subject. We used a least squares optimization to minimize the difference between subject-reported and mapped distances between colors with that dimensionality. We then repeated the process for values from one to nine dimensions. Our results showed an optimal number of dimensions of three when using a cosine similarity measure, which indicates a resemblance to the way the perception of colors is cognitively encoded from mere physical properties of color maps. We discuss the implications and limitations of these results in the light of color theory, and their relevance in both our understanding of the topology of mental concepts and major applications in fields where color theory is important, including composing color scales for designer tools, color psychology in marketing, color matching in interior architecture, and chromatic treatments in post-production of film-making.

Beyond Automaticity: Cognitive Resources Orchestrate Evaluative Conditioning, Revealed by tDCS

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Poster Session 5, Friday July 5th, Ito International Research Center, 10:00AM-11:00AM

Evaluative conditioning (EC), a fundamental learning paradigm, shapes our preferences through repeated pairings of neutral stimuli (conditioned stimuli, CS) with emotionally charged stimuli (unconditioned stimuli, US). Two competing theoretical frameworks illuminate the underlying mechanisms. The associative account posits a purely automatic process where strengthened memory associations between CS and US drive changes in CS evaluation. The propositional account postulates a more cognitively demanding process, where propositions encoding the CS-US relationship are formed and influence subsequent evaluative responses. Notably, this account predicts diminished EC under constrained cognitive resources. The present study employed transcranial direct-current stimulation (tDCS) to probe the role of cognitive resources in EC by modulating activity in the left dorsolateral prefrontal cortex (dlPFC) implicated in reasoning, cognitive control, and memory processes. Sixty healthy adults participated in the study involving cathodal high-definition tDCS administered over the left dlPFC. The study employed a within-subject design with a 2x2 factorial structure (active/sham stimulation and the learning/evaluation stage at which such stimulation was applied). Participants attended two separate meetings as part of the study. At each session, the experiment unfolded in three phases: a) conditioning: participants witnessed repeated pairings of a neutral (CS) with either positive or negative images (US) while receiving their assigned tDCS intervention; b) 45-minute break during which participants filled in the questionnaires, and c) testing in which implicit and explicit evaluations of the CS were assessed via direct rating and affective priming tasks. We hypothesized that inhibitory tDCS would suppress EC effects compared to sham, supporting the propositional account's dependence on cognitive resources in the dlPFC. Specificity of effects: We posited stronger tDCS effects for negative EC (CS paired with angry faces) due to higher cognitive demands imposed by negative stimuli. Our findings revealed a significant moderation of EC by tDCS stimulation. Inhibitory tDCS diminished EC compared to sham, highlighting the critical role of dlPFC in EC. This observation supports the propositional account, suggesting that EC transcends simple memory associations and engages cognitive processes mediated by the dlPFC. Future studies utilizing diverse tDCS protocols, sensitive tasks, and larger samples can shed further light on these nuances. Conclusion: This study leverages tDCS to demonstrate that automatic associations do not solely drive EC but rely on cognitive resources orchestrated by the dlPFC. While the specific nature of this reliance requires further investigation, our findings support a more nuanced understanding of EC, encompassing both associative and propositional processes.

Ketamine perturbs the spatiotemporal organisation of information across the brain

Joseph MarkPeill (University of Washington), Gabriella Sawicka (Imperial College London), Danielle Kurtin (Imperial College London)

Poster Session 5, Friday July 5th, Ito International Research Center, 10:00AM-11:00AM

Sub-anaesthetic doses of ketamine yield rapid and enduring antidepressant effects, which have been suggested to be the result of the neuroplastic effects of this psychoactive compound. Neuroimaging is a powerful tool for unravelling the intricate organization of the human brain, facilitating the exploration of its spatial and temporal information processing. Recent advances in neuroimaging research highlight the brain as a complex dynamical system operating near criticality, a state crucial for optimal cognitive function. Psychedelics are known to perturb the dynamic balance of brain activity, both acutely and over the long term. Long-lasting alterations in brain function following psychedelics are linked to changes in neuroplasticity, underscoring the enduring effects of these compounds.This study aimed to explore the effects of ketamine administration on electroencephalography (EEG)-derived measures of functional neuroplasticity, and functional Magnetic Resonance Imaging (fMRI)-informed measures of functional connectivity and modularity. Healthy subjects (n=11) received a single intravenous ketamine infusion (1 mg/kg). The visual long-term potentiation (vLTP) and the mismatch negativity (MMN) paradigms were performed during EEG recording to measure functional neuroplasticity one day and one week following ketamine exposure. FMRI data was collected at the same timepoints. The 400-region Schaefer atlas was used to extract regional timeseries, and pairwise mutual information functional connectivity (miFC) was computed as in our previous work (Kurtin et al 2023). Modularity quantifies the extent to which a graph (i.e., functional connectivity matrix) matches the optimal topology, and was computed on each subject's miFC matrix for each session using the Brain Connectivity Toolbox (Rubinov and Sporns, 2010). Wilcoxon sign-rank tests evaluated the effect of session on pairwise miFC and modularity. All p-values were FDR corrected for multiple comparisons. EEG-derived changes in functional neuroplasticity are currently being analysed. FMRI analysis showed widespread, significant changes in miFC across all functional networks (1876 edges), with most edges occurring between (69%) vs within (31%) network. There was a greater proportion of edges with lower vs higher miFC from pre- to post-dose (61% and 39%, respectively). Edges with post-dose decreases in miFC were predominantly between higher-order networks, such as the Default Mode Network (DMN) and Control Network. Edges with significantly increased miFC were between regions in lower-order, sensorimotor/visual networks to regions in higher-order networks (e.g., Control Network and DMN). There was a trend towards a significant decrease ($p=0.51$, $z=1.96$) in modularity from pre- to post-dose sessions. In summary, we provide evidence that the administration of ketamine produces changes in the spatiotemporal organisation of information across the brain that extend beyond the acute dosing session. The increased between-network FC and decreased modularity aligns with the effects of "classic" serotonergic psychedelic drugs, such as LSD (Tagliazucchi et al 2016) and psilocybin (Daws et al 2022). Modular disintegration seems to be commensurate with a broader or 'flatter' energy landscape (Lord et al 2019) - an effect related to the therapeutic benefits of psilocybin (Daws et al., 2022). Overall, this study provides evidence for future exploration into the computational underpinnings of ketamine's antidepressant effects.

Decreased integrated information Φ during sleep and anesthesia in Human fMRI

Keiichi Onoda (University of Washington), Satoru Miyauchi (Kansai Medical University), Shigeyuki Kan (Ritsumeikan University), Hiroyuki Akama (Tokyo Institute of Technology)

Poster Session 5, Friday July 5th, Ito International Research Center, 10:00AM-11:00AM

Integrated information theory constructs an axiomatic system from phenomenological properties, allowing the formulation of the quality and quantity of consciousness by means of a measure called Φ. According to this theory, Φ coincides with the level of consciousness and is therefore expected to decrease with loss of consciousness, but empirical data are scarce. In this study, we used two fMRI datasets, one during sleep and other under anesthesia (propofol), to test whether Φ changes with loss and recover of consciousness. The analysis was based on version 4 of integrated information theory. We constructed a system consisting of five functional networks as units, calculated transition probability matrices from these time series data, and obtained Φ from these matrices. As predicted from integrated information theory, Φ decreased with sleep (N2/N3) and anesthesia-induced loss of consciousness. Considering the functional network as a unit of the system, we find that its integrated information is linked to fluctuations in consciousness. This result suggests that the criticality of the amount of integrated information for consciousness is established not only at the micro level, consisting of irreducible units (neuron), but also at the global level, consisting of functional brain networks.

The ConTraSt and UnconTrust databases: open resources for studies of theories of consciousness and unconscious processing

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Poster Session 5, Friday July 5th, Ito International Research Center, 10:00AM-11:00AM

How can we make progress in the study of consciousness, and in better understanding the interplay between conscious and unconscious processes? Decades of prolific research has yielded a multitude of studies and experiments, whose results are not always compatible. In this talk, we will present two novel resources that would hopefully aid both newcomers and experienced researchers navigate this vast corpus of knowledge towards making progress and formulating new insights: the ConTraSt database (Yaron et al., 2022), and the UnconTrust database. The former focuses on studies that interpreted their findings in light of at least one of four theories of consciousness: the Global Neuronal Workspace theory, Higher Order Theories, the Integrated Information Theory, and First Order & Predictive Theories. It has now been updated to allow a more interactive interphase, and to enable users to upload their own papers and enrich the database. The latter has recently been created, following ConTraSt, and focuses on studies probing unconscious processes. Both databases are available on open websites, where users can obtain a birds' eye view of the field, across definitions, methodologies, populations, and findings, as well as to look for possible biases. They can also employ analytic tools to conduct queries, create plots that can then be used in papers and presentations, as well as download lists of relevant studies, according to different filters. We hope that these websites will become major resources for the community of consciousness researchers, helping them to capitalize on previous knowledge in a collaborative manner. In this talk, we will present these websites, explain how they can be used, and how the community can participate in shaping and developing them, to provide a comprehensive and meaningful depiction of the field and its leading trends.

Distinct the roles of edge-based and surface-based information in the representation of basic and superordinate-level scene categorization

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Poster Session 5, Friday July 5th, Ito International Research Center, 10:00AM-11:00AM

People can easily recognize a scene as a forest or a city at the basic level categorization, or as a natural scene or a man-made scene at the superordinate level categorization. What type of neural representations supported the scene categorization at different abstract levels. What are the roles of edge-based and surface-based features in dynamic neural representation for scene categorization at different abstract levels? To address the issues, we adopted multivariate pattern analysis (MVPA) on electroencephalogram (EEG) signals recorded in a one-back task, in which six natural scenes at the basic level were included: beach, city, forest, highway, mountain, and office. The scenes can be also categorized into natural scene or man-made scene at the superordinate-level. Each scene had three variations: color photographs, grayscale images, and line drawings. Time-resolved decoding analysis of results revealed that the decoding peak latency of the supra-ordinate representation for line drawings was significantly earlier than for color photographs and grayscale images, and the peak value of line drawings was significantly larger than that of color photographs and grayscale images. However, there were no such differences in peak latency of the three types of images at the basic level representation, while the peak value of color photographs was significantly larger than that of grayscale images and line drawings. The results suggested that the edge-based features carried by line drawings played a crucial role in the scene representation especially at the superordinate-level, while surface-based features could significantly facilitated only to the basic-level scene categorization. These findings provide new insights into the dynamic processes of neural representations of scenes at different abstract levels.

When the interoceptive and the conceptual clash: the case of oppositional phenomenal self-modelling in Tourette syndrome

Liberty Severs (University of Washington)

Poster Session 5, Friday July 5th, Ito International Research Center, 10:00AM-11:00AM

Tourette syndrome (TS) has been associated with a rich set of symptoms that are said to be uncomfortable, unwilled, and effortful to manage. Furthermore, tics—the canonical characteristic of TS—are multifaceted and their onset and maintenance is complex. A formal account that integrates these features of TS symptomatology within a plausible theoretical framework is currently absent from the field. In this paper, we assess the explanatory power of hierarchical generative modelling in accounting for TS symptomatology from the perspective of active inference. We propose a fourfold analysis of sensory, motor, and cognitive phenomena associated with TS. In section 1, we characterise tics as a form of action aimed at sensory attenuation. In section 2, we introduce the notion of epistemic ticcing and describe such behaviour as the search for evidence that there is an agent (i.e., self) at the heart of the generative hierarchy. In section 3, we characterise both epistemic (sensation-free) and non-epistemic (sensational) tics as habitual behaviour. Finally, in section 4 we propose that ticcing behaviour involves an inevitable conflict between distinguishable aspects of selfhood; namely, between the minimal phenomenal sense of self—which is putatively underwritten by interoceptive inference—and the explicit preferences that constitute the agent's narrative sense of self. In sum, we aim to provide an empirically informed analysis of TS symptomatology under active inference, revealing a deep continuity between covert and overt features of the condition.

Subtle Touch, Significant Impact: The Influence of Unconscious Tactile Stimuli on Heart Rate and Related Cortical Processing

Mai Sakuragi (University of Washington), Yuto Tanaka (Keio University), Kazushi Shinagawa (Keio University), Koki Tsuji (Keio University), Satoshi Umeda (Keio University)

Poster Session 5, Friday July 5th, Ito International Research Center, 10:00AM-11:00AM

Our bodies are regulated by various mechanisms to maintain a constant internal environment. One such mechanism is the autonomic nervous system. In psychophysiological and cognitive neuroscience studies, tasks employing visual or auditory stimuli are mainly employed, and changes in autonomic activity during these tasks and the cortical processing of these changes are often discussed based on cardiac activity measurements, which are relatively easy to measure. In such studies, tasks using visual or auditory stimuli have mainly been employed. Recently, there has been renewed interest in how tactile stimuli presented directly to the body affect the autonomic nervous system and the related cortical processing in humans. However, most of these studies have dealt with relatively strong and specific suprathreshold stimuli such as pain, and it still needs to be clear how subtle tactile stimuli that do not even reach the level of consciousness affect the human heart rate. In this study, we investigated how the presentation of subthreshold tactile stimuli changes the heart rate and heartbeat-evoked potential (HEP), the afferent signal processing of cardiac activity. Subthreshold electrical stimuli were presented during an image-viewing task, and electrocardiogram (ECG) and electroencephalogram (EEG) were measured. To explore the differences in the effects of different stimulus intensities and waveforms of subthreshold electrical stimulation on heart rate and HEP, we prepared two different stimulus intensities (50% and 90% of the threshold) and two different waveforms (sine and square waves). Our results showed that deceleration of the heart rate occurred immediately after the presentation of subthreshold electrical stimuli. The amplitude of HEP was greater in the condition in which the electrical stimuli were presented than in the condition without them. The greater the degree of acceleration immediately after the heart rate deceleration caused by the stimulus presentation, the greater the HEP amplitude. These changes in heart rate and HEP were more pronounced under the sine wave condition, and for both waveform conditions, greater heart rate deceleration was observed in the 50% subthreshold condition. Stimulus frequency, tempo of stimulus presentation, and direction of heart rate change suggest that the heart rate deceleration induced by subthreshold electrical stimuli was due to a potential attentional division-induced orienting response. Greater heart rate deceleration occurred when stimuli of weaker intensity were presented or when sine waves, which are less acute than square waves, were presented. This phenomenon is similar to that observed in the orienting response to suprathreshold stimuli. This is the first study to show that tactile stimuli presented directly to the body, even if too weak to be consciously perceived, can influence autonomic nervous activity and afferent signal processing.

Conscious perception plays a key role in influencing action

Marjan Persuh(Manhattan College), Fatemeh Alhabib(City College, City University of New York) and Robert Melara(City College, City University of New York)

Poster Session 5, Friday July 5th, Ito International Research Center, 10:00AM-11:00AM

A compelling proposition suggests that our visual systems distinguish between information for perception and action, yet consensus remains elusive despite numerous studies using visual illusions where object properties diverge between veridical and perceived. In exploring response priming, evidence hints that only the physical attributes of prime stimuli govern motor responses. Across three experiments, we investigated the interplay of physical and consciously perceived locations in response priming, leveraging the well-known flash-lag illusion—a scenario where a briefly flashed disk and moving bars, perceived at the same location, appear displaced. Participants rapidly responded to the target disk's location presented above or below static bars. In the first experiment, maintaining the physical location of the prime disk constant resulted in both the disk and moving bars appearing at the same spot. Responses to the target disk consistently showed a bias influenced by the prime disk, indicating that the illusory perception of the prime location primed rapid motor responses. In the second experiment, we inverted the physical and perceived location of the prime. After estimating the illusion size for each participant, we presented the prime disk either above or below the moving bars, aligning the perceived location with the moving bars. Motor responses were moderated by the physical location of the disk, revealing that the visuomotor system utilized the veridical prime location. In the third experiment, we juxtaposed physical and perceived locations, situating them on opposite sides of the moving bars. Under this arrangement, motor responses remained unaffected by primes. Our experiments underscore that visuomotor systems integrate both sources of information—veridical and consciously perceived location—to guide behavior..

A new method for controlling for performance confounds in awareness reports using relative psychometric functions

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Poster Session 5, Friday July 5th, Ito International Research Center, 10:00AM-11:00AM

Perceptual task performance is a potential confound in the study of consciousness and metacognition (henceforth "awareness"), since performance typically correlates with, but is dissociable from, measures of awareness. Many studies have sought to control for this confound by contriving experimental conditions that yield matched task performance but different awareness. However, experimentally achieving precise performance matching can be difficult, and differences in awareness may depend on the exact performance level(s) chosen by the experimenter. We remedy these shortcomings by expanding the performance-matching approach to measure the entire psychometric function of awareness vs. task performance, from chance performance to ceiling. We call this the metaperceptual function, analogous to the classical psychophysical function relating perception to stimulus properties. Entire metaperceptual functions can then be used to compare awareness in different experimental conditions across a matched range of task performance.

In this work we develop mathematical methods for characterizing, fitting, and summarizing the metaperceptual function. To circumvent the nonlinear "errors in variables" statistical problem posed by fitting the metaperceptual function directly, we fit separate psychophysical functions for performance and awareness as a function of stimulus strength. The metaperceptual function fit is given by plotting the fits for awareness and performance against each other. We derive an equation for the metaperceptual function in the special case where performance and awareness curves are both fitted with Weibull functions, and examine its complex behavior arising from the relationships of their respective parameters. As no single metaperceptual parameter single-handedly captures simple attributes like slope and location, we instead summarize metaperceptual functions by taking the area under the curve (AUC). AUC can then be compared across conditions to assess how much awareness differs over a matched range of task performance. We showcase our analysis method on data from a spatial 2-interval forced-choice random dot kinematogram task with varying levels of dot motion coherence and density, showing that confidence is higher for higher dot density while controlling for the influence on performance.

Importantly, although inspired by the special case of the metaperceptual function, our approach is sufficiently general to assess the relationship between any two psychometric functions P1 = F(x) and P2 = G(x), where P1 and P2 could include performance, response probability, visibility, confidence, metacognitive sensitivity, reaction time, neural response, etc. Comparing the composite function P2 = H(P1) across conditions reveals how the conditions modulate P2 over a matched range of P1, effectively controlling for P1's influence on P2. We call this more general function the relative psychometric function or RPF. We also show, through simulations, that nonparametric approaches can be used to estimate the RPF AUC in cases where a specific functional form for P1 and/or P2 cannot be specified a priori. Our approach therefore holds wide promise for isolating a variety of behavioral or neural variables of interest by controlling for complex, nonlinear dependencies among them.

Control theory enhances understanding of brain responses to stimulation: Analysis of tES-EEG in sleepy state

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Poster Session 5, Friday July 5th, Ito International Research Center, 10:00AM-11:00AM

Assessing the level of consciousness is crucial for differentiating and appropriately treating patients with disorders of consciousness. To accurately determine the level of consciousness, previous research have attempted to represent brain activity by mathematical theories of multidimensional dynamics and spatial and temporal change of network. For identifying networks with such changes, i.e., functional networks, one of the powerful methods is perturbation. Why is perturbation effective? This is because by applying forced changes on the network, information about specific conditions can be added to the network, thereby correctly estimating network connectivity. This framework is already widely adopted in several research fields. The complexity of brain responses can be measured by the “zap and zip” technique (Massimini & Tononi, 2018), causal inference methods such as “do operation” are employed for directed acyclic graph network (Pearl et al., 2009), and control theory uses impulse responses to estimate the systems (Ogata, 2010). As part of these frameworks, the perturbational complexity index (PCI) has been effectively employed to quantify the level of consciousness, which is calculated by stimulating the cortex using transcranial magnetic stimulation (TMS) to activate interactions within the brain and compressing the spatiotemporal pattern of these electrocortical responses as complexity index. However, the PCI is a one-dimensional measure that captures the degree of propagability or complexity, which may not sufficiently characterize the behavior of the functional network. Here, we introduce control theory to address this limitation. Specifically, we estimate the controllability Gramian to obtain both the direction (eigenvector) and degree (eigenvalue) of controllability. These allow us to evaluate consciousness from multiple perspectives within the framework of control theory. We applied this methodology to the tES-EEG dataset with sleepiness scores to examine the associations between controllability and sleepiness. The controllability Gramian was calculated from the matrices of a linear model consisting of a matrix representing the intrinsic behavior of the system and a matrix representing the effect of the control inputs on the system, which is called a linear time-invariant (LTI) system. We identified the system coefficients from the tES-EEG by utilizing maximum likelihood estimation. We found that controllability was more limited in the sleepy state. The first eigenvector of the sleepy state was contained around the locations of brain stimulus. Furthermore, only the first eigenvalue was extremely large. In contrast, the first eigenvector in attentional state was unrelated to the stimulus locations, and the second eigenvalue was also significant, along with the first eigenvalue. These findings not only accord with intuitive interpretations based on prior research on consciousness but also successfully express differences in consciousness in terms of controllable direction and intensity. We hope that the proposed control theory will in the future be applied to the identification of the optimal location of brain stimulation and determination of the detailed location of brain areas related to consciousness.

Unravelling consciousness fluctuations in patients with disorders of consciousness

Min Wu (University of Washington)

Poster Session 5, Friday July 5th, Ito International Research Center, 10:00AM-11:00AM

Patients with disorders of consciousness (DOC) frequently experience fluctuations in consciousness levels. The current assessment tool, the behavioral scale, is limited in its capacity to detect rapid and transient changes occurring over seconds to hours. To address this gap, electroencephalographic (EEG) data were recorded at multiple time points from DOC patients in a resting state and during a passive auditory task, with the aim of elucidating the neural dynamics associated with fluctuations in consciousness. The data analysis involves the application of hidden Markov modeling to the resting-state EEG to identify dynamic hidden neural networks, alongside frequency tagging methods to evaluate neural responses to auditory stimuli. Results indicate that while behavioral assessments show no significant variations at different time points (i.e., 8-10:30 am, 12-2:30 pm, 4-6:30 pm), EEG data can capture more subtle changes in consciousness levels. These observations point to the potential of EEG patterns to predict fluctuations in consciousness with greater precision than behavioral scales.

Exploring the neural representation of hypnagogic imagery using magnetoencephalography: A preliminary study

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Poster Session 5, Friday July 5th, Ito International Research Center, 10:00AM-11:00AM

Dreaming during sleep offers a unique opportunity to delve into the neural correlates of consciousness with minimal external stimuli. Because dreams are believed to be less influenced by processes such as prediction error minimization or specific cognitive tasks, they provide a window into the autonomous neural representation of phenomenal consciousness. This study aimed to evaluate the feasibility of characterizing the neural representations of phenomenal consciousness during hypnagogic imagery using magnetoencephalography (MEG). Brain activity was recorded by a 306-channel MEG scanner while a young, healthy participant was napping. Upon detection of solitary vertex sharp waves in the parietal region via simultaneously monitored electroencephalography, the participant was promptly awakened and underwent a semi-structured interview regarding their conscious experiences during sleep. Any recalled imagery, along with its modalities and details—such as the appearance of people, objects, landscapes, colors, motion, words, narratives, strangeness, and emotions—was recorded. This process was repeated to obtain data in multiple hypnagogic transients. Three-dimensional source reconstruction was performed using SPM12, and the multiple sparse priors method with 10-second MEG data was collected immediately before each awakening. The same analysis was conducted for periods immediately after falling asleep as baseline. Dissimilarities in content between imageries were calculated based on reported conscious experiences, as were dissimilarities in neural representation based on activity patterns of strong sources. Results revealed prominent activity in the superior parietal lobule during pre-awakening periods with visual imagery compared to the periods without recalled imagery and the baseline periods. A small correlation was observed between dissimilarity matrices of imagery content and neural representation. While further detailed analyses for multiple participants, including optimization of time epochs for source estimation and exploration of neural activity dynamics, are needed, this preliminary study suggests that specific autonomous neural activity patterns can connect to various conscious experiences during hypnagogic imagery in the absence of external stimuli.

The effects of sensory adaptation on confidence judgments in a visual detection task

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Poster Session 5, Friday July 5th, Ito International Research Center, 10:00AM-11:00AM

Our sensory system changes its response characteristics in response to recent stimulus history, a phenomenon known as sensory adaptation. In particular, in visual adaptation, prolonged exposure to a specific visual environment not only gives rise to illusory percepts called aftereffects, but also alters certain processing characteristics, e.g., changing detection or discrimination thresholds. Many psychophysical studies have documented the effects of adaptation at the perceptual level, but few have systematically investigated how visual adaptation may influence our metacognition. In the present study, we adopted a classic orientation-adaptation paradigm (Regan & Beverley, 1985) and measured the effects of adaptation on both detection threshold and confidence judgments. Each participant completed a grating-adaptation session and a noise-adaptation session (order randomly assigned), with 8 blocks of trials in each session. Each trial consisted of the adaptation, test, and response phases. Duration adaptation (an initial adaptation of 60s with subsequent top-ups of 1s), participants viewed the adapting stimulus for a prolonged duration. The adapting stimulus was either a Gabor pattern with a subject-specific orientation randomly assigned before the experiment (grating-adaptation session) or a noise pattern with every pixel having a uniformly-sampled luminance level (noise-adaptation session). Then, after a 250ms inter-stimulus interval, a test stimulus was presented for 250ms. The test stimulus either contained gratings (as a Gabor pattern) with noisy pixels superimposed on it or contained noisy pixels only (without gratings). For test stimuli that contained gratings, the orientation was either the same or orthogonal to the adapting stimulus. This resulted in a 2x2 design, with the adaptation factor (gratings or noise) and test factor (adapted or orthogonal). During the response phase, participants completed a yes-no, grating-detection task and a 4-point confidence-rating task simultaneously by pressing one of the eight keys on the keyboard. Detection performance was held constant by varying the contrast of the gratings via an adaptive-staircase procedure so that the probability of correctly detecting the gratings was made to a converge of 67.5%. We replicated the classic orientation-selective perceptual effect, in which the detection threshold increased only when the test and adapting stimuli had the same orientation. Interestingly, there was a weak trend that confidence ratings were higher when the adapting and test orientations were the same than in other conditions (i.e., when they were different or when participants adapted to a noise pattern). Furthermore, confidence was found to depend on both the presence of gratings in the test and participants' grating-detection (yes or no) responses. Our findings suggest that sensory adaptation does not only alter perceptual processes, but could also lead to biases in metacognitive judgments.

AFFECTIVE QUALITY OF PSYCHEDELIC EXPERIENCES IS ASSOCIATED WITH PERCEIVED CHANGES IN PEACE OF MIND

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Poster Session 5, Friday July 5th, Ito International Research Center, 10:00AM-11:00AM

In recent years, interest in the potential of psychedelics (e.g., psilocybin, LSD, ayahuasca) for treating various mental health conditions has gained momentum. However, the specific aspects of the psychedelic experience contributing to its therapeutic effect remain unclear.

It is proposed that the affective content of the experience, specifically awe, may underlie observed benefits. Yet, the relationship between the affective quality of these experiences and improvements in well-being is not well understood. Additionally, while the impact of psychedelics on different facets of well-being has been extensively studied, their effect on peace of mind has not been explored.

In this study, we investigated how the affective content of psychedelic and meditation experiences is associated with perceived changes in well-being, especially peace of mind.

Participants (psychedelic group: $N = 147$; meditation group: $N = 66$) retrospectively described their most meaningful psychedelic or meditation experience and rated their positive mood during that experience using the positive mood subscale of the Mystical Experience Questionnaire (MEQ30). They also rated perceived changes in peace of mind. The affective content of their descriptions was analyzed using the Linguistic Inquiry and Word Count (LIWC-22) and by counting the frequency of all awe-related words.

We found no significant relationships between the affective content of the descriptions of experiences and perceived changes in peace of mind ($ps > .05$). However, positive mood during the psychedelic and meditation experience predicted increased levels of peace of mind ($\beta = .38$, $p <.001$ and $\beta = .51$, $p <.01$, respectively). The strongest predictor of peace of mind was the feeling of peace and tranquility during the experience ($\beta = .40$, $p <.001$).

The findings suggest that while positive affect during the psychedelic experience may play a role in enhanced well-being, this may also extend to other meaningful experiences.

What crosses your mind when you fall asleep? Data-driven clustering of conscious experiences during the sleep onset period.

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Poster Session 5, Friday July 5th, Ito International Research Center, 10:00AM-11:00AM

The sleeping brain is an insightful model to depict the mechanisms underlying consciousness, given the marked variations in brain activity concurrent with fluctuations in conscious experiences. As one falls asleep, notable physiological changes are observed, including slow eye movements, decreased muscle tone and decelerated heart rate. The EEG (electroencephalogram) activity also transitions from alpha waves to slower theta and delta oscillations. Concurrently, a rich repertoire of conscious experiences arise, ranging from fleeting thoughts to vivid, immersive dream-like experiences. However, the conceptual and neurophysiological definitions of these experiences are unclear, impeding a clear understanding of the mental states that humans navigate through as they transition to sleep.

Here, we aimed to characterize conscious experiences during the sleep onset period at both phenomenological and neurophysiological levels. To this end, we conducted polysomnographic recordings on 77 healthy participants, equipped with a 64-channel EEG, an electrooculography (EOG), an electromyograph (EMG) and an electrocardiogram (ECG). Participants rested in a dark and quiet room during two 20-minute periods. During these periods, they were regularly interrupted and asked to report the mental content preceding the alarm and to rate them across several dimensions including perception, bizarreness, fluidity, spontaneity, subjective level of wakefulness, and elapsed time.

We sought to identify mental states during the sleep onset period in an agnostic manner, based on their phenomenological properties. As a first step, we reduced the dimensionality of the data using Principal Component Analysis (PCA). The dimensions were found to be independent (absolute Pearson coefficient $|r| < 0.2$), thus effectively capturing the variety of phenomenological qualities of mental contents. We used the Elbow method to determine the optimal number of clusters that best represented the data and found that it best aligned with 3 distinct clusters. We therefore grouped the mental contents (Ntrial=310) in 3 clusters based on their dimension scores using k-means clustering. The 3 retrieved groups presented distinct phenomenological properties. Cluster 1 seemed to match the phenomenological properties of mind wandering (low perception and bizarreness, high spontaneity). Cluster 2 evoked a dream-like state (highly perceptual, fluid and spontaneous, drowsy). Cluster 3 possibly represented a state of voluntary imagery (highly perceptual and fluid, low spontaneity and bizarreness, more alert). To identify EEG signatures associated with each cluster, we extracted the 10-second EEG segment preceding each interruption and computed spectral power measures. Preliminary results suggest significant differences in absolute power in the delta (0.5-4Hz; $p=0.003$) and theta (4-8Hz; $p=0.001$) bands between the clusters. These preliminary results suggest that distinct mental states of the sleep onset period can be defined by their phenomenological and neurophysiological properties. This approach lays the groundwork for a data-driven exploration of conscious experiences and can provide further insights into the neurophysiological mechanisms underlying their production.

Exploring ECG Variability and Complexity in Disorders of Consciousness: Insights from a Clinical Trial Investigating Ketamine

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Poster Session 5, Friday July 5th, Ito International Research Center, 10:00AM-11:00AM

Disorders of consciousness (DoC) are neurological conditions that can affect patients with severe brain injuries following a stroke, haemorrhage, or trauma. With very few treatment options available, several investigations have sought to find new therapeutic avenues and efficacy biomarkers. Among other drugs, psychedelics have been proposed for ameliorating consciousness in these subjects by enhancing brain complexity. One method for measuring brain complexity is using Lempel-Ziv complexity (LZC) on EEG. Interestingly, ECG metrics have been recently proposed to complement EEG ones in describing psychedelic effects, providing a more accessible tool. Here, we present, for the first time, metrics of ECG heart rate variability (HRV) and HRV complexity in DoC patients undergoing continuous infusion of ketamine at increasing subanaesthetic concentrations, along with EEG results. Ketamine, commonly used as an anaesthetic agent, exhibits psychedelic effects when administered at low concentrations. We performed a double-blind, placebo-controlled, cross-over study on 3 male patients with DoC (UWS, 32yo, TBI; MCS-, 50yo, subarachnoid haemorrhage; MCS+, 62yo, CO intoxication). We administered increasing concentration of intravenous ketamine or placebo (maximal concentration 0.75 µg mL-1; steps of 0.15 µg mL-1 every 10-minutes) for a maximum of 90-minutes with a target-controlled infusion. Each patient underwent 2 sessions (one for ketamine, one for placebo) within a week. We recorded high-density EEG (BrainVision, 128Ch) along with ECG (dipole). We recorded EEG-ECG during the whole administration. For each concentration, we measured broadband LZC on the EEG and the Root mean square of the successive differences (RMSSD) for HRV, HRV approximate entropy (ApEn), and HRV sample entropy (SampEn) on the ECG. We corrected RMSSD and ApEn by the mean heart rate, as they significantly correlate with it. We measured the effects via repeated-measured ANOVA, considering both conditions (placebo; ketamine), concentrations (0.15, 0.30, 0.45, 0.60, 0.75) and their interaction. When looking at the whole-brain LZC, we could not see any effect of the condition ($F_{1,2}$=5.31, P=0.15), concentration ($F_{4,8}$=1.87, P=0.21), or the interaction ($F_{4,8}$=1.28, P=0.36). Similarly, we report no significant change for RMSSD (condition: $F_{1,2}$=6.0, P=0.14; concentration: $F_{4,8}$=1.7, P=0.24, interaction: $F_{4,8}$=0.59, P=0.68) or ApEn (condition: $F_{1,2}$=0.6, P=0.50; concentration: $F_{4,8}$=2.23, P=0.16, interaction: $F_{4,8}$=1.33, P=0.39). When we considered SampEn, we observed higher values during ketamine ($F_{1,2}$=33.16, P=0.03, not significant if corrected for multiple comparisons), while we could not find any effect of concentration ($F_{4,8}$=2.07, P=0.18), or interaction ($F_{4,8}$=1.92, P=0.20). Interestingly, we observed a significant positive correlation between LZC and SampEn (ρ=0.45, P=0.01), but not between LZC and ApEn (ρ=-0.12, P=0.50). In this pilot study, we showed that ECG is a valuable tool to investigate pharmacological interventions in this sensible population. Our work expands the current applicability of ECG in clinical neuroscience, showing that ECG SampEn correlates with the EEG LZC, possibly demonstrating a link between these metrics, at least in small cohorts. The nature (and specificity) of this correlation should be investigated thoroughly in future studies. We plan to extend these results to a larger population and to provide a more refined investigation of ECG biomarkers.

Encoding others' attention as implied motion: a possible mechanism for implicitly tracking other people's mental states

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Poster Session 5, Friday July 5th, Ito International Research Center, 10:00AM-11:00AM

Humans automatically reconstruct the mental states of other social agents without explicit awareness, even when it is irrelevant to their own behavioral goals (Kovacs et al., 2010, Science). This ability to implicitly track others' belief and intentions ('implicit mentalizing') must depend on an efficient system for encoding others' attention and tracking it over time. However, the mechanisms by which the brain automatically encodes others' attention during the process of implicit mentalizing remains unknown. Here, we hypothesized that implicit mentalizing relies on a dynamic internal model of other's attention encoded as an implied motion (Guterstam & Graziano, 2020a, Prog Neurobiol; Guterstam et al., 2020b, PNAS). We recently showed that viewing static images of agents attending to objects elicits behavioral motion aftereffects (Guterstam & Graziano, 2020), suggesting that people implicitly encode others' attention as an implied motion streaming from an agent toward an attended external object. Here, we tested whether this mechanism is involved in implicit mentalizing: We adapted the implicit mentalizing paradigm (Kovács et al., 2010) by integrating our paradigm evaluating motion aftereffects using a random dot motion task (Guterstam & Graziano, 2020). In the experiment, participants were presented with short video sequences featuring an agent watching a ball fall and get stuck behind an occluder, hiding everything that falls behind it. In half of the trials, after the agent left the scene, the ball appeared briefly from behind the occluder and then disappeared from the scene. After the agent returned to the scene facing the occluder, they held the false belief that the ball was still present behind the occluder ("Belief condition"). Conversely, in the "No Belief condition", the agent observed the ball fall and disappear from view before they left the scene, thereby having no expectation that there would be a ball behind the occluder when they returned. After this belief formation phase, the participants either performed an object detection task where participant detected the presence of a ball after the occluder suddenly opened (exp 1), or a random dot motion task evaluating motion aftereffects (exp 2). Results from experiment 1 showed that participants were faster at detecting the presence of a ball in the Belief than No Belief condition ($t = 2.51$, $p = 0.018$), suggesting that participants implicitly tracked the agent's beliefs even though it was task-irrelevant. Results from experiment 2 showed a stronger motion aftereffect in the Belief vs No Belief condition ($t = -2.07$, $p = 0.047$). Importantly, increased implicit mentalising (i.e., faster reaction times in Belief vs. No Belief) was significantly linked with a stronger motion aftereffect as measured by the dot motion task ($r = -0.42$, $p = 0.02$). This suggests that participants encode the mental state of others as an implied motion travelling from an agent toward an attended object (even when the object's presence is a false belief). These results demonstrate a link between the visual motion system and implicit mentalizing, thereby enhancing our understanding of the mechanisms underlying humans' ability to automatically and effortlessly reconstruct the minds of others.

How Multisensory Information Facilitates Category Learning: Evidence from ERPs

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Poster Session 5, Friday July 5th, Ito International Research Center, 10:00AM-11:00AM

Although it has been found that multisensory information can facilitate category learning, it remains unclear how information from different senses facilitates processing in category learning. To address the issue, we adopted the EEG method in an audiovisual prototype category learning task, in which the stimuli were presented in visual, auditory, or audiovisual modalities during the training phase. In testing, participants were asked to respond to either visual or auditory stimuli, which presented alone or accompanied with a congruent or incongruent stimulus in the other modality. Behavioral results showed that accuracy was significantly higher for audiovisual trials than for visual-only or auditory-only trials during the training phase, also called the multisensory facilitation effect. In addition, audiovisual congruent trials showed higher accuracy than incongruent trials during the testing phase, i.e., the congruency effect. The ERP results revealed that the multisensory facilitation effect was related to the P2, N2, N4, and LPN effects, while the congruency effect was related to the N4 effect over frontal and posterior electrodes. These findings suggest that multisensory information can facilitate category learning, possibly via a multi-stage system in which features from multi-senses are integrated and then multisensory integration facilitates semantic categorization judgement.

The influence of visual perspective and tactile feedback on posture learning by superimposing learner and instructor avatars in virtual reality

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Poster Session 5, Friday July 5th, Ito International Research Center, 10:00AM-11:00AM

Virtual reality (VR) has been utilized for study of motor learning. Virtual body (avatar) is presented in a first-person or a third-person perspective in the VR motor learning studies. Moreover, some studies examined the effect of superimposing learner and instructor avatars in a first-person perspective (e.g., Hoang et al., 2016) or in a third-person perspective (e.g., Hülsmann et al., 2019; Le Naour et al., 2019) as augmented visual feedback for motor leaning in VR.
However, the effects of visual perspective (first-person perspective vs. third-person perspective) in superimposing learner and instructor avatars for motor learning have not been fully investigated. Another issue is that tactile feedback has also been presented as augmented feedback (Sigrist et al., 2013), but it is not clear whether tactile feedback is still effective when using avatar in a the third-person perspective. In addition, embodiment (i.e., ownership and agency) for the virtual body part is a factor that influences movement (e.g., Burin et al., 2019). Therefore, it may be a confounding factor that influences motor learning.
Therefore, we examined the effects of visual perspective (first-person perspective/third-person perspective) in superimposing learner and instructor avatars and visuo-tactile feedback (visual feedback/ visuo-tactile feedback (tactile feedback for correct + visual)/visuo-tactile feedback (tactile feedback for incorrect +visual)) on subjective (ease of learning) and behavioral measure for head and waist during learning (number of matches/cumulative match time) and after learning (post-learning error) in posture learning. Ownership and agency for learner avatar were also measured by avatar embodiment questionnaire (Peck & Gonzalez-Franco, 2021). We developed an experimental environment by Xperigrapher (Ohyama, 2021), a VR experimental platform.
Results showed the effect of perspective and visuo-tactile feedback. Third-person perspective was higher ease of learning and longer cumulative match time for head and waist compared to first-person perspective. Post-learning error for head learning were less in the third-person perspective than in first-person perspective.
Visuo-tactile feedback (tactile feedback for correct + visual) and visuo-tactile feedback (tactile feedback for incorrect +visual) were higher ease of learning and longer cumulative match time for head than visual feedback. Interaction of perspective and visuo-tactile feedback were not found.
In addition, there was a negative correlation between agency and post-learning error for waist, with the more agency for learner avatar the lower post-learning error for waist.
These results showed that avatar presented in a third-person perspective may be superior to in a first-person perspective in motor learning. It might be from the wider viewing angle for viewing one's own full-body movements. Also, even avatar presented in a third-person perspective could be flexibly utilized.

Does the filling-in phenomenon in momentary natural scene images occur in children?

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Poster Session 5, Friday July 5th, Ito International Research Center, 10:00AM-11:00AM

Recent studies of rapid natural scene perception have shown that human adults can discriminate between what they see and not in the rapidly presented natural scene photograph, which they have not seen before, with graded levels of confidence. This study examined this issue with children aged 5–12 years. How does natural scene perception develop from children to adults? What about the development of metacognitive accuracy in the perceptual discrimination in this task? Furthermore, we examined whether children “fill in” a part of the image (e.g., a fire extinguisher blown by a guy) based on the contextual gist information of the image (e.g., a saxophone blown by a guy). In this registered report study, the experiment involved 246 5-12-year-old children and adults in the online natural scene discrimination task. In each trial, participants first viewed a target natural scene image for 133 ms with strong backward masking (300 ms). The target image was either semantically congruent (e.g., a man scratching a disc) or incongruent with a critical object modified (e.g., a man scratching a pizza). Afterward, participants answered six questions, each asking them to briefly view a small image patch (133 ms, masked for 300 ms) and judge whether the patch was part of the target image (with high or low confidence). The image patches consisted of present patches (made from the target image), modified patches (made from the modified critical object of the target image), and absent patches (made from different images). There were six patches presented per trial. We tested over 180 images over 30 trials. We found age differences in discriminative performance but not in metacognitive performance. Furthermore, We identified three image clusters using hierarchical clustering and multidimensional scaling. The three clusters included images where the filling-in phenomenon occurred only in adults, 7-9-year-olds, and 7-12-year-olds. The findings suggest that children also have filling-in phenomena, but the filling-in phenomena differed by image and age. Furthermore, the findings indicate that 5-6-year-olds are less likely to experience the filling-in phenomenon.

Involvement of primary visual cortex for comparing visual stimuli at left and right monocular visual fields

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Poster Session 5, Friday July 5th, Ito International Research Center, 10:00AM-11:00AM

Our brain represents multiple visual features such as shape, color, and texture in different brain regions in both hemispheres. The brain integrates the visual components located in both the binocular and monocular visual fields to form a unified visual perception. As many studies investigate the neural circuits of visual perception within the binocular visual field (e.g. binocular stereopsis), it is unclear how the visual stimuli of the right and left monocular visual fields, located in both hemispheres of the primary visual cortex, are integrated to form a unified vision. Here we developed a visual discrimination task in head-fixed mice in which the mice were required to compare visual stimuli at the left and right monocular visual fields. The task simultaneously presented elliptical visual stimuli (0, 12, 255 relative luminance) on left and right screens for 50 milliseconds, positioned around 35 degrees laterally from the mouse midline, allowing only one eye to see the stimulus. If the left stimulus had higher luminance than the right, the mice received a 10% sucrose water reward by licking a spout located in front of the mice (Go trial), followed by an inter-trial interval (ITI) of 0.5 sec. In contrast, when the right screen displayed a higher luminance stimulus than the left, the mice had to refrain from licking for 1 second (No-Go trial). Failure to resist licking during the No-Go trial resulted in a prolonged ITI of 3 seconds. We trained 7 mice for a month and found that the mice achieved an accuracy of 93.6% and 96.7% during Go trials for 0 vs. 12 and 12 vs. 255 conditions, respectively, on average. On the other hand, No-Go trials had an accuracy of 92.9% and 62.3% for 0 vs. 12 and 12 vs. 255, respectively (average performance of 7 mice). We then tested whether the primary visual cortex (V1) was a necessity in visual discrimination in our task. In each mouse, intrinsic signal optical imaging identified the V1 regions which represented the visual stimulus of the target location during the task. We injected pAAV-CamKIIa-stGtACR2-FusionRed into the identified V1 regions to optogenetically suppress the neural activity via optic fibers in the right visual cortex during 0 vs. 12 condition. A significant decrease in accuracy was observed during Go trials under light suppression ($p = 7.4e-4$ in the Wilcoxon signed rank test, 6 mice), while no behavioral changes were observed during No-Go trials ($p = 0.65$). These results suggest that the neural activity in V1 contributes to discriminating luminance in the left and right monocular visual fields.

The Evolution of Sense of Agency Through Learning New Sensorimotor Skills

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Poster Session 5, Friday July 5th, Ito International Research Center, 10:00AM-11:00AM

The sense of agency, the subjective experience of controlling an external object through one's actions, is generally believed to emerge from the alignment between predicted and actual action outcomes. This alignment, however, presupposes prior exposure to the action, rendering the prediction of outcomes for unfamiliar actions challenging. Our research aimed to explore the development of the sense of agency through the acquisition of novel motor skills. In our study, participants engaged in multiple sessions of motor learning tasks, where they manipulated a cursor on a screen using hand movements. Interspersed with these tasks were agency evaluation tasks, where participants assessed their control over the cursor's movements. The findings reveal a significant shift in the basis of participants' sense of agency judgments: prior to the learning process, judgments were predominantly influenced by the temporal synchrony between hand and cursor movements; following the acquisition of the skill, however, judgments leaned heavily on the internalized spatial correlation between the movements. This shift underscores the pivotal role of internal models, developed through novel motor learning, in facilitating accurate predictions of action outcomes and, consequently, in the evolution of the sense of agency. Our results contribute to a deeper understanding of the mechanisms underpinning the sense of agency, highlighting the dynamic nature of this phenomenon as it adapts to newly acquired sensorimotor skills.

Developing and Validating the Mind Blanking Questionnaire

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Poster Session 5, Friday July 5th, Ito International Research Center, 10:00AM-11:00AM

Sometimes we have moments when our focus wanders or our brains become blank. Mind blanking (MB) is a psychological phenomenon that has attracted greater attention lately. Experience sampling techniques, where participants complete a cognitive activity, after which prompts ask them to describe what's on their minds at that moment, have been used to evaluate MB at the state level. MB could, however, be assessed at the "trait level," much like other mental states (such as anxiety, mind-wandering, and the like). We created a new scale for this study called the Mind Blanking Questionnaire (MBQ), to measure propensity for MB at the trait level in both Japanese and English. The MBQ demonstrated strong test-retest reliability and internal consistency. It has also demonstrated good psychometric qualities, such as construct and criterion validity, test-retest reliability, and internal consistency, and shown measurement invariance across age groups, genders, and language variations. The MBQ can be a useful instrument to evaluate individual propensity for MB, support research on cross-cultural differences, and promote international MB research.

Islands of Practical Rationality and Pushmi-Pullyu Representations

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Poster Session 5, Friday July 5th, Ito International Research Center, 10:00AM-11:00AM

Do animals act for reasons? Hurley (2003) argues that non-human animals can act for reason. She proposes two conditions that have to be met for non-human animals to act for reasons: holism and the possibility of mistake. Holism is characterized as the flexible relation between intentions and perceptions, and ends and means. Normativity condition is understood in terms of the possibility of a mistake. Hurley claims that a system's internal complexity and externalism about reasons will be jointly necessary and sufficient for normativity e.g possibility of a mistake. Thus, in order to attribute reasons to non-human animals both holism and normativity conditions have to be met. In this paper, I offer a novel framework in which I combine Hurley's account of non-human animal intentionality with Millikan's (1995) account of Pushmi-Pullyu representation (PPR). First, I argue that Hurley's means/ends contingencies and general flexibility she attributes to them should be understood in terms of PPRs and affordances. My suggestion is that Millikan's characterization of PPR allows us to interpret means/ends contingency. The descriptive content in a certain PPR could be combined with different directive content within another type of PPR. Given that the proper function of PPRs are primarily attributed to mechanisms, there is no reason why certain mechanisms allow for general abilities by which non-human animals can combine different descriptive representations with different directive representations. Secondly, I argue that the possibility of a mistake is a possibility of misrepresenting. The possibility of a misrepresentation is in return a failure of mechanism to perform its function. For instance, consider vervet monkeys. If in the absence of a threatening situation e.g predator, a velvet monkey uses the alarm call 'thinking' that there is a predator, this would be a case of misrepresentation because the proper function of the alarm call is to warn the other monkeys that there is a predator. In this case, the organism fails to perform its function and thus it misrepresents. Thus, I maintain that the possibility of a mistake in following a general rule is to be interpreted in terms of misrepresenting and failure of performing proper function.

A recurrent cortical circuit triggers somatosensory perception

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Poster Session 5, Friday July 5th, Ito International Research Center, 10:00AM-11:00AM

We tend to believe that our senses tell us the real world as it is, but in fact our perception is wavering, and even identical stimuli are sometimes perceived and sometimes not. In a lowly example, we may swat off mosquitoes perched on our arm or suffer from itching after their bite. What neural mechanisms generate perceptions and how do they differ from those when they are not perceived? is one of the most fundamental questions in consciousness and perception research. A number of recent hypotheses, including GNWT, have proposed that cortical interactions comprising feedforward (FF) and feedback (FB) inputs would be involved in perception. Indeed, clinical studies on human subjects have shown that the prefrontal cortex as well as the sensory cortex is required for perception and their neural dynamics in perceptual processes. However, the information obtained non-invasively is limited to the brain region level, and the neural circuit level are still poorly understood.
In this study, we present our work applying mouse behavioral models and optogenetics towards understanding the operating principles of neural circuits in perception. We had previously reported a recurrent circuit consisting of cortical long-range projections between the primary somatosensory cortex (S1) and the premotor cortex (PMC) and they respond to somatosensory stimuli in S1→PMC→S1 pattern (Manita et al., Neuron 2015). To investigate the role of this neural circuit in perception, we first trained mice to report a somatosensory stimulus with drinking behaviour. Then, S1->PMC FF inputs or PMC->S1 FB inputs was controlled positively or negatively during the perceptual task using optogenetic manipulation. Positive control enhanced their perception, while negative control attenuated it. Furthermore, we combined pharmacology and showed that S1 activities were necessary throughout the perceptual process, while PMC activity was not required once activity was transmitted to S1. These results support that recurrent input originating from S1 is required for somatosensory perception. We continue to work on neurophysiological studies to clarify what activity this neural circuit is involved in perceptual process, and will discuss the latest data from these studies.

Perception of consciousness in nonhuman entities makes them potential targets of gratitude

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Poster Session 5, Friday July 5th, Ito International Research Center, 10:00AM-11:00AM

Anecdotally yet commonly, people give thanks to all kinds of nonhuman entities. Take the great Tecumseh (1768-1813), the Shawnee chief and warrior who once beautifully put, “When you arise in the morning, give thanks for the morning light, for your life and strength. Give thanks for your food, and the joy of living.” In comparison, modern psychological science has only built and tested theories (Algoe, 2012; McCullough et al., 2001) concerning gratitude toward human targets and how such emotion promotes inter-“personal” bonding. The current research hence tackles this intellectual gap and asks if and how the emotion of gratitude becomes possible for nonhumans. Inspired by the discussion on the other minds problem in consciousness research, we follow the cognitive approach in emotion research and propose that grateful feelings are generated from individuals’ cognitive appraisal of “perceived” beneficial consciousness in the world, human and nonhuman alike. That is, so long as one can anthropomorphize (i.e., seeing and attributing some human-mind qualities to) nonhuman entities and subjectively see beneficial will in them, the latter gain the status to be potential targets of thanks. Effectively and importantly, our hypothesis thus diverges from existing theories focusing on the relational utility of gratitude in evolution (Algoe, 2012; McCullough et al., 2001), instead implying that the emotion was evolutionarily selected for its function as a detector of beneficent consciousness, which, as many anthropologists (Guthrie & Porubanova, 2022) have argued, served as humanity’s prehistoric foundation for regions and their immense society-structuring power. Testing the hypothesis, Study 1 (N = 386) revealed that participants’ retrospective reports of grateful experiences toward both artificial (e.g., phones) and natural (e.g., plants) nonhuman entities were significantly associated with their anthropomorphism tendencies, even with general positivity begin controlled for. Studies 2 (N = 332) and 3 (N = 276) subsequently discovered that experimentally induced anthropomorphism in participants for artificial (computers) and natural (forests) nonhumans, respectively, made the participants perceive the targets to be caring, validating, understanding, and overall responsive as human others. This subjectively seen responsiveness in turn predicted gratitude for the nonhuman targets and, in the case of forests, downstream intention for pro-environmental behavior. Together, the present research then points to the possibility that the emotion of gratitude, through facilitating the perception of consciousness in the world – the illusion of other minds – not only supports people’s social bonding today but also might have played a key role in the long civilization process of humanity.

Shape Constancy and the Two-Tiered Perceptual Intentionality

Yen-TungLee (University of Washington)

Poster Session 5, Friday July 5th, Ito International Research Center, 10:00AM-11:00AM

This paper aims to account for the nature of perceptual contents that change and those that remain invariant through shape constancy by the two-tiered approach of perceptual intentionality. Shape constancy is extensively examined by philosophical and empirical studies (e.g., Burge, 2010; Morales et al., 2022; O'Dea, 2022). It is the phenomenon where we "perceptually represent properties of objects as remaining invariant despite relevant changes in proximal stimulation received from them" (Green, forthcoming: 4). For instance, we commonly perceive a coin as circular from a slanted angle despite its elliptical appearance. What accounts for the conflict between what we perceive and what appears to us in this case? Many argue that shape experience has both appearance properties (i.e., experiential properties that change as the perceiver's location in relation to the perceived object changes ceteris paribus) and constancy properties (i.e., experiential properties that remain the same as the perceiver's location in relation to the perceived object changes ceteris paribus), and these properties contribute to the overall perceptual phenomenology (Green & Schellenberg, 2018; Cheng, 2022). Assuming that these properties feature in the having of contents, the explanation is reframed in the way that shape experiences involve two kinds of contents: 1) its appearance contents vary with the perceiver's location in relation to the object, and 2) its constancy contents that remain the same regardless of changes of their spatial relation. In the slanted coin experience, its appearance content represents the coin as elliptical, while its constancy content represents the coin as circular. This paper explores the nature of appearance contents and constancy contents. I situate this inquiry within a two-tiered approach to perceptual intentionality, which accounts for the nature of mental representation in terms of one account for simple representations and another for complex representations (Chalmers, 2021; Neander, 2017; Mendelovici, 2018, forthcoming; Williams, 2020; Pautz, 2021). Particularly, I endorse Mendelovici's account, according to which perceptual experiences involve two kinds of content. The immediate contents of an experience are grounded in its sensory phenomenology, while the derived contents are derived from the associated immediate contents. The derivation of contents rests on the self-ascription of contents to the experience upon sufficient reflection. This paper accounts for shape constancy by the two-tiered approach of perceptual intentionality. I contend that the distinction between appearance contents and constancy contents can be integrated into the framework of immediate and derived contents. Specifically, appearance contents are grounded in the sensory phenomenology of shape experience, while constancy contents are derived from appearance contents through self-ascription. A subject well-acquainted with the environment would have the derived content <circular> in her slanted coin experience by self-ascribing the content to the experience. Consequently, the slanted coin experience represents not only <elliptical>, which aligns with its sensory phenomenology, but also <round>, the content derived from self-ascription upon sufficient reflection. The resolution to the earlier question thus emerges: the slanted coin experience involves the representations of both contents, yet it exclusively presents appearance contents in sensory phenomenology, as they are immediate contents by their nature.

Does Less Knowledge Lead to More Bias? Investigating Metacognition's Role in Self-assessment

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Poster Session 5, Friday July 5th, Ito International Research Center, 10:00AM-11:00AM

This study examined the influence of undergraduate students' levels of knowledge on the bias in their self-efficacy assessments regarding exam performance, both before and after exams, as well as after completing a learning strategy questionnaire. A total of 112 students from a high-knowledge group and 145 students from a low-knowledge group were recruited. They were required to assess their exam performance three times: before, after the psychology exam, and after filling out the learning strategy questionnaire. The results revealed: (1) Before the exam, students from both high and low-knowledge groups overestimated their performance, showing a significant bias in self-efficacy assessment. The bias was notably larger in the low-knowledge group, indicating higher levels of overconfidence. (2) After the exam, both groups exhibited a significant reduction in their self-efficacy assessment bias and a substantial decrease in overconfidence levels. No significant difference in assessment bias was observed between the two groups. (3) After completing the learning strategy questionnaire, there was no significant change in the bias of self-efficacy assessment in the high-knowledge group, while the low-knowledge group demonstrated an increase in this bias, with a rise in overconfidence levels. These results suggested a common phenomenon of overconfidence in self-assessment among undergraduate students. Individuals with lower metacognitive abilities showed poorer self-assessment capabilities. Professional knowledge, by enhancing metacognitive experiences and abilities, can effectively inhibit the phenomenon of overconfidence. Motivational belief strategies within learning strategies can interfere with self-assessment, leading to an increase in overconfidence. The impact of motivational belief strategies was more significant in students with lower levels of knowledge

Rhythmic action alleviates attentional blink

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Poster Session 5, Friday July 5th, Ito International Research Center, 10:00AM-11:00AM

Attentional blink is a temporal restriction on conscious access of perceptual processing — subjects would miss the second target in a rapid serial presentation of stimuli. This 'temporal deficit' is caused by the distribution of limited cognitive resources via the modulation of selective attention. The dynamic attending theory proposes that selective attention may operate as rhythmic neural activities that modulate the sensitivity of perceptual processes. Whereas, the premotor theory further proposes that attention may be driven by the motor system and the modulatory effects of selective attention may directly originate from action. The causal relationship between motor and attention systems is yet to be elaborated. In this study, we investigated how the action can modulate the attentional system by using an updated attentional blink paradigm in which participants pressed a button rhythmically while performing the auditory attentional blink task. Our results showed that the button-press decreased the identification rate of the first target but surprisingly, increased the detection rate of the second target. That is, the rhythmic action alleviates the attentional blink. These preliminary findings support the hypothesis that the motor system drives attention and grants sensory information to conscious awareness.

Rubber Hand Illusion at the Edge of Chaos

Adam Ponzi (University of Washington), Keisuke Suzuki (CHAIN, Hokkaido University)

Poster Session 6, Friday July 5th, Ito International Research Center, 4:00PM-5:00PM

The experience of an embodied self is associated with multisensory integration. Illusions, like the rubber-hand and ventriloquism, demonstrate that simultaneous but spatially incongruent multisensory sensations can be integrated into a single unified experience, providing they are not too incongruent. When sensations are integrated, the experienced location is usually somewhere between the true stimuli, depending on the relative reliabilities of the sensory modalities. Intriguingly, this process is stochastic. On some trials sensations are integrated, on others experienced as separate, even though the true stimuli are the same in both cases. Fluctuations in localization belief increase with spatial disparity. For any given true disparity, fluctuations are small on trials when a single cause is experienced, but much larger when causes are experienced separately, whereby sensations are sometimes close to their true locations, but on other trials, close to each other. These observations are usually understood with Bayesian Causal Inference (BCI), whereby the brain computes the likelihoods of a single cause, or multiple, by inverting a generative model. Only when two causes are likely, are sensations combined according to the Bayes optimal reliability weighted average. In this model, fluctuations are not needed for any particular cognitive function. They are simply thought to originate from noise in the external sensory world, independent across stimuli, or from stochastic biophysical sources. A unified experience sometimes occurs, even when a large spatial disparity between the true stimuli exists, because independent sensory fluctuations happen to fall the right way. However, brain fluctuations can also be generated internally, and on purpose, by deterministic network chaos. Here we show that when an initially unstructured network composed of a sensory input layer and a recurrently connected multisensory association layer, including unsupervised Hebbian learning in only a purely feedforward way between the layers, is trained on spatially congruent multisensory stimuli, spatially tuned cells emerge in the multisensory network which fully tile the spatial environment and facilitate the recall of one sensory modality by the other, but this is only optimal when the multisensory layer endogenously generates activity which is just above a transition from a stable fixed point state to a slowly chaotically fluctuating one. Training selectively enhances the activity of some multisensory neurons and silences others, thereby suppressing chaos and generating selective winners-take-all like network states specifically for those congruent multisensory stimulus combinations. When tested on novel multisensory stimuli which fall in a distinct low spatial disparity regime, highly reproducible fixed point attractor responses representing stimulus reliability weighted locations between the true spatial locations, are activated. Network states activated by more spatially disparate multisensory stimuli remain chaotic and fluctuate inconsistently across trials. Thus fluctuation magnitude is intrinsically dependent on spatial disparity, not just on sensory noise. Thus a distinct fused integration regime associated with suppressed neural fluctuations and a unified experience, and a strongly fluctuating segregation regime where experiences are distinct, emerges after training, but only in edge of chaos networks. Our model suggests how sensations are combined to produce the experience of a unified embodied self.

The Bodily Basis of the Feeling of Effort: Condemned to Repeat the Past?

Alexander MugarKlein (University of Washington)

Poster Session 6, Friday July 5th, Ito International Research Center, 4:00PM-5:00PM

Is the experience of bodily effort caused by outflowing nerve signals—by the central nervous system sending a "command" to do work? Or is it caused by inflowing signals providing feedback from just-performed work? This debate dates to the 1860s, when it drew in figures like Helmholtz, Wundt, Mach, James, Ferrier, and Bastian. Recently, philosophers and physicians have claimed that new experimental work answers this old question (Bergevin et al. 2023, Bermúdez and Massin 2023, Pageaux and Gaveau 2016; also see Barbosa et al. 2016, Fernandes et al. 1990). I show that the new experimental work is in fact inconclusive, and for precisely the same reasons that empirical evidence proved incapable of settling this issue going back to the 19th century. The recent experiments record perceived effort in exercising subjects who are under epidurally-administered anesthesia. The rate of perceived exertion is claimed to be unaffected by this anesthetic protocol, and this is supposed to show that the feeling of effort cannot be due to peripheral factors. But the latter claim is unconvincing. First, the epidural injections are invariably made in the lumbar region of the spine, typically between either L2-L3 or L3-L4. This means subjects have been desensitized roughly below the waist, and afferent feedback is only being blocked from some of the muscles actually employed during exercise. Afference from core muscle groups involved (e.g., from the abdomen, chest, or glottis) has not been blocked, which is what afference theorists have typically hypothesized is a key source of the feeling of effort. Second, all these experiments specifically block group III/IV muscle afferents only, leaving afferent feedback in the legs from groups Ia/II intact. Group III/IV afferents modulate cardiovascular response during exercise (Amann 2012); group Ia/II afferents, in contrast, give proprioceptive feedback of the position and speed of change of the muscles (Taylor 2009). The results do not block the peripheralist theory from claiming that Ia/II (proprioceptive) afferents are key to perceived effort. In the 19th-century, centralists often pointed to clinical evidence that patients with paresis in an arm or an eyeball (to take two key examples) perceive an increase in effort when attempting to move the paretic appendage, counter to what the peripheralist theory might predict. But it is impossible to block every afferent nerve signal in an exercising subject. The two sides stalemated, with centralists proffering evidence that the feeling of effort persists even when *this* specific afferent signal is blocked, and peripheralists responding by pointing to *that* afferent signal that the experiments had not blocked. I shall argue that the failure to settle the matter is structurally the same, today.

Advances in “Replicating the unconscious working memory effect: A multisite preregistered study.”

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Poster Session 6, Friday July 5th, Ito International Research Center, 4:00PM-5:00PM

Although in recent years some studies have found evidence suggesting that working memory (WM) may operate on unconscious perceptual contents, decisive demonstrations of the existence of unconscious WM are lacking. In this poster we present our in-principle accepted Registered Report in Neuroscience of Consciousness, whose goal is to test whether WM can operate unconsciously, by replicating the original study of Soto et al. (2011). We will use a multisite sample from different laboratories, with a larger number of participants and trials than those typically used in previous studies. As a result, a highly-powered, open-access dataset will be available for researchers and future analyses. Furthermore, some minimal baseline requirements will be guaranteed for the experimental task (i.e., number of valid trials, motivation, and consistent labels for the Perceptual Awareness Scale, PAS). We will critically test the hypotheses commonly proposed: above-chance performance in cue-present trials reported as unseen, a null correlation between performance and cue detection sensitivity, and a significantly above-chance intercept in the regression of performance on sensitivity. All three results are threatened by measurement error, and consequently, we will calculate reliability estimates for our measures in a series of exploratory analyses, allowing us to diagnose and – if needed – to correct any bias. The goal of this poster is to recruit more potentially interested laboratories around the world to participate in the project. In addition, we will share the process of piloting the experimental task, which has opened up many reflections on the influence of instructions and illustrations for participants to accurately report their subjective experience of perceptual awareness. For instance, including examples on how to use the PAS, explicitly informing participants that “Our brains may be able to process more information than we are aware of”, reminding the participant the meaning of a PAS = 1 report between blocks of trials, and adjusting their expectancies with messages like “It’s okay if you don’t see the Gabor in many of the trials”, is expected to enhance their performance and understanding of the task. Our objective is to share qualitative recommendations for the design of instructions in tasks that require perceptual awareness reports.

Disambiguating consciousness: A framework for empirical investigation and scientific communication

Andrew Proulx (University of Washington)

Poster Session 6, Friday July 5th, Ito International Research Center, 4:00PM-5:00PM

What is consciousness? What is intelligence, information processing, and agency? How do these concepts relate to each other? Building on work from Nagel (1974), Block (1995), and Chalmers (2023), and incorporating concepts from molecular and evolutionary biology (Godfrey-Smith, 2019; Levin, 2019) and Eastern philosophical traditions, this project disambiguates these terms and provides a conceptual framework that can be used in empirical investigation and scientific communication. In this framework, consciousness is defined as a process in which there is something it is like to go through that process. The origin of this process is the ability to detect phenomena, allowing for the capacity to react and respond, which we define as awareness. The contents of consciousness depend on the entity's reception, processing, and interpretation of information, which depend on the constitution of the entity's sensory and perceptual mechanisms. Both consciousness and information processing come in degrees depending on the complexity and organization of the corresponding physical substrate. Consciousness is logically distinct from information processing, however the two are co-occurring and usually co-evolve. Thus, consciousness can be understood as an ongoing union between awareness and the physical substrate of an entity's perceptual mechanisms. With this foundation, we propose corresponding definitions for subjectivity, agency, information processing, intelligence, cognition, and global access, carefully delineating and disambiguating many overlapping concepts. We then apply the framework to examples from across the biological and non-biological world, including humans and non-human animals, plants, inanimate objects such as rocks, as well as to artificial neural networks such as ChatGPT. We conclude with a discussion of how this framework can be used in empirical investigation and scientific communication.

Towards blinded classification of loss of consciousness: distinguishing wakefulness from general anesthesia and sleep in flies using a massive library of univariate time series analyses

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Poster Session 6, Friday July 5th, Ito International Research Center, 4:00PM-5:00PM

The neural mechanisms of consciousness remain elusive. Previous studies on both human and non-human animals, through manipulation of level of conscious arousal, have reported that specific time-series features correlate with level of consciousness, such as spectral power in certain frequency bands. However, such features often lack principled, theoretical justifications as to why they should be related with level of consciousness. This raises two significant issues: firstly, many other types of times-series features which could also reflect conscious level have been ignored due to researcher biases towards specific analyses; and secondly, it is unclear how to interpret identified features to understand the neural activity underlying consciousness, especially when they are identified from recordings which summate activity across large areas such as electroencephalographic recordings. To address the first concern, here we propose a new approach: in the absence of any theoretical priors, we should be maximally agnostic and treat as many known features as feasible as equally promising candidates. To apply this approach we use highly comparative time-series analysis (hctsa), a toolbox which provides over 7,700 different univariate time-series features originating from different research fields. To address the second issue, we employ hctsa to high-quality neural recordings from a relatively simple brain, the fly brain (Drosophila melanogaster), extracting features from local field potentials during wakefulness, general anesthesia and sleep. For each feature, we constructed a classifier for discriminating wakefulness and anesthesia in a discovery group of flies (N = 13). Using a registered report framework (with a Stage 1 manuscript in-principle accepted at PLOS Biology; https://doi.org/10.31234/osf.io/rmsv8), we are now evaluating their performances on an evaluation group of flies (N = 12 for graded levels of anesthesia, N = 18 for single dose anesthesia, and N = 19 for sleep). Current results indicate that while no features classify significantly better than chance across all datasets and conditions, limiting the extent of generalisation to conditions most similar to the discovery flies yields ~100 significantly performing features, including some related to spectral power and complexity, supporting existing literature, as well as previously unexplored features related to forecasting or model-fitting, and simple distribution related features. Meanwhile, looking at the consistency of the direction of change in feature values with loss of consciousness in individual flies, rather than at across-fly classification, yields hundreds more features which may classify conscious level when baseline measurements are available. These significantly performing time-series features may serve as fruitful avenues to explore towards robust discoveries of the neural correlates of consciousness.

Open-monitoring and focused-attention meditation induce shifts in brain complexity and critical dynamics: Novel insights from an MEG study

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Poster Session 6, Friday July 5th, Ito International Research Center, 4:00PM-5:00PM

Focused-attention meditation (FAM) involves directing one's attention to a specific object while open-monitoring meditation (OMM) maintains a state of non-reactive monitoring without a specific focus, allowing attention to any experience that arises, without judgment (Lutz et al., 2015). These different attentional processes suggest that these different meditation techniques are mediated by distinct neural mechanisms. Yet, these differences in the underlying brain patterns are still poorly understood. A growing body of research suggests that cognitive performance and distinct states of consciousness may be quantifiable by neural complexity and criticality metrics, which index the brain's information processing capacity (O'Byrne & Jerbi, 2022). To date, findings on the relation between brain criticality and meditation are still at an early stage (Irrmischer et al 2018, Dürschmid et al 2020; Walter et al 2022; D'andrea et al. 2024). Here, we aimed to characterize changes in brain dynamics induced by the different meditative states and their relation to complexity and criticality related measures by analyzing brain signals recorded in a group of expert Buddhist monks with magnetoencephalography (MEG) during resting state (RS), FAM and OMM. We reconstructed the neural activity using minimum norm estimation and computed source-space spectral power density (PSD) in different frequency bands. To quantify the complexity and dynamics of the estimated time series, we computed: long-range temporal correlation on neural oscillations using Detrended Fluctuation Analysis (DFA), Lempel-Ziv complexity (LZc), Spectral Entropy (SpecEn), Higuchi's fractal dimension and the exponent of the aperiodic component of the PSD (1/f). The role of these features were then examined using (a) group-level differences assessed with non-parametric statistical tests and (b) a multi-feature supervised learning approach, where a Random Forest (RF) classifier was trained to discriminate between the different brain states. We found that FAM and OMM were associated with common as well as distinct neural patterns; Compared to RS, FAM showed a decrease of power in beta and gamma bands in occipital and parietal regions. The LRTC analysis revealed an overall decrease in the DFA exponent in FAM and OMM compared to RS in gamma bands. The complexity indices LZc and SpecEn increased in both FAM and OMM (compared to RS) mainly in the parietal and central regions while an increase of fractal dimension was evident only in FAM compared to RS in central and parietal regions. Finally, the 1/f slope decreased both in FAM and OMM in the parietal and motor regions. Investigating the feature importance of the RF classifier highlighted a central role of the DFA exponent in distinguishing the two meditative states from RS. Taken together, our findings support the idea that examining brain dynamics through the lens of complexity and critical dynamics is a particularly promising approach to elucidating the neural mechanisms of meditative states, possibly more so than measuring changes in spectral power. The reduction in the 1/f slope and in the DFA exponent together with the increase of complexity may be linked to an increase in the E:I ratio during meditation (cf. Gao et al., 2017).

Can a sense of control on the task enhance task performance?

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Poster Session 6, Friday July 5th, Ito International Research Center, 4:00PM-5:00PM

Being and feeling as an active agent is crucial to conscious experience. Intentional behavior is associated with a sense of control over one's actions and outcomes. Many studies on the sense of control have focused on examining what it depends on (Chambon & Haggard, 2012), while what it influences remains relatively understudied. For example, although some studies have examined changes in perceptual detection by manipulating the sense of control (Whitson & Galinsky, 2008), no studies have examined the effects of the sense of control on everyday behavior and performance. This suggests that it is worth examining the possibility that the mere feeling of having performed an action can induce a change in performance. We therefore designed two experiments to examine how the feeling of having made a subjective choice in relation to a task influences an individual's performance on that task. In Experiment 1, we considered the number of breaks as an indicator of task performance load and investigated whether participants' perception that they had subjectively chosen the task's difficulty level could reduce the number of breaks in the arithmetic task, without actually changing the task's difficulty. The experiment consisted of two conditions: the choice condition, in which participants were allowed to enter the difficulty level of the task, and the no-choice condition, in which participants were given no choice. We conducted an analysis using a generalized linear mixed model to verify the effects of condition (choice conditions: choice, no choice) and time (early phase, mid phase, second phase). The results showed that the number of breaks voluntarily taken during the block intervals was significantly lower in the choice condition ($z = -2.037$, $p = .0416$). The subjective choice can influence the continuity of the task, even if the consequences of the choice do not follow it. In Experiment 2, we used a line trace task, which requires motor control and is difficult to maintain correctly. The line trace task was used to investigate the accuracy of the tasks that were not fully verified in Experiment 1. In this task, participants traced a random wavy line displayed on a tablet. The line tracing task consisted of 30 blocks of 30-second trials. The rest of the experimental design was the same as in Experiment 1. These data will be analyzed using a two-factor mixed model analysis of variance to test whether subjective choice increases the accuracy of task performance. This study's findings, which suggest that the mere feeling of making a choice can influence subsequent cognition and behavior even without tangible outcomes, suggest that the subjective experience as a chooser has implications for our everyday performance.

Functional role of increased neural complexity after low doses of LSD

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Poster Session 6, Friday July 5th, Ito International Research Center, 4:00PM-5:00PM

Title: Functional role of increased neural complexity after low doses of LSD Authors: Conor H. Murray, PhD1,2, Joel Frohlich, PhD3,4, Royce Lee, MD1, Harriet de Wit, PhD1 1 Department of Psychiatry and Behavioral Neuroscience, University of Chicago; 5841 S Maryland Ave, Chicago, IL, 60637, USA 2 Department of Psychiatry and Biobehavioral Sciences, University of Los Angeles, California; 760 Westwood Plaza, Los Angeles, CA 90024, USA (current address) 3 Institute for Neuromodulation and Neurotechnology, University of Tübingen; Otfried-Müller-Straße 45, Tübingen, 72076, Germany 4 Institute for Advanced Consciousness Studies, Santa Monica, California; 2811 Wilshire Blvd # 510, Santa Monica, CA 90403, USA
Abstract: Neural complexity refers to the diversity of signals in neuroimaging data, such as from electroencephalography (EEG). A common measure of neural complexity is Lempel-Ziv complexity (LZC), which measures the compressibility of the recorded brain signals using a compression algorithm. Relative to an eyes closed resting state, neural complexity is lower during general anesthesia and non-REM sleep, and higher during the watching of a film. Higher complexity is also associated with better task performance and faster reaction times. In addition, neural complexity measured by LZC increases after high doses of lysergic acid diethylamide (LSD) relative to placebo. Together, neural complexity has been theorized to be a marker of consciousness as well as altered states of consciousness. In the current analysis of 23 healthy participants, we recorded EEG brain signals under 10-20 electrodes during eyes closed resting state at the time of anticipated peak effects after low doses of LSD (13 and 26 µg). We sought to determine whether neural complexity measured by LZC increases after doses that do not induce altered states of consciousness. In addition, we test the functional role of neural complexity after LSD by examining relationships to behavioral outcomes during an EEG emotional faces recognition task. The task is an oddball design wherein happy faces are presented frequently and “oddball” angry and neutral faces are presented infrequently. We first confirmed that the LSD doses did not induce altered states of consciousness as measured by the self-reported 5 Dimensions of Altered States of Consciousness (5D-ASC) questionnaire at the end of sessions. Nonetheless, during EEG eyes closed resting state, we found that LSD dose-dependently increased LZC across all electrodes (RM-ANOVA linear effect of dose; $p < 0.001$). During the EEG emotional faces recognition task, we found that LSD dose-dependently reduced response errors in facial recognition (RM-ANOVA linear effect of dose; $p = 0.015$). However, there was no significant relationship between the increased complexity at rest and improved behavior. Instead, we identified a trend toward greater complexity after 26 µg predicting poorer task performance with greater errors in the facial recognition. Future work is needed to examine the EEG signals during the facial recognition task to more completely tease apart the functional role of increased neural complexity after low doses of LSD.

Exploring the links between mindfulness problematic screen usage amongst preadolescents

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Poster Session 6, Friday July 5th, Ito International Research Center, 4:00PM-5:00PM

Problematic screen usage has been considered an emergent public health issue (Van Velthoven et al., 2021), affecting to approximately 1 in 4 children and young individuals (Sohn et al., 2019). Problematic screen usage is significantly linked to poorer mental health, including symptoms for depression, anxiety, perceived stress, and poorer sleep quality (Sohn et al., 2019). Mindfulness is characterised by the non-judgemental awareness that emerges when paying attention to the present moment with kindness (e.g., Shapiro et al., 2018). Mindfulness has been considered as a protective factor against a range of psychological disorders, including anxiety, depression and smartphone addiction. However, evidence regarding the link between mindfulness and problematic screen usage in preadolescents stills in its infancy. Given children and adolescents may be more vulnerable to psychopathological developments (Sohn et al., 2019), it is essential to examine risk factors for problematic screen usage in preadolescents. Therefore, the main aim was to explore the link whether problematic screen use and mindfulness in a sample of preadolescents. A total of 90 boys and 74 girls participated in the study (M =10.2; the age ranges from 9 to 13 years-old). Participants answered the following self-reported scales: Child and Adolescent Mindfulness Measure, the Digital Addiction Scale for Children and dairy frequency of screens. A series of hierarchical multiple regression were conducted in order to examine the relationships between problematic screen usage and mindfulness. Problematic screen usage dimensions (preoccupation, tolerance, withdraw, problems, conflicts, displacement, relapse, mood management and deception) were introduced as outcomes in the regression models. Age and dairy frequency of screen usage were imputed in the first block of the regressions and mindfulness in the second block. The hierarchical regression analyses revealed significant links between higher problematic screen usage dimensions (specifically, preoccupation, tolerance, withdraw, problems, conflicts, displacement, relapse, and mood management) and lower mindfulness scores, even controlling for age and dairy frequency of screen usage. Dairy frequency of screen usage was a significant predictor for all problematic screen usage subscales. The results suggest that the lack of awareness of the present moment, as well as a self-critical attitude and non-acceptance of thoughts and emotions may increase the risk for problematic screen usage amongst preadolescents. Cultivating mindful awareness and self-acceptance may help to reduce problematic screen usage amongst children.

Common signatures of loss of consciousness in human and macaque electrocorticogram

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Poster Session 6, Friday July 5th, Ito International Research Center, 4:00PM-5:00PM

Despite the widespread application of general anesthesia for surgical procedures since the 19th century, a fundamental understanding of its operating principle and a reliable metric for Loss of Consciousness (LoC) remain elusive, leaving unmitigated risks such as overdose or intraoperative awareness. Given that LoC is inducible by the same anesthetics in various animal species, here we propose that there are corresponding shared neuronal mechanisms that underlie LoC, which manifest as common signatures in neural signatures across species. Identifying these signatures would pave a way for a refined metric of LoC applicable to both humans and other species. In this project, our goal is to identify shared metrics for detecting LoC in both humans and macaque monkeys. Recognizing that LoC can occur within a fraction of a second, our approach involves uniformly applying multiple metrics to the brain signals of both species, pinpointing the optimal metric(s) for detecting LoC in short 200ms segments. To facilitate this, we employed highly comparable time-series analysis (hctsa, Decat et al., Sleep Medicine 98 (2022) 39-52; Fulcher and Jones Cell Systems 5(2017) 527-534), computing over 7000 univariate time-series features from various disciplines. Initial results from our pilot study (one monkey and one human) will be followed by more extensive analyses in the registered report format. For Stage 1 of the registered report, we first identified hctsa feature(s) that distinguish awake and propofol-anesthetized states from one macaque intracranial data set (Yanagawa et al., PLoS ONE 8(11) (2013) e80845-13). For each feature, we trained a nearest median classifier (Leung et al., PsyArXiv (2023)) using 200ms data epochs, and evaluated its classification accuracy with 10-fold cross-validation in the macaque. We subsequently evaluated its classification accuracy in Human intracranial data, recorded from one participant with medically refractory epilepsy (Nourski et al., J Neurosci. 38 (2018) 8441-8452). Results from Stage 1 provide strong evidence of univariate features capable of discriminating between awake and propofol-induced unconscious states in both species. For example, a hctsa feature characterizing model fitting performance trained on the macaque frontal lobe achieved significant ($p<0.00013$) classification accuracy both in macaque (75% accuracy) and human frontal lobe recordings (82%) after a False Discovery Rate correction ($q=0.01$). However, other features such as root-mean square, showed significant accuracy only in the macaque data. Across six recording sites randomly sampled from the frontal and temporal lobes, we found 1945 +- 887 (mean +- S.D.) features that performed significantly above chance level in both macaque and human recordings. Moreover, these features show potential for training using short segments of epochs as brief as 200ms. Building on Stage 1 findings, Stage 2 will expand the investigation to include recordings from another macaque and ten humans, aiming to validate the generalizability of identified features across species. Ultimately, the project seeks to enhance our understanding of LoC mechanisms, mitigating risks associated with anesthesia administration in surgical procedures. This work is supported by Center for Open Science (DS, NP, NT) and National Institute of Health (KN).

Visuospatial attention involves a theta-band network of posterior and midfrontal brain areas

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Poster Session 6, Friday July 5th, Ito International Research Center, 4:00PM-5:00PM

Prominent rhythmic brain activity, observed in continuous electroencephalography (EEG) as the alpha and theta oscillations, has been implicated in the processes underlying attentional selection and conscious perception of visual information. Particularly, a hemispheric reduction in the local contralateral vs. ipsilateral posterior alpha power has been commonly observed, and most often interpreted as suppression of the irrelevant spatial location. However, as this alpha activity often emerges relatively late, the question has been raised whether it possibly reflects a more secondary role in the time-course of visuospatial processing. Some studies indeed observed earlier changes in the theta band that might be rather crucial. In the current study, we demonstrated that activity in the theta band may become very relevant for selective visuospatial processing, particularly when there is a strong need for the suppression of interfering and distracting stimuli. Participants (N 33) performed a variant of the Eriksen flanker task with bilateral stimulus arrays; one array included a target with congruent or incongruent flankers, and the second array consisted of neutral distractors. The bilateral arrays were preceded either by a 100% valid spatial cue indicated the target location, or by a neutral cue. The EEG was recorded during the task performance, and time-frequency analyses of local and inter-areal EEG activity was carried out. To estimate functional connectivity, we measured inter-areal phase synchrony, and used graph theory metrics of node strength (indicating the centrality, i.e., importance of each node within the network), and graph strength indicating the summed strength of all links in the network. We analyzed the activity in both the cue-target and post-target intervals. In the cue-target interval, we observed a major burst in medial frontal theta power, which was largest in the spatial cue condition. In the latter condition, also a posterior theta increase was observed that was larger over sites ipsilateral to the forthcoming target array. Functional connectivity analyses revealed that this pre-target posterior theta was related to the midfrontal theta. No such effects were observed in the neutral cue condition. After onset of the bilateral arrays, a significant enhancement in posterior theta coherence was observed in both cue conditions, which again was larger above sites ipsilateral to the target array. Furthermore, this posterior theta was in all the cases connected to the midfrontal theta. Taken together, the findings suggest that a fronto-posterior theta network plays an important role in the suppression of irrelevant and conflicting visual information. The results also suggest a close reciprocal relation between visuospatial selection and action control, in line with the idea that these processes are just two entangled components of an integrated selection-for-action system.

Investigating visual consciousness with natural scenes and the attentional blink.

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Poster Session 6, Friday July 5th, Ito International Research Center, 4:00PM-5:00PM

The Attentional Blink (AB) phenomenon offers a window into the fleeting moments of awareness that shape our interaction with the rapidly unfolding visual world. In the AB, a controlled brief lapse in visual awareness is observed in healthy volunteers during a rapid serial visual presentation (RSVP). The temporal dynamics of the AB are well documented, with decades of research confirming the critical temporal window during which participants often blink when trying to detect two targets (T1 and T2) presented in rapid succession (200 to 500 ms inter-target interval). Using visual images depicting a broad set of object categories, a recent study revealed important categorical differences in the ability to detect and report the second target in the AB (Lindh et al. 2019). For example, images depicting animate objects showed smaller AB depths compared to images depicting inanimate objects. Importantly, the largest AB effects were observed with images depicting natural scenes. The limited set of natural scenes used in this study depicted outdoor scenes with no clear objects in focus. Here, we extend on these previous findings, and introduce a novel AB dataset measuring the depth of the AB in thousands of richly annotated natural scene images selected from the natural scenes dataset (NSD; Allen et al., 2022). Importantly, the stimuli depict a wealth of outdoor and indoor natural scenes, with objects from 80 different categories presented in varying scene contexts, offering a more ecological account of one's typical visual diet. Each stimulus is also supplemented by a rich set of annotations (category labels, object boundaries, natural language captions, etc.; provided with the Microsoft COCO dataset; Lin et al. 2014) allowing for the investigation of visual consciousness at varying levels of abstraction. In our AB task, the targets are presented within a stream of phase-scrambled distractors, and each stimulus is presented as T2 at both 200 ms (lag 2) and 700 ms (lag 7) following the presentation of T1 in the stream. This allows measuring the depth of the attentional blink for each natural scene (by computing the difference in T2 accuracy at lag 7 and lag 2). Consistent with previous findings, we observed strong AB effects using natural scenes, with a significant reduction in T2 identification at a lag 2 compared to lag 7 (T1 mean = 0.92, sd = 0.26; T2lag2|T1 mean = 0.65, sd = 0.20; T2lag7|T1 mean = 0.95, sd = 0.09). Preliminary results show markedly smaller AB depths for natural scenes depicting animate objects, consistent with our previous results using object-centric stimuli. The rich characterisation of AB depths across thousands of natural scenes will allow revealing the precise underlying visual features at varying levels of abstraction that influence the AB in ecological settings. In addition, it will allow investigating the neural correlates of visual awareness by relating the image-dependent AB depths with the high-resolution fMRI activity patterns measured in the NSD dataset. Finally, this dataset will enable developing novel image-computable models of vision that are predictive of visual awareness.

Local sleep-like activity in the awake human brain

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Poster Session 6, Friday July 5th, Ito International Research Center, 4:00PM-5:00PM

Sleep and wake are generally considered as global brain states. However, recent work suggests that sleep-like activity, characterized by slow wave oscillations in the delta and theta range, can occur in large task-related networks in sleep-deprived humans. The present study probed whether the extended use of an specific neuronal population could cause sleep-like activity in this population in well-rested, awake participants. Volunteers participated in four consecutive sessions spanned over one day in which they performed the texture discrimination task (TDT). Previous studies have shown that the repeated exposure to the TDT results in performance deterioration, but that performance is restored by changing the target's spatial location or by taking a nap in between sessions. Behavioral and neuroimaging studies have related this use-dependent deterioration to local changes in the neural activity of the primary visual cortex. In this study, participants underwent two resting-state EEG recordings before and after the prolonged exposure to the TDT, and eye-tracking and EEG recordings were also captured during the first and last session of TDT performance. We predicted an increase in sleep-like activity in neural areas involved in task performance when comparing the second to the first resting-state session (i.e., an increase in slow wave oscillations after extensively performing the TDT) and between the last to the first TDT-performing session. Our behavioral results replicate earlier studies showing a significant decrease in TDT performance after repeated exposure to the task. Crucially, an increase in theta power in the visual cortex is detected in the resting-state condition after extensive exposure to the TDT. This implies that awake, well-rested humans may exhibit sleep-like activity in heavily utilized neural networks. In addition, a slow-wave detection algorithm is currently being applied to characterize the topography and features of the slow waves in the delta and low-theta frequency ranges (1-6Hz) during performance and resting state conditions.

The role of informational value on value-modulated attentional capture

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Poster Session 6, Friday July 5th, Ito International Research Center, 4:00PM-5:00PM

Stimuli associated with rewards are more likely to attract attention, a phenomenon often referred to as value-modulated attentional capture (VMAC). VMAC is widely assumed to be implicit in nature. However, the role of explicit awareness of reward-stimulus contingencies has mostly been assessed using post-hoc awareness tests, which are known to be prone to many methodological problems. In this study, we aimed to investigate how explicit information about stimulus-reward contingencies can modulate the acquisition of VMAC. In a first well-powered replication of a previous study, we found that VMAC was not observed when no information about stimulus-reward contingencies was provided in the pre-task instructions. Furthermore, there was no correlation between explicit reports of stimulus-reward contingency and the VMAC effect. To better understand our previous findings, in a second experiment we manipulated participants' explicit awareness of stimulus-reward contingencies by varying the amount of information provided, with some participants performing the task with no prior information and others with full information about these contingencies. Interestingly, VMAC was modulated by our manipulation, with only the contingency instruction group showing a VMAC effect. In addition, as expected, the instruction manipulation also affected measures of explicit awareness, but within each group there was no significant correlation between these measures and the VMAC effect. This study demonstrates that it is possible to examine how awareness modulates the learning process behind the VMAC effect by manipulating the information available to participants, and that post-hoc measures of awareness appear to be poorly suited to this purpose. These results suggest that the learning process behind VMAC may not be entirely implicit.

Dimensionality of Positive Affect Valence

Gabriel Brandolini (University of Washington), Olivia Carter (University of Melbourne), Stefan Bode (University of Melbourne)

Poster Session 6, Friday July 5th, Ito International Research Center, 4:00PM-5:00PM

Affect valence is the intrinsic attractiveness (positive valence) or aversiveness (negative valence) of an emotion, feeling, or mood. It is the dimension that captures the overall pleasantness or unpleasantness of an affective state. Emotion scientists disagree on whether valence is unidimensional, a single spectrum ranging from positive to negative, or multidimensional, a complex construct that accommodates multiple distinct ways an emotion can be experienced as positive or negative. To test whether positive valence is unidimensional or multidimensional, we provided participants (N=292, Female=61%, Age: M=19.96, SD=5.66) choices between video stimuli from different emotion categories (Admiration, Amusement, Awe, Romantic-Love, and Surprise) while utilising a film+instructions mood induction procedure. Participants selected the response option which resembled their more ideal emotional state, and also rated the videos on valence, emotional-intensity and novelty (adapted from Affect Rating Dial). Results showed participants reliably chose the option with more positive valence, regardless of emotional category (Predictions=2113/2308, Accuracy=91.55%, WAIC=1.258). This provides evidence that valence functions as a ‘common currency’ across these different positive emotions, pointing towards the unidimensionality of valence by suggesting a shared form of positivity. We also generated stimuli with response options combining videos from multiple emotional categories to explore how valence was operationalised in the decision-making process. Rather than using a lexicographic, winner-takes-all, or loser-takes-all strategy, results showed participants usually summed the valence of individual videos to determine decision outcomes (Predictions=2121/2906, Accuracy=73%, WAIC=1.635). This suggests individuals tend to aggregate the valence of complex stimuli in an additive process when determining their ideal emotional state Finally, we had participants evaluate their experience of 11 positive emotions in terms of 15 candidate valence dimensions (e.g., pleasure, goal-congruence, action-tendency, morality, object-appraisal, inner-reinforcer). We utilised factor analysis to discern whether valence emerged as a single unified factor (unidimensional) or whether distinct elements of valence emerged as multiple factors (multidimensional). Parallel analysis indicated that only one of these factors was statistically significant beyond random chance. This finding lends further support in favour of the unidimensional view of positive valence.

Transcranial Direct Current Stimulation of the motor network to increase responsiveness in cognitive motor dissociation.

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Poster Session 6, Friday July 5th, Ito International Research Center, 4:00PM-5:00PM

Therapeutic options for patients with prolonged disorders of consciousness (PDOC) are limited, and patients often show little to no functional progress over time. It is widely recognized that a significant number of PDOC patients retain a much greater level of cognition and awareness than can be expected from their clinical diagnosis but are simply unable to demonstrate this with purposeful motor behaviours. This cognitive-motor dissociation (CMD) has been linked to specific impairments in the motor network that lead to a reduction in thalamo-cortical coupling. In previous work with healthy participants, we have demonstrated that transcranial direct current stimulation (tDCS), combined with passive mobilisations of the thumb, can successfully modulate this coupling and facilitate dynamics that are relevant for behavioural responsiveness in PDOC. In this study, we translated our tDCS intervention and multimodal neuroimaging assessments to PDOC patients to assess responsiveness to tDCS at clinical, behavioural and neural levels. Specifically, patients completed a 6-week long protocol including multiple sessions of magnetic resonance imaging (MRI), electroencephalography (EEG), electromyography (EMG), motion tracking, and standardised clinical assessments. All patients received 3 weeks (anodal, cathodal, sham, in a counterbalanced order and with at least 1 week washout) of 5 consecutive daily sessions of tDCS over the primary motor cortex (M1) combined with passive mobilisation of the thumb (2mA, 20 minutes). We used well-established CMD assessments and measured tDCS-induced changes in brain activity and connectivity, as well as in overt command following with EMG and motion tracking and the Coma Recovery Scale Revised. Three patients have completed the study to date (recruitment and data collection is ongoing). Patient 01 (UWS, 22y/o, ~1y post hypoxic-ischaemic brain injury) showed no evidence of CMD in MRI or EEG assessments. They exhibited temporary increases in CRS-R scores after each day of anodal tDCS, accompanied by an increase in alpha connectivity into the range commonly found in healthy individuals. Patient 02 (UWS, 81y/o, ~9m post hypoxic-ischaemic brain injury) also showed no evidence of CMD and, in this case, no behavioural changes in response to tDCS. While we observed a temporary decrease in power in the delta band and increase in power in the alpha bands after cathodal stimulation, neither of these changes moved the values into a range expected from a diagnosis other than UWS. Finally, Patient 03 (MCS-, 22y/o, ~5months post traumatic brain injury) showed covert command-following in both MRI and EEG assessments. After anodal tDCS, they showed increases in CRS-R with the presence of new behaviours not previously exhibited. This was accompanied by a strengthening of MRI markers of command following and increased EEG alpha network complexity. Unfortunately, this patient withdrew from the study and we were not able to complete the control (sham) assessments. It is thus unclear whether the identified improvements were related to the stimulation or if simply spontaneous fluctuations in the participant's clinical status. While our data at present are preliminary, our results suggest that M1-tDCS is a promising therapeutic intervention for PDOC patients and provide an initial insight into understanding the mechanisms of CMD.

Investigating the relationship between experiences of depersonalisation/derealisation, empathy and compassion

Harry Farmer (University of Washington)

Poster Session 6, Friday July 5th, Ito International Research Center, 4:00PM-5:00PM

Depersonalisation/Derealisation (DP/DR) is a dissociative state of consciousness characterised by the experience of disconnect from both oneself and the external world. A recent systematic review has found that transient symptoms of DP/DR have a lifetime occurrence rate between 26–74% of the general population while more chronic experiences occur in 1–2% Despite this prevalence, DP/DR is still an under research condition. On area in which there has been only very limited research is the how this detachment from the experience of the self impacts on sufferers relationship to others. The three studies presented here seek to address this lacuna by examining the relationship between non-clinical experiences of DP/DR, measured using the Cambridge Depersonalisation Scale, and two key aspects of social interaction: empathy and compassion. In study 1 we measured levels of cognitive and affective empathy using the Multifaceted Empathy Test and found that levels of DP/DR experiences negatively predicted both forms of empathy but that this effect was strongest for cognitive empathy, i.e. the ability to correctly identify the emotional states of others. Study 2 investigate the extent to which DP/DR experiences predicted compassion as measured by the Sussex-Oxford Compassion for Others Scale and found that overall levels of DP/DR negatively predicted compassion. Subsequent analysis revealed that the emotional numbing subscale of the CDS negatively predicted two components of compassion, significantly accounting for variance in understanding the universality of suffering and feeling for the person suffering. Finally, in study 3 we measured both empathy and compassion and found that the relationship between depersonalisation and compassion was mediated by levels of affective, but not cognitive, empathy. Taken together these results indicate that as well as modulating the experience of the self DP/DR experiences are also associated with decreased empathy and compassion for others. These effects may be explained by the self-other model of empathy which argues that in order to effectively empathise with others it is vital that an individual can clearly distinguish between their mental representations of self and other. The lack of this clear boundary in individuals with high levels of DP/DR may impact their social cognitive abilities and social interaction.

Feeling the Other through the Internet: A Scalable Web Platform for Perceptual Crossing Experiments

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Poster Session 6, Friday July 5th, Ito International Research Center, 4:00PM-5:00PM

The Perceptual Crossing Experiment (PCE) represents a minimal experimental paradigm for studying dyadic human interactions and social presence (Auvray & Rohde, 2012). This paradigm enables participants to sense each other's presence, allowing researchers to observe characteristic interaction patterns, such as turn-taking (Froese et al., 2014), and to quantitatively characterize behaviors indicative of social presence (Zapata-Fonseca et al., 2016; Kojima et al., 2017). Such characterizations, grounded in dyadic interactions and second-person perspectives (Schilbach et al., 2013), are crucial for understanding psychological disorders related to social deficits, prompting some studies to investigate these areas (Zapata-Fonseca et al., 2018). However, the scalability of these experiments has been limited, primarily due to the need for specialized equipment and personnel. In this study, we aimed to address this limitation by developing a new, scalable PCE experimental platform. Our design allows for the execution of experiments via web, requiring only smartphones for participant involvement. We adopted touch control as the input interface for controlling agent avatars and provided sensory feedback through sound. This setup enables subjects to interact with each other over the internet, facilitating the conduct of the experiment as a web-based activity. Preliminary experiments with our system confirmed its ability to replicate the basic characteristics of traditional PCE setups, which suggest the possibility to conduct PCE experiment with large number of subjects. The direct perception of the other's presence, emerging from bodily interactions, is an intriguing phenomenon that encourages us to pursue consciousness as a social phenomenon, not just a personal one. The PCE has provided an experimental paradigm to investigate the relationship between dyadic bodily interactions and the conscious feeling of social presence. However, due to the nature of dyadic interactions, the experiment has less controllability, and the resulting patterns tend to be diverse, which has resulted in relatively weak conclusions. We believe that collecting large-scale experimental data of PCE using our web-based platform will overcome this disadvantage and lead to a profound understanding of the joint agency or joint presence emerging from social interactions.

Motor Adaptation and Sense of Agency in Patients with Schizophrenia in Reaching Tasks

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Sense of agency (SoA) refers to the feeling of controlling one's actions and their effects on the outside world. Prior studies showed abnormal SoA in schizophrenia, and its cause is considered an imbalance between the precision of predictions (priors) and sensory inputs (likelihoods) based on Bayesian inference in computational psychiatry, which leads to an inability to update the internal model properly. This suggests that the motor adaptation process, which adapts one's action to environmental changes, is closely related to SoA(Bansal et al., 2019). In this study, we evaluated SoA and motor adaptation in schizophrenia within the same experimental framework for the first time. Twenty-one patients with schizophrenia and 20 healthy controls performed reaching tasks, including self-attribution and adaptation tasks. In both tasks, a part of the participant's trajectory was visually fed back with a random spatial bias after reaching. In the self-attribution task, visual feedback with a spatial bias ranging from 0cm to 5cm was presented, and participants made self-attribution after each trial. In the adaptation task, visual feedback with a spatial bias of either 2cm or 4cm was presented, and the adaptation rate was assessed by how much participants adjusted the direction of their reaching in the subsequent trial. We conducted t-tests to compare self-attribution rates and adaptation rates between the groups. There was no significant difference in self-attribution rates between groups ($p=0.6957$). However, the variance in self-attribution rates under spatial bias was significantly greater in patients than in healthy controls ($p=0.0479$). In the adaptation task, healthy controls showed higher adaptation rates with smaller spatial biases (2cm) compared to larger ones (4cm) ($p=2.9699\times10^{-4}$), while no significant difference in adaptation rates was observed in patients between conditions ($p=0.0726$). Finally, we examined the relationship between SoA and motor adaptation. In healthy controls, the self-attribution rate in no-spatial bias (0cm) condition was significantly negatively correlated with the adaptation rates in 2cm and 4cm conditions ($r=-0.7771$, $p=5.5494\times10^{-5}$; $r=-0.7714$, $p=6.8076\times10^{-5}$, respectively), while such correlation was not significant in patients. Even though many patients showed excessive or diminished self-attribution, there was no significant difference between groups due to high variability in SoA among patients. In healthy controls, while the adaptation rate increases with spatial bias up to a certain point, surpassing this level shifts the emphasis towards internal models over external information, consequently decreasing the adaptation rate, which is consistent with previous research. However, patients did not show significant changes in adaptation rates, which suggests they have difficulties in proper motor adaptations in response to environmental changes. A strong negative correlation between tasks in healthy controls implies participants who could accurately attribute visual feedback to themselves under no spatial bias tended to have lower adaptation rates, possibly indicating less influence from external distortions with more accurate internal models. This result suggests a close link between SoA and motor adaptation. However, the results suggest that they do not work well together in patients. This study is the first to suggest that there may be a dissociation between SoA and motor adaptation in schizophrenia.

Relationship between visual self-face processing and self-referential tasks in 24-month-old infants: Insights from eye movements and pupillometry

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Poster Session 6, Friday July 5th, Ito International Research Center, 4:00PM-5:00PM

Background
Mirror self-recognition (MSR) is the most prominent milestone in early developmental stages. According to Rochat's (2003) model of the development of self-awareness, it is assumed that infants acquire the ability to understand the self beyond the here and now after MSR, which is referred to as the "permanent self". Recent studies showed that the task using photographs of the self-face is a valid method to examine the development of self-recognition beyond the here and now sense. However, much is still unknown about how infants process and encode their self-face after they have acquired MSR and the permanent self. More specifically, it remains an open question whether the development of self-face processing is parallel with the emergence of MSR and the permanent self.
Aims
The current study was conducted to reveal the scanning pattern for own face in infants who have MSR and the permanent self by measuring infants' eye movements and pupil dilation for their own face, a strange peer's face, their mother's face, and a stranger female face presented in either upright or inverted orientation.
Methods
Participant Thirty-two 24-month-old infants (female = 15; mean = 734.281 days; range = 655 – 821 days) who passed the MSR task were included in the final analysis.
Procedure
1. 3-s free exploring task Each of the four different facial identities was presented in either the upright or inverted orientation. Infants were presented with all 16 possible facial stimuli.
2. MSR task This task measured whether infants exhibited self-directed behaviors toward a sticker surreptitiously put on their head, referring to the mirror reflection of themselves, which is considered a criterion for success.
3. Photo self-recognition (PSR) task This task measured whether infants recognized themselves based on the static image of their own-face. Passing the PSR task is considered to be an indicator of the acquisition of the permanent self. To pass this task, infants had to point to the image of their own face from an array of three images on the screen, correctly use any personal pronouns, or say their name or nickname.
Results
Analyses with GLMM models revealed that (1) infants fixed longer and more on the central part of faces regardless of face identity and orientation; (2) pupil dilation was greater in the upright orientation than in the inverted orientation only on self-face trials; and (3) there were no group differences between infants who passed and failed the PSR task in terms of eye movements and pupil dilation when viewing self-face.
Discussion & Implication
Our findings suggest that although visual scan patterns are similar between self-face and other identities, they may put more cognitive effort into processing the self-face. The results also imply that the capacity to understand temporal and spatial continuity of the self may not affect self-face processing in infancy. The lack of a relationship between PSR performance, eye movements, and pupil dilation suggests that self-face processing in infancy develops independently of understanding the spatiotemporal extended self.

Typical and disrupted small-world architecture and regional communication in full-term and preterm infants

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Introduction One fundamental property of conscious experiences is that they are both differentiated and integrated (Tononi & Edelman, 1998). Adult functional brain networks exhibit an elegant "small world" architecture. This optimal architecture enables efficient and cost-effective localized information processing and information integration between long-distance regions across the brain (Bassett & Bullmore, 2017). It remains unclear whether the functional small-world architecture is developed in neonates at birth and how this development may be altered by premature birth. Methods We used high-quality resting-state fMRI data from 278 full-term neonates (postmenstrual age at scan = 41.2 weeks ± 12.2 days) from the developing Human Connectome Project. We considered the effect of neonate age at the time of assessment separately from the effect of premature birth, by including two preterm neonate groups: the first (n = 72; PMA at scan = 40.9 weeks ± 14.6 days) born prior to but scanned at TEA, and the second (n = 70; PMA at scan = 34.7 weeks ± 12.7 days) born and scanned before TEA. The adults (n = 176, 22–36 years) from the Human Connectome Project were used as a reference group. 217 regions of the Power atlas were used for graph construction. To ensure our results were not driven by specific connection densities, we applied 21 proportional thresholds, from 10% to 30% in 1% increments, to threshold functional matrices. The global scale network efficiency was measured using small-world propensity (φ) (Muldoon et al., 2016), and nodal scale communication efficiency was measured using nodal efficiency (Achard & Bullmore, 2007). Results At the global scale, neonate groups had significantly lower small-world propensity and higher normalized clustering coefficient (lower segregation) relative to adults. Although different from the adults', full-term born neonates at birth and preterm neonates at TEA exhibited strong small-world architecture ($\varphi > 0.6$). Relative to full-term neonates, preterm neonates before TEA showed significantly lower small-world propensity and higher normalized path length (lower integration). Preterm neonates at TEA showed lower small-world propensity and higher normalized clustering coefficient relative to full-term neonates. At the nodal scale, relative to full-term neonates, premature neonates before TEA showed significantly lower nodal efficiency in 9/11 brain networks, with 32% of nodes primarily distributed within the somatomotor, dorsal attention, cingulo-opercular, and frontoparietal control network. By TEA, premature neonates showed large-scale recuperation of regional communication, with 1.4% of nodes, distributed in the frontoparietal, salience, and visual networks showing lower nodal efficiency relative to full-term neonates. Conclusions Our results suggest that, at full- term birth or by term-equivalent age, infants possess well-developed small-world architecture, which facilitates differentiated and integrated neural processes that give rise to conscious experiences. Conversely, they suggest that this brain infrastructure is significantly underdeveloped before infants reach term-equivalent age. Lastly, although functional network architecture matured significantly as preterm neonates reached TEA, some effects of premature birth persist. These findings improve understanding of the ontogeny of functional small-world architecture and efficiency of neural communication across distinct brain networks in infants at birth.

Looking at ourselves: Self-face recognition involves a theta-band network of posterior and midfrontal brain areas.

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Self-related visual information, especially one's own face and name, are processed in a specific, prioritized way. However, the spatio-temporal brain dynamics of this self-prioritization remains elusive. It is unclear, whether the self-prioritization occurs as an effect of enhancement and amplification, or rather as a facilitating automatization of processing self-referential information. In this EEG study, 25 married women (who changed their surnames after marriage, so that their past and present surnames could be used as stimuli) performed a detection task with faces and names from five categories: self, self from the past, friend, famous, and unknown person. The main aim was to determine the spectral, temporal, and spatial characteristics of early electrophysiological markers of self-referential processing. We report results of event-related component (ERP) and time-frequency analyses of local and inter-regional EEG activity, including analysis of theta phase coherence as a marker of functional connectivity, as well as local modulations of theta power. The earliest ERP self-relevance effects were displayed in the N2 component over midfrontal sites, where self-relevant conditions evoked smaller amplitudes than non-self-relevant categories. An increase of the midfrontal N2 often reflects a stronger involvement of some forms of executive control. Therefore, the N2 decrease may reflect a reduced need for control in terms of e.g., allocation of attentional resources when own face has been processed. Whereas at a later stage of processing, the P3b component showed a reversed pattern of activity, with the highest amplitude for the self-categories, possibly related to the allocation of attention. The ERP results suggest that self-prioritization might involve both, enhancement and automatization; the two effects could occur at different stages or levels of processing. Importantly, the analysis of local theta power at the occipitotemporal (visual) areas and interregional theta phase coherence between the visual and midfrontal areas showed that selfrelevance differentiation of faces began already about 100–300 ms after stimulus onset, thus earlier than the ERP effects. Specifically, the self-related faces (present and past self) elicited a smaller increase of the visual theta power than the self-irrelevant faces (i.e., famous and unknown face). Similarly, while phase coherence between the midfrontal and occipito-temporal areas showed an early burst of theta-band connectivity, this phasic increase tended to be smaller in the self-face condition than in the other face conditions. No such early effects were found for names. In conclusion, unlike the ERPs, the time-frequency results indicate that self-face relevance modulates already the early perceptual processing; locally in visual areas and in terms of functional connectivity between the visual and midfrontal areas. This could be interpreted as facilitation of visual processing of well-known faces; the occipital theta effect might reflect an automatization of self-referential processing. The findings of decreased N2 amplitudes in the self-referential conditions suggest that, at least in some cases, self-prioritization may not entail enhancement and amplification. Rather, we suggest that perceptual facilitation is attained through less effortful and more automatic processing of self-related information.

Is the prefrontal cortex necessary in conscious perception?

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Poster Session 6, Friday July 5th, Ito International Research Center, 4:00PM-5:00PM

The necessity of the prefrontal cortex (PFC) in generating consciousness remains a mystery. Frontal theories argue that the PFC is necessary for consciousness, while sensory theories propose that consciousness arises from posterior activity alone. To adjudicate between these theories, inattentional blindness (IB) is a particularly relevant visual phenomenon that can be used to study the role of the PFC in consciousness. IB is a phenomenon where a stimulus presented in plain-sight fails to reach conscious perception in some participants. IB is particularly useful because the stimuli is kept constant across participants, yet it reaches awareness for some but remains unconscious for others. Thus, any differences in neural activity between participants who were aware or unaware of the stimulus can be interpreted as being related to conscious awareness. We re-analysed EEG data from a no-report IB paradigm (N=30) conducted by Shafto and Pitts (2015) to assess the role of the PFC in the conscious perception of faces. This task systematically manipulated awareness and task-relevance of face stimuli. Here, frontal theories predict the PFC is involved in awareness, even when faces are task-irrelevant, whereas sensory theories predict the PFC should only be involved when faces are task-relevant. To test the role of the PFC in consciousness, we used DCM, a technique which enables estimating the directed influence that a brain region has on another. DCM is based on an anatomically-informed generative model to simulate EEG data given some parameters (e.g. effective connectivity). Using a data-driven approach, we specified a neuronal network consisting of nodes at the left- and right-occipital, fusiform gyri, and inferior frontal gyri. A second-level parametric empirical Bayes model was conducted on the modulatory connection parameters of the DCMs. This allowed us to estimate how connectivity was modulated at the group level across the variables of awareness and task-relevance. Results show that awareness increased connectivity from right-fusiform to the right-PFC and decreased from the left-PFC to the left-occipital ROIs (all posterior probability>0.95). These results do not entirely support either class of theories. Firstly, sensory theories predict recurrent connectivity should increase under awareness within sensory regions however, this was not observed. Secondly, although frontal theories predict an increase in connectivity to PFC as seen here (right-fusiform to PFC), they also predict an increase in recurrent connectivity to sensory areas. In our study, a decrease in feedback connectivity was observed instead. Moreover, an increase in connectivity was observed from the right-fusiform to the right-PFC, which was not predicted by either theory. Regarding the effect of task-relevance, connectivity from the right-fusiform to the right-PFC decreased, while intrinsic connections within the right-occipital, left- and right-PFC all increased. This was unexpected as both theories predict PFC connectivity to sensory regions should increase with task-relevancy. While this study does not provide evidence conclusively supporting either family of theories, this study advances research forward through hypothesis-driven studies of consciousness. This is currently much needed in the field and clarifying the role of the PFC in conscious processing remains vital in understanding the neural basis of consciousness.

Investigating the effects of chaotic aperiodicity on flicker light-triggered hallucinatory phenomena

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Poster Session 6, Friday July 5th, Ito International Research Center, 4:00PM-5:00PM

Flicker Light Stimulation (FLS) using a strobe light can induce transient hallucinatory perceptions of geometric patterns, colors, and motion. The intensity of the hallucinatory perceptions changes with its periodicity and frequency of FLS, suggesting that a certain periodicity most strongly induces perceptions. The mechanism for inducing geometric patterns through FLS is suggested to be the interaction of cortical lateral inhibition in the human visual system with resonant periodic stimulation. It is known that neurons in the cerebral cortex, including the visual cortex, engage in random spontaneous activities, and non-periodic FLS which resonances spontaneous activities might induce a stronger perception of geometric patterns than periodic FLS. Therefore, in this study, we investigated whether hallucinatory perceptions could be induced by FLS using chaos, which is theoretically known to strongly demonstrate non-periodicity. We prepared three stimulation conditions: Chaotic, Rhythmic, and Arrhythmic. The chaotic condition was a square wave with frequencies uniformly distributed from 3-18Hz according to the output of the Logistic map (with a duty cycle of 30%). The rhythmic condition was a square wave of a constant frequency at the average frequency of the chaotic condition, and the arrhythmic condition was based on normally distributed arrhythmic stimulation. Participants were exposed to each condition's stimulation for two minutes and then responded to the Altered State of Consciousness Scale and the Stroboscopic Visual Experience Survey (Amaya et. al., Plos One, 2023). The results showed a tendency for the rhythmic condition to induce a wider variety of geometric patterns and colors more strongly than the other conditions. Under the chaotic condition, the value for "How well do you recall your visual experience right now?" was lower, indicating difficulty in recalling the experience and a tendency for fewer types of geometric patterns to be remembered. This suggests that the increased complexity (in terms of the motion and arrangement of geometric patterns) over time in the chaotic condition might make it harder to remember. This study could serve as a starting point for investigating how the aperiodicity of FLS affects hallucinatory phenomena.

Introspecting influence in choice: accuracy of metacognitive reports in detecting choice bias

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Poster Session 6, Friday July 5th, Ito International Research Center, 4:00PM-5:00PM

Humans are often subject to biases and their decisions can be easily influenced by irrelevant or unreliable information. How much do people know about their own choice biases? Can people resist the influence of unreliable information on their choices? One crucial aspect of decision-making is the need to ponder information according to its trustworthiness. The ideal observer integrates pieces of evidence based on their reliability and entirely ignores unreliable information. In the present study, we investigated how participants deviate from the ideal observer by looking at their use of different levels of reliability of the information. We also investigated the capacity to introspect the influence of unreliable information on their choices as the measure of the metacognitive insight on one's own choice. We found that participants fail to ignore unreliable information even when its reliability is explicitly labelled. Furthermore, we found that participants less optimally integrated the sources of information that are reliably incorrect for the evidence, even though this was as informative as the reliably correct sources of information. Critically, participants were able to introspect the influence of different levels of reliability on their choices and participants reported their choices being influenced by unreliable information. Taken together, our study suggests that becoming aware of choice bias may not be sufficient to be able to ignore unreliable information and shed light on the distinction between choice bias and bias awareness.

Centre of gravity: A developmental foundation for self-consciousness in body and then mind

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Poster Session 6, Friday July 5th, Ito International Research Center, 4:00PM-5:00PM

For children, the immediate sense of “what” and “where” they are precedes the longer-term knowledge of “who” they are. Children feel and recognise their present bodily self years before they gain higher-order, complex knowledge of identity and selfhood (Butterworth, 1992:10.1207/s15327965pli0302_1). At some point during development, children must therefore learn how to disembody their sense of self, which is most evident during play when they imagine their self-consciousness inhabiting different bodies or other identities (e.g., animals, fictional characters, alter-egos, etc). But how do they perform this disembodiment? How do they cognitively generate a sense of “who” they are over the extended course of their life, and how does this process relate to the foundational bodily sense of “what” and “where” they are in time and space? The philosopher Dan Dennett (1992) proposed long ago that the imagined “who” sense of self can be ascribed to a “centre of narrative gravity”, which is analogous to the body’s centre of physical gravity except that physical matter is replaced by autobiographical memory. The key principle is that, although physically real, the body’s centre of gravity is an abstraction. It is always precisely at the self-centre because it is not a material “part” of the body. It is a point in space that is instead defined by the whole. Likewise, the accumulation of autobiographical memory revolves around an analogous abstraction in the mind, namely the narrative self. The centre of narrative gravity is the point in mental space that moves relative to all the autobiographical parts (i.e., discrete events) but remains fixed at the centre of the whole (i.e., continuous narrative). So when children disembody their self-consciousness, cognitively they have somehow learned to pinpoint this central point by placing discrete events on a temporal dimension from past to present and on into the future (and even tangentially into imaginary timelines). But, again, how do they effortlessly perform such a complex task? I would like to propose that disembodied self-consciousness only develops after the emergence of embodied self-consciousness because the former intimately and necessarily depends on the latter. As evidence, I point to various pathologies that demonstrate dysfunctional embodied-to-disembodied progression and regression. Neglected, institutionalised, and under-stimulated infants develop acute problems with vestibular functioning (Lin et al, 2005), episodic memory (Evren Gular et al., 2012: 10.1111/j.1467-7687.2011.01131.x), and self-concept (Ertekin, 2021: 10.1080/10888691.2019.1617146). In later life when narrative self-consciousness can be lost to pathology or cognitive decline, vestibular dysfunction is implicated in dementia (Previc, 2013: 10.1016/j.brainres.2013.08.058) and various psychiatric conditions (Gurvich et al., 2013: 10.1016/j.brainres.2013.08.058). I speculate that cognitive processes responsible for narrative self-consciousness have co-opted vestibular functioning that evolved to regulate the body’s centre of gravity. This points to the possible neurobiological reality of Dennett’s notion of a centre of narrative gravity, with specific neural correlates likely found in vestibular/graviceptive functioning of the salience network (Rousseau et al., 2020: 10.1093/cercor/bhaa376) and autobiographical functioning of the default mode network, the latter of which has been dubbed the brain’s centre of gravity (Davey & Harrison, 2018: 10.1002/wps.20553).

Neurophenomenological Dynamics of Attention and Chronic Pain

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We present a novel neurophenomenological approach to investigate the dynamics between attention and the experience of chronic pain. Building our paradigm around an individual-based approach, we used continuous ratings over 20 days to capture the pain and attention dynamics of two individuals diagnosed with complex regional pain syndrome (CRPS). Participants engaged in 20-minute attention tasks at their homes, directing their conscious focus towards either their painful limb, unaffected limb, heartbeat, or breath, leading to four task conditions. Low density EEG captured neural dynamics during the task. On an interface developed by our lab, after each condition, they reported their attention to the pain, to the task, pain intensity, type of pain and emotional levels over the time course of the task. The novelty of this approach lays in the insights gained into the temporal dynamics of the phenomenological experience of individuals, by analysing continuous ratings. Participants drew graphs to rate the intensity of an experience, such as the intensity of their pain over time, allowing us to analyse the temporal dynamics of their experience represented by the traces. Multiple regression analyses with adjusted R-squared and p-values revealed that up to 70% of variance in the pain intensity traces could be explained by attention to the pain and vice versa. The attention-pain relationship proved strongest when patients were consciously aiming to focus on their painful limb. Contrary to expectations, pain intensity generally better predicted attention to pain than attention to pain predicted pain intensity. This suggests that pain influences attention more than attention influences pain levels. Temporal analysis showed that interactions occurred primarily instantaneously, pain additionally showing delayed effects on attention. Neural analysis uncovered changes in the power bands between conditions, suggesting changes of conscious attention to reflect in continuous neural measures. The findings from our novel neurophenomenological measures show that interaction between attention and pain is strong and strongly predicts both pain intensity and attention to pain. Interestingly, pain levels appear to generally influence attention more than the other way around. Our results uncover insightful individual patterns and variations between objects of conscious attention for the temporal dynamics of pain and attention, accompanied by neural changes. These insights may ultimately not only lead to innovative, personalized therapeutic approaches, but also to a better understanding of the dynamical role of attention in the structure of the neurophenomenology of pain.

Troubles with Panpsychism: Micro-psyches and the Complex Subject Thesis

Liam P.Dempsey (University of Washington)

Poster Session 6, Friday July 5th, Ito International Research Center, 4:00PM-5:00PM

Troubles with Panpsychism: Micro-psyches and the Complex Subject Thesis ABSTRACT: The first decades of this century have witnessed a resurgence of interest in the idea that consciousness is a fundamental and ubiquitous feature of the natural world. One version of panpsychism posits the existence of micro-psyches; according to this view, the intrinsic natures of fundamental units of matter -- "physical ultimates" -- are experiential. The physical world, advocates maintain, is more interesting than it seems. This is true, I think, but the ubiquity of subjective experience at a fundamental level is ultimately untenable. Consider, if we accept, as seems plausible, that experience implies a subject having that experience, then the world contains innumerable micro-psyches, that is, innumerable micro-subjects of experience. One worry over such a view is that it leads to the "combination problem," the problem of explaining how micro-psyches combine so as to produce macro-minds of the sort we see in humans and other animals. I take this to be a species of the more familiar explanatory gap challenge and will set it aside for the purposes of this paper. Rather, I argue that micro-psychism is belied by the Complex Subject Thesis which holds that the subjects of experience are very complex, recursively self-maintaining systems of matter. Drawing upon insights from the embodied mind thesis as well as Peter Godfrey-Smith's recent work on the evolution of animal minds, I argue that micro-psychism is untenable because physical ultimates lack the prerequisites from which subjectivity arises, namely, complex and dynamical patterns of neural activity in systems of matter that interact with their environments to maintain themselves far from thermodynamic equilibrium. Subjectivity and agency, then, are natural outgrowths of the evolution of animals, beginning with sensing and targeted motion and culminating in global patterns of neural activity of dizzying complexity involving rhythmic patterns of synchronization and the electromagnetic fields they produce. Physical ultimates, by contrast, are windowless simples. Subjectivity, then, is a resultant feature of biological life that involves and encompasses many activities, including activities within exceedingly complex nervous systems. If one accepts that a necessary condition of experience is that it is subjective, then experience is a relatively rare phenomenon in nature. Lacking the necessary conditions for subjectivity, and thus experience, micro-psychism is either incoherent or is using "experience" equivocally. Whatever exists at the most fundamental levels of physical reality, it cannot be subjective experience. References Dempsey, L. and Shani, I., "Stressing the Flesh: In Defense of Strong Embodied Cognition," in Philosophy and Phenomenological Research, vol. 86, no. 3, 2013, 590-617. Dempsey, L. and Shani, I., "Three Misconceptions Concerning Strong Embodiment," in Phenomenology and the Cognitive Sciences, vol. 14, n. 4, 2015, 827-849. Godfrey-Smith, P., Metazoa: Animal Life and the Birth of the Mind, (New York: Farrar, Straus and Giroux, 2020). Godfrey-Smith, P., "Gradualism and the Evolution of Experience," in Philosophical Topics vol. 48, no. 1, 2020, 201-220.

Do infants have a sense of agency over their vocal behavior?

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Human infants start vocalizing in a goal directed fashion from birth, and to engage in coordinated proto-conversations with their caregivers a few months later. Roughly at the same time, they also start using their hands and limbs in a goal-directed fashion. But do infants experience a sense of agency (SoA) when they perform these actions? Research with adults suggests that forward models linking motor programs to their probable sensory consequences support the SoA. However, when and how these sensorimotor models emerge during childhood to support the SoA remains unclear. Despite the early onset of vocal behaviors in ontogeny, research on the development of the SoA has neglected this behavior so far, focusing instead on limb movements, which provided ambiguous findings potentially because infants do not yet master these motor behaviors. Vocalizations are interesting however because infants quickly master at least some aspects of their vocal behavior. We investigated whether infants already have a SoA over their vocal behaviors by measuring whether they monitor and correct for real-time perturbations of their fundamental frequency (f0) while vocalizing. We created an infant-friendly version of the "altered auditory feedback" paradigm used in speech motor control research to transpose the f0 of 3, 6 and 9-month-old infants' voices while they engaged in proto-conversations with their caregivers. Preliminary findings on a sample of 19 infants showed that 16 of them adjusted the f0 of their voice in the expected compensatory direction after the transposition. If confirmed in our whole planned sample of 40 participants, these results would constitute the first demonstration that infants can already predict with some specificity the likely consequences of some of their actions before their first birthday. I will discuss the potential implication of these findings for theories about the acquisition of vocal communication, and for theories about the function of the SoA.

Hallucinations: an interdisciplinary case-based approach to consciousness in undergraduate education

Luca Iemi (University of Washington)

Poster Session 6, Friday July 5th, Ito International Research Center, 4:00PM-5:00PM

Consciousness stands out as one of the most interdisciplinary topics in neuroscience research. While this may be challenging for students focused on one discipline, it is precisely the interdisciplinarity of consciousness that makes this topic so compelling for a wide range of people. How do we, as instructors, harness the potential of this interdisciplinarity to create and sustain a meaningful student engagement? In this project, I use case studies that focus on the phenomenon of hallucinations as an innovative pedagogical tool to introduce students to consciousness research and to increase student engagement. Hallucinations provide a direct insight into the workings of the brain because they are self-generated conscious experiences occurring in the absence of a corresponding sensory stimulus; yet, hallucinations are also deeply personal experiences which are shaped by individual and cultural interpretations. As such, they present an ideal subject for interdisciplinary case studies that challenge students to integrate and apply both biological (neuroscience) and non-biological (anthropology, philosophy of mind) perspectives. The case studies proposed in this project focus on childhood hallucinations of imaginary companions (e.g., “Slenderman”), trauma-related hallucinations in genocide survivors, the “prisoner’s cinema” experienced during solitary confinement, and psychic phenomena in religious and spiritualist groups. These case studies introduce key concepts in consciousness research including the integration between first-person and third-person data, the interaction between bottom-up and top-down brain signals, as well as various cognitive mechanisms shaping conscious experience (e.g., reality monitoring, voluntary and involuntary imagery). To determine whether this teaching method had a positive impact on students’ attitudes toward consciousness research, we conducted a mid-semester anonymous survey with 14 students enrolled in an undergraduate-level seminar at Barnard College (Columbia University, NYC). Preliminary findings demonstrate a significantly positive impact of the case studies on students’ self-reported interest in consciousness ($M = 1.40$, $SEM = 0.19$, on a scale of -2 to 2; $t(13) = 7.44$, $p < 0.001$, Cohen’s $d = 2.8$). Moreover, students expressed a significant interest to continue studying consciousness research post-course ($M = 1.07$, $SEM = 0.22$, on a scale of -2 to 2; $t(13) = 4.84$, $p < 0.001$, Cohen’s $d = 1.83$). Thematic analysis of open-ended survey comments revealed that students find case studies more effective than passive teaching methods used in other classes: this preference is attributed to case studies enhancing memorability, facilitating better comprehension of consciousness through lived experience, and increasing students’ ability to share their knowledge with students from other disciplines. Notably, there was a non-significant trend of increased interest in consciousness research at mid-semester evaluation compared to pre-course with a medium effect size ($p=0.08$, Cohen’s $d = 0.56$). A follow-up survey will be conducted at the end of the semester to confirm and expand upon these findings.

Qualia as intrinsic - Can one have their cake and eat it too?

Lucie Cauwet (University of Washington)

Poster Session 6, Friday July 5th, Ito International Research Center, 4:00PM-5:00PM

The term qualia is widely used by philosophers to refer to the phenomenal, subjective aspects of our mental life and experience. Yet, the nature of qualia and how they relate to the physical world remains a major source of disagreement which lies at the very core of one of philosophy's most hotly debated issues: the mind-body problem. One particularly contentious matter is the frequent claim that qualia are intrinsic. But what does it mean to say that qualia are intrinsic? And what repercusions does this claim have regarding the disputed relationship between minds and matter?

I argue that there are reasons to consider qualia to be intrinsic, but that this quickly leads to ontological complications. In particular, while most philosophers and scientists are commited to both physicalism and realism about phenomenal consciousness, I suggest that this can not be coherently defended.

In a broad sense, a thing has intrinsic properties in virtue of the way that thing is in itself, independently of other things. Intrinsic properties matter to our understanding of the world because many philosophers accept that they account for qualitative similarities and differences between the objects we study. Intrinsic properties are also intimately tied to our understanding of causal powers, since it is often argued that it is in virtue of their intrinsic properties that things can affect other things. Various proposals have been presented in the literature in order to better delineate the distinction between what counts as intrinsic or extrinsic. I especially explore influential attempts to analyze this distinction given by Kim (1982) and Lewis (1986). I outline two interpretations of "intrinsic" as either "fundamental" or "internal" and consider how they are connected in an ontology of the natural world. Within this framework, all that exists is either a fundamental relatum or is constituted by such relata and the relations between them. Although higher-level relata may exhibit internal intrinsic properties, these are ultimately derived from the fundamental intrinsic properties of the lower-level relata that constitute them, and to which they owe their potential causal powers.

I proceed to argue that, following Kim's account, qualia can be construed as internal and therefore intrinsic. However, as we tie our two notions of intrinsicality together, one is forced to either deny the reality of phenomenal consciousness, or to accept it at the cost of commiting to qualia being basic constituents of nature. I investigate how different responses to these complications lead to different stances on the nature of phenomenal consciousness and conflicting views regarding physicalism. In particular, I examine perspectives from panpsychism, neutral monism, emergentism and eliminativism.

Finally, I briefly contemplate the possibility of epistemic access to intrinsic properties and, turning towards structuralist views, consider an alternative ontology that might do away with, or at least minimize, the intrinsic-extrinsic (or relata-relation) distinction.

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Can the heart help unlock the neural correlates of time perception?

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Poster Session 6, Friday July 5th, Ito International Research Center, 4:00PM-5:00PM

Perception of time is a crucial element of conscious experience. Mounting evidence shows that physiological signals originating from within the body affect perception, including the perception of time. Indeed, a recent study from our lab (Arslanova et al., 2023 Curr Biol.) demonstrated that experienced time is distorted by autonomic signals arising from the heart. Participants judged the durations of simple visual stimuli, time-locked to the specific phases of the cardiac cycle. The stimuli were experienced as shorter when presented during the systole - when the heart contracts and baroreceptors fire signals to the brain, as compared to diastole - when the heart relaxes, and baroreceptors deactivate. While these results suggest that ascending cardiac signals play an important role in shaping time perception, the exact mechanisms by which these signals affect temporal processing remain unknown. In the present study, we combined the same experimental paradigm with electroencephalography (EEG) to examine how ascending cardiac signals during systole affect sensory-evoked electrophysiological responses - particularly P300, the contingent negative variation (CNV), and the stimulus offset response – and how these EEG components relate to the subjectively experienced stimulus duration. The study has been pre-registered, and the data collection will be completed in April. Firstly, we hypothesise that contracted experience of time during the cardiac systole may be related to the suppression of the EEG components associated with sensory processing (i.e., P300; Al et al., 2020 PNAS), implying that our experience of time arises directly from the way the brain processes sensory information. Secondly, cardiac systole may also modulate CNV – a component associated with evidence accumulation. This would suggest that the experience of time is intimately linked to how the brain accumulates evidence during perception, with slower accumulation leading to slower perceived passage of time (Damsma et al., 2021 J. Neurosci.). Thirdly, cardiac systole may increase EEG response at the stimulus offset that is related to predictive processing (Ofir & Landau, 2022 Curr Biol.), suggesting that distortions in how time is experienced are related to the decision-making process. Additionally, we anticipate that these EEG components will be modulated by the strength of the cortical processing of cardiac signals, reflected by the amplitude of heart-evoked potential. Identifying which of these EEG components predict the subjective contraction of time during the heart's contraction could offer a crucial insight into our understanding of neural mechanisms underlying subjective experience of time. Whilst data collection is still underway, we have a strong hypothesis-driven approach based on a robust behavioural paradigm, where any result would help understand the exact mechanism in which cardiac signals modulate the subjective experience of time – a missing link in understanding time perception as an embodied process.

Exploring the Dynamics of Consciousness and Sleep Disturbances in Alzheimer's Disease Through Integrated Information Decomposition

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Poster Session 6, Friday July 5th, Ito International Research Center, 4:00PM-5:00PM

Background: Recent studies and theoretical arguments have reformulated Alzheimer's disease (AD) as a disorder of consciousness (Huntley et al., 2021). Related to this, disruptions in sleep patterns and the sleep-wake cycle are among the earliest symptoms of AD (Cordone et al., 2021), offering an opportunity through which to examine the disease's impact on consciousness. Objective: This study uses resting state fMRI data from the Alzheimer's Disease Neuroimaging Initiative (ADNI), comprising 418 Controls (CN), 108 Alzheimer's Disease (AD) patients, and 310 individuals with Mild Cognitive Impairment (MCI), to explore the relationship between sleep disturbances and consciousness in AD. Methods: First, alertness was quantified via the functional connectivity k-means clustering methods of Haimovici et al. 2017, classifying individuals into Sleep or Awake state. The Integrated Information Decomposition (ΦID) approach (Luppi et al. 2022; Mediano et al. 2021) is an analytical framework that extends Partial Information Decomposition to study the distribution and dynamics of synergistic (generated jointly by the combination of sources), unique (provided by one source but not the other), and redundant (provided by both sources separately) information processing across brain regions over time. ΦIDwas applied to decompose the different types (synergistic vs redundant) of information flow between 232 cortical and subcortical brain regions, in two different conscious states (sleep vs awake). Results: No significant differences were found in the number of Sleep/Wake clusters between groups at the onset of the scan or throughout its duration. However, significant correlations were identified in the dynamics of information processing, particularly in the transition from redundancy to synergy across different states (Wake and Sleep) and among diagnostic categories. Notably, individuals with AD during sleep showed a relative increase in synergistic interactions, compared to both their control counterparts in sleep and wake states, and to MCI individuals in sleep. This was statistically significant in comparisons of Dementia Sleep vs CN Sleep ($p = 0.037$, $U = 11488.00$), Dementia Sleep vs CN Wake ($p = 0.008$, $U = 8238.00$), and Dementia Sleep vs MCI Wake ($p = 0.001$, $U = 7492.00$), highlighting altered information processing dynamics in AD. Conclusion: These initial findings show alterations in information processing and consciousness in AD, particularly during sleep. Significant differences were identified in synergistic and redundant brain interactions across states and diagnoses, suggesting that during sleep, the AD brain shifts towards increased synergistic information processing. This could indicate a compensatory mechanism or a breakdown in the normal information processing pathways, leading to more complex but potentially less efficient patterns of brain activity. Such shift could be a marker of disease progression or an inherent characteristic of AD pathology affecting brain dynamics during sleep. This approach offers a promising avenue by which to both AD as a disorder of consciousness. Furthermore we hope that future work here will lead to early diagnosis and prognosis, to facilitate effective early pharmaceutical intervention.

Vicarious experiences of music performance: Development of an online questionnaire

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Poster Session 6, Friday July 5th, Ito International Research Center, 4:00PM-5:00PM

Vicarious perception refers to our ability to co-represent the experiences of others. For example, passively observing another person being touched is associated with activity in similar brain regions as when we experience touch ourselves. For some people, vicarious perception can elicit a physical sensation (e.g., of touch) on their own body. These conscious vicarious experiences can be reliably assessed using self-report measures (the Vicarious Experience Questionnaire; VEQ). However, little is known about the extent to which we consciously represent the bodily experience of musicians when watching a performance, or how this might contribute to our perception of the piece. Here we designed an online questionnaire (based on the VEQ) to assess conscious vicarious experiences of music performance in 108 pianists and 95 non-pianists. Participants watched 4 videos of piano performances in a range of musical styles. After each one, participants answered questions about their vicarious experiences of touch, as well as the sense of body ownership and agency over the musician's movements. Vicarious experiences were more common among pianists than non-pianists. The strongest predictor of vicarious experience was whether the participant could play the particular piece of music being performed. Vicarious experiences were also associated with a greater emotional response to the performance. Next steps for the project will be to validate questionnaire responses with laboratory measures of vicarious representation.

Electrophysiological signatures of intentional and unintentional mind-wandering

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Poster Session 6, Friday July 5th, Ito International Research Center, 4:00PM-5:00PM

Mind-wandering (MW) refers to the experience wherein attention is engaged with thoughts uncoupled from ongoing external stimuli or demands. Estimated to occupy between 20-50% of waking activity, MW has been found to predict a wide range of functional outcomes in both the laboratory and daily life. It also varies along several phenomenological and cognitive dimensions, such as metacognition, emotional valence, or motivation which are associated with distinct neural, behavioral, clinical, and functional outcomes. A recent distinction with relevant practical and clinical applications concerns whether mind-wandering is engaged with or without intention. While some have argued that task unrelated thoughts (TUTs) primarily occur due to unintentional failures of executive control prior work suggests that mind-wandering does occur intentionally. We here aimed to delineate the neurophysiological substrates differentiating on-task thoughts, intentional TUTs, and unintentional TUTs. To this end, we analyzed an existing set of electroencephalography (EEG) recordings obtained during the performance of a sustained attention to response task (SART). Throughout the former paradigm, participants were prompted to report on their attentional state via thought probes which intermittently interrupted the task at hand and prompted them to classify their ongoing thoughts into on task (focused attention), and three categories of off task states: intentional task-unrelated thoughts (iTUT; future plans/memories) and unintentional TUT (uTUT; daydreaming). We analyzed 54 EEG markers derived from event-related potentials (ERPs), spectral power, information theory, and connectivity metrics (Sitt et al. Brain 2014) and conducted both, univariate and multivariate analyses. Univariate analysis revealed that theta band activity, both normalized and non-normalized, significantly discriminated between on-task and off-task states. Multivariate analysis further corroborated theta's pivotal role, demonstrating robust predictive accuracy in classifying cognitive states and particularly distinguishing on-task from uTUT with high feature importance attributed to theta EEG markers. Additionally, signal complexity (permutation entropy) and connectivity (weighted symbolic mutual information) within the theta band emerged as significant marker for the differentiation between on-task and iTUT states,. When differentiating within TUT categories, theta's relevance persisted, albeit this was slightly less pronounced compared to alpha band markers and signal Kolmogorov complexity. Our findings underscore the role for theta band as a marker across all contrasts, highlighting its significance in differentiating cognitive states. These results align with existing literature on the association of theta activity with executive functioning and cognitive control. Additionally, our observations shows how advanced statistical and novel machine learning techniques on EEG marker analysis,may Notstanding, inconsistencies in theta activity reports across studies, particularly those using the SART, alongside a limited sample of probe-caught on-task reports, imposes a cautious interpretation of this frequency´s specific role in MW contexts and calls for future research in this domain which diversifies datasets and tasks.

Non-ordinary states of consciousness to improve quality of life in oncology

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Poster Session 6, Friday July 5th, Ito International Research Center, 4:00PM-5:00PM

Background: The study of non-ordinary states of consciousness (NSC) through the study of their phenomenological, neurophysiological and clinical dimensions allows us to better understand the processes underlying these states and their clinical interests. In recent years, significant advancements have been made in hypnosis and meditation in oncology. Hypnosis is a NSC characterized by focused attention, increased suggestibility, dissociation and absorption. Mindful self-compassion (MSC) meditation is also a non-ordinary, self-induced and voluntary state of consciousness, characterized by a set of attentional processes and practices aimed at self-regulation of body and mind, with a focus on self-kindness. The positive effects of these mind-body interventions on recurrent symptoms in oncology (such as pain, fatigue, sleep or cognitive difficulties, or emotional distress) open the field to new therapeutic offers such as self-induced cognitive trance (SICT). SICT is derived from traditional Mongolian shamanic practice and can be induced by body movements, vocalizations, and chanting. It is still little-known, and its potential therapeutic benefits have never been rigorously studied. The goal of our innovative project is to characterise the phenomenological dimensions, neurophysiological mechanisms and to robustly evaluate the clinical benefits of these interventions (hypnosis, MSC meditation, and SICT) on patients with all types of cancers. Method: We used a controlled longitudinal design based on preferences to assess the impact of the three group interventions (self-hypnosis, MSC meditation, SICT; duration: 2 to 8 weeks) compared to a control group, for a total sample of 160 participants. These interventions provide practical exercises to teach the chosen technique and patients are encouraged to practice at home. Each patient is assessed using various phenomenological (e.g., absorption, automaticity, dissociation), neurophysiological (electroencephalography, electromyogram, electrocardiogram, respiration, body temperature and tumor markers) and clinical measures (e.g., pain, fatigue, sleep or cognitive difficulties, or emotional distress) before the group sessions, immediately after, 3 months and 1 year post-intervention. Results: Regarding preliminary phenomenological results carried out on half of the sample, all participants entered in an NSC. The results showed an increase of the dissociation for the 3 techniques compared to ordinary consciousness and an increase of the absorption and automaticity of thought for SICT. At the neurophysiological level, preliminary analyses were carried out on the first complete group (SICT, N = 33). The results indicate a significant increase in cortical activity in the delta, theta and gamma bands and a decrease in beta frequency and 1/f exponent in SICT compared to ordinary consciousness. A left hemispheric prevalence is apparent for the gamma, beta and theta frequency bands. Preliminary clinical results for the three interventions, assessed immediately after the intervention, point to an improvement in sleep difficulties, general fatigue, emotional distress, as well as perceived cognitive difficulties and their impact on daily life. Only pain seemed to show no particular modification. Conclusion: These preliminary results show phenomenological and neurophysiological changes during 3 NSC compared to ordinary consciousness. In addition, clinical results point to an improvement in quality of life after cancer.

The Effort State Theory of The Experience of Effort

Oliver Josef DumoloRalley (University of Washington)

Poster Session 6, Friday July 5th, Ito International Research Center, 4:00PM-5:00PM

Why do we have an experience of effort when we perform certain mental and physical tasks? On this poster I present a novel theory to explain the experience of effort and, in so doing, provide an account of how and why this unique experience arises, why it is a conscious phenomenon and why it has its peculiar phenomenology. Crucially, this theory states that the experience of effort is the experiential aspect of a brain state that functions to enable sustained attempts at demanding tasks. This concept stems from observations that the experience of effort occurs when subjects perform tasks that are, in various ways, resource-demanding. I develop the view that, because the performance of a resource-demanding task is likely to carry significant costs, an accompanying process of monitoring and analysis of the estimated costs and benefits of continued task-oriented activity occurs. I propose that, in these circumstances, subjects must deploy a high level of cognitive control in order to maintain motivation to continue the given activity, rather than discontinuing it or switching to an alternative activity. In doing so, a brain state arises that is characterised by the performance of a higher order task that enables the continued performance of a given lower order task. I call this state an ‘effort state,’ and conjecture that effort states are the defining correlates of the experience of effort. I then make two arguments in support of this view. First, I outline how effort states seem to provide the required conditions for instantiating consciousness, in accordance with two leading theories of consciousness - Global Workspace Theory and Integrated Information Theory. Second, I argue that effort states help to explain the phenomenology of the experience of effort because they are, in a sense, mixed affective states, by virtue of them involving simultaneous representations of both costs and benefits. I conclude by highlighting that the experience of effort is a key component of human agency and a fascinating phenomenal type in its own right. Accordingly, I hope that this theory contributes to a deeper understanding of this important subject and provides useful conceptual underpinnings for future research.

The many lives of Phi: integrated information theory as a multidimensional and multilayered framework

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Integrated Information Theory (IIT) stands as an ambitious evolving framework in the field of consciousness studies, encompassing novel scientific, mathematical and philosophical ideas. This complexity, while enriching, can make it challenging to simultaneously attain a full view of the theory and a grasp of its concepts up close. This work offers a fresh perspective on IIT with the aim of highlighting and clarifying the theory's multidimensional and multilayered structure. In this presentation, we will navigate through the conceptual layers of IIT, from its general meta-theoretical premises for explaining consciousness, its cause-effect power view of the physical domain, to the core concepts that underpin the formulation of its measure of consciousness, namely Φ and Φ-structures. We will then delineate the experimental, formal and metaphysical/epistemological dimensions of IIT, which we argue are irreducible yet interdependent on each other. By focusing on each dimension while bracketing the other ones, we identify three distinct versions of the theory: neuronal, theoretical and worldview IIT. After exploring IIT's internal structure, we situate it more broadly, examining its position as a pivotal research program in consciousness science and its interactions with neighboring disciplines such as complex systems theory, psychophysics and philosophy of mind. By presenting IIT in this multifaceted manner, wherein 'weaker' and 'stronger' approaches coexist, we aim to underscore the myriad ways one can engage with the theory, either critically or constructively, paving the way for clearer and more nuanced discussions in the field. Finally, built upon this scaffold, we consider possible ways IIT could be proven wrong. Crucially, our exposition makes it clear how specific types of failure of IIT in one dimension or layer may not affect its validity and contribution in others.

Neural Dynamics of Emotional Processing: Aperiodic EEG Components and Thalamo-Cortical Mechanisms in Response to Emotional Stimuli

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Poster Session 6, Friday July 5th, Ito International Research Center, 4:00PM-5:00PM

Emotions embody intricate phenomena spanning various dimensions, notably arousal and valence, where arousal signifies the level of excitement, and valence gauges the degree of pleasantness. Existing research has primarily focused on changes in canonical frequency bands, characterized as periodic activity, to comprehend the electrophysiological foundations of emotions. However, the impact of aperiodic activity, characterized as electrophysiological noise, on emotional arousal and valence states remains relatively unexplored. Here, we examined the relationship between the aperiodic component of the power spectra, and the arousal and valence states using the EEG dataset sourced from the Open Source Affective Database for Emotion Analysis using Physiological Signals (N=32, mean age = 26.9, Female = 16). Participants engaged in viewing 40 distinct 60-second music videos with fixed 5-second inter-trial intervals, followed by providing emotional ratings on 1-9 Likert scales for valence and arousal. Data were categorized into high and low arousal and valence trials based on participant ratings. Subsequently, we assessed the power spectrum and segregated it into periodic and aperiodic components using fitting oscillations and the one-over method. Our findings revealed a significant rise in the exponent and offset, key parameters defining the aperiodic component, during the exposure to video clips evoking high arousal, compared to those inducing low arousal. This outcome suggests a potential link between aperiodic components and the intensity of emotional arousal, expanding our understanding beyond the traditionally studied rhythmic components. Interestingly, we did not observe notable differences in aperiodic components when comparing high and low valence, indicating that the influence of valence on these EEG features may be more nuanced. The reduction in peak alpha power during high arousal, in contrast to low arousal conditions, aligns with previous studies associating alpha power with emotional arousal. However, our results contribute novel insights by highlighting the role of aperiodic components alongside alpha oscillations, underscoring the complexity of EEG signals in emotional contexts. Delving deeper into the mechanistic foundations of both arrhythmic and rhythmic constituents, our investigation employed the thalamo-cortical model. Simulations were conducted to replicate neural responses associated with emotional arousal states by manipulating the coupling strength between the reticular and relay thalamic nucleus. Our findings suggest that enhanced coupling between thalamic reticular and relay nuclei within this model can replicate the observed changes in aperiodic and periodic activity with increasing arousal. This implies that a thalamo-cortical circuit plays a pivotal role in shaping arousal-related brain dynamics. Overall our results demonstrate the significance of aperiodic activity in determining emotional arousal states. Moreover, these results also contribute to the growing body of research endorsing the physiological role of aperiodic activity.

Exploring the influence of optimism on perceptual color vividness

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The human inclination towards optimism is a well-documented phenomenon, playing a crucial role in shaping our behaviors and decision-making processes across various contexts. Despite extensive research, the potential impact of this optimistic predisposition on perceptual experiences, specifically in the construction of our colorful world, remains underexplored. This study seeks to investigate whether the concept of 'rose-colored glasses', a metaphor for viewing challenges with a positive outlook, have a psychological underpinning – such as the ability to perceive a desaturated scene as more colorful and lively. Specifically, we aim to examine the hypothesis that individuals' perceptions of the color of natural scenes are systematically biased towards greater vividness and explore whether such biases are correlated with individual differences in optimism.

Two hundred healthy participants were recruited to participate in two tasks designed to assess their perception of saturation and their level of optimism. The first task, referred to as the saturation reproduction task, aimed to measure participants' biases in perceiving the saturation of natural scenes. During this task, participants were shown images of natural scenes for a brief period and were then asked to replicate the saturation of these images using a slider bar. The degree of saturation bias was determined by calculating the average difference between the saturation levels reproduced by the participants and the actual saturation levels of the images. The second task, named the future prediction task, quantified optimism levels among participants. In this task, participants were prompted to predict the likelihood of experiencing various positive and negative life events in the future. The optimism bias was determined by comparing the estimated probabilities of positive events occurring versus negative events.

The results of our study revealed that approximately 70% of participants exhibited a significant bias towards perceiving colors in natural scenes with increased vividness. More importantly, we identified a positive correlation between this saturation bias and the participants' levels of optimism. This suggests that individuals with higher levels of optimism are more likely to perceive and remember natural scenes as being more colorfully vivid than they are.

Our findings align with the notion that optimism does not merely color emotional assessment but also extends to the sensory perception of the environment, manifesting in a saturation bias in color perception. This suggests that optimistic individuals may experience the world in a more vibrant and colorful manner. The association between optimism and enhanced perception of color vividness could contribute to the broader understanding of how positive psychological states influence sensory experiences, offering insights into the intricate relationship between cognition, emotion, and perception.

Steepness of aperiodic EEG spectrum predicts conscious auditory perception of errors during participant’s own vocalization

Sampo Tanskanen (University of Washington), Daniel Suchý (University of Turku), Henry Railo (University of Turku)

Poster Session 6, Friday July 5th, Ito International Research Center, 4:00PM-5:00PM

Individual’s speech is regulated based on auditory feedback: When a mismatch between attempted and produced speech is detected, the brain initiates corrections to speech motor commands. While being largely an automatic and reflective process, evidence suggests that participants’ perception of vocal errors may correlate with the corrections to the motor commands. Previous studies suggest that ongoing activity in the brain predicts how individuals consciously perceive environmental (i.e., not self-produced) sounds. In studies utilizing near-threshold stimuli, the power of pre-stimulus encephalogram (EEG) in 8-14 Hz (alpha band) has been shown to correlate with stimulus perception. However, since the brain can predict the consequences of its own actions, neural processing of one’s own speech is remarkably different from the processing of external sounds. Here, we examine whether pre-stimulus EEG predicts the conscious perception of errors in individual’s own vocalization during speech production. We studied the perception of errors in one’s own speech with the frequency-altered feedback (FAF) paradigm. In the paradigm, participants hear their own voice in real-time through headphones during vocalization, and an artificial pitch change (perturbation) is introduced to their auditory feedback. We gathered data from 35 right-handed healthy participants who participated in an EEG study consisting of an FAF experiment where the perturbation was presented near the level of the perceptual threshold. The EEG was recorded with 32 channels and the participants reported their perception of the perturbation using the four-step “Perceptual Awareness Rating Scale”. Power spectral density was obtained from each participant’s EEG (1000–800 ms before the perturbation onset) using the Welch’s method. The FOOOF package was used for estimating periodic (alpha- and beta powers) and aperiodic (exponent and offset powers) parameters of the EEG powers spectrum separately for aware (three highest awareness ratings) and unaware (the lowest awareness rating) trials. The correlation between the variables were tested with linear mixed-effects models. Our results indicate that the power of alpha or beta oscillations did not predict the participants’ perception of the perturbation. However, a steeper pre-stimulus power-frequency spectrum (i.e., the exponent of the FOOOF model) predicted the participants’ likelihood of reporting aware perception of the perturbation. The EEG spectrum’s overall level of power (i.e., offset of the FOOOF model) did not correlate with awareness of the perturbation. In previous studies, the changes in the exponent has been associated with the balance of excitatory and inhibitory activity (E:I) in the brain. In light of this, our results suggest that pre-error E:I ratio of electrophysiological brain activity may predict conscious perception of errors in one’s own vocalization.

Do low gamma range auditory steady-state responses indicate loss of consciousness during general anesthesia?

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Poster Session 6, Friday July 5th, Ito International Research Center, 4:00PM-5:00PM

The auditory steady-state response (ASSR) is an EEG response elicited by periodic auditory stimulation. The ASSR is generated by various brain structures, with the response to 40-Hz stimulation falling within the low gamma range (LGR), attributed to the thalamocortical system. The objective of the current study was to assess the sensitivity of ASSR to the induced loss of consciousness during propofol-remifentanil anesthesia. The study involved 26 participants undergoing planned surgical procedures. The experimental protocol consisted of two types of stimulation: a constant, click-based 40-Hz stimulation and a series of clicks covering high and low gamma frequencies (30-100 Hz). EEG data were collected during anesthesia induction, maintenance, and the post-anesthesia period. Additionally, bispectral index (BIS) scores, and propofol and remifentanil effect-site concentrations were simultaneously recorded. For the analysis of ASSR, frontocentral channels were included, and the inter-trial phase clustering was calculated. We observed a significant abolition of the 40-Hz auditory steady-state response (ASSR) during anesthesia maintenance. The selectivity of the 40 Hz response for the loss of consciousness was further affirmed by wide-band stimulation results, where the most discriminative part of this response was observed in the low gamma range (28-50 Hz). Interestingly, no dose-dependent relationship was observed between propofol concentration and the strength of the LGR response during anesthesia maintenance. Furthermore, no discernible relationship was identified between bispectral index (BIS) levels below 60 and the LGR response, which, in both cases, was virtually absent. These findings suggest that, at the concentration levels utilized in our study, the LGR response uniformly became suppressed upon reaching surgical levels of anesthesia. The study demonstrates that the LGR ASSR (40 Hz) could potentially function as a marker for the loss of consciousness during anesthesia maintenance. However, the absence of a correlation between BIS index, propofol concentration, and low gamma during this phase suggests that LGR responses may not be suitable for monitoring the depth of anesthesia and the titration of anesthetics. Our findings align with other evidence indicating that LGR ASSR is sensitive to changes in the level of consciousness in disorders of consciousness and during sleep. In conclusion, the outcomes of our study suggest the potential of LGR ASSR in discriminating between different states of consciousness, presenting possible clinical applications in the future.

Subjective bodily sensations in aesthetic experiences based on image stimuli using the Body Map Test.

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Poster Session 6, Friday July 5th, Ito International Research Center, 4:00PM-5:00PM

Aesthetic experiences influence our mind and body. For instance, watching an emotionally moving picture can stimulate our cardiovascular system, accelerating our heart rate, while seeing a fearful image might induce goosebumps. These bodily sensations are also closely related to emotions. Despite the impact of aesthetic experiences, the relationship between subjective feeling and bodily sensations remains unclear. Recently, the body-map test, which enable researchers to assess how emotions/feelings are associated to representation within one's body schema, has emerged as a tool to assess subjective bodily sensation. In this study, we conducted an online experiment utilizing the body-map test to explore the relationship between subjective bodily sensation and the experience of beauty. 511 participants (female = 238) were randomly presented with 18 images, which were selected from a corpus of 347 images randomly extracted from the PARA dataset. These images were carefully chosen to ensure a balanced representation of aesthetic ratings and categories. Subjects were then asked to evaluate the experience of beauty and emotional variables (Valence, Arousal) of each image using a 9-point Likert scale. Additionally, the body-map test was employed to identify the specific body parts that participants felt from the images. The intensity of the body map was then totaled for each body part, and correlation analysis was performed between the intensity of the body map and subjective aesthetic sensation. The results revealed a correlation between the intensity of the experience of beauty and heart sensations (r=0.23), as well as a correlation between the strength of arousal and abdomen sensation (r=0.17). These findings suggest a link between aesthetic experiences and heart sensation, among other interoception. Moreover, abdominal and heart sensations may play distinct roles in the elicitation of emotions, even within the realm of subjective bodily sensations. Future research is expected to explore the differences between physical sensation as a physiological response and subjective bodily sensation.

Sleep scoring of unusual bodily experiences facilitated by a pre-sleep meditation protocol

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Poster Session 6, Friday July 5th, Ito International Research Center, 4:00PM-5:00PM

Unusual bodily experiences (UBE) refer to illusory sensations involving vestibular-motor experiences and distorted perceptions of the body and/or surroundings. These can include floating and falling sensations, or out-of-body experiences, where individuals perceive themselves as located outside of the physical body. The study of UBEs offers a unique window to explore the foundations of (un)conscious mental states, and potentially also contribute to unveil the brain processes involved in body representation and self-location. While UBEs are relatively common in sleep and dreaming states, previous neuroimaging studies have primarily focused on either clinical patients or healthy awake subjects. Thus, only anecdotal reports of sleep-related UBEs are available in the literature, all conducted with a small number of EEG electrodes. In this study, we have performed sleep staging of high-density EEG data from individuals who reported UBEs in a controlled sleep laboratory. Other polysomnographic parameters such as ocular (EOG), muscular (EMG) and cardiac (ECG) activity were also examined. Building on prior research, we hypothesize that UBEs arise specifically during transitions to sleep and/or during rapid eye movements (REM) sleep. During experiments in the sleep lab, 30 volunteers followed a specific pre-sleep meditation protocol to facilitate UBEs and lucid dreams (a sleep phenomenon where individuals are aware of being in a dream state). Participants were instructed to conduct a left-right-left-right (LRLR) eye movement each time they experienced any UBEs—either during the falling asleep process or while lucid dreaming—and to describe these experiences in detail both upon waking up and during a final phenomenological interview. To date, N=15 individuals reported UBEs that were successfully time-matched with the electrophysiological recordings using LRLR eye movements as onset markers, resulting in a total of n=28 episodes (up to 4 per subject). We examined the phenomenology of these experiences and identified common patterns, grouping UBEs into different categories. Furthermore, we are currently performing sleep staging of the electrophysiological data following the rules provided by the American Academy of Sleep Medicine (AASM). Our preliminary results reveal that UBEs tend to appear during episodes of either physiological wakefulness (33.33%), fragmented non-REM sleep (33.33%), REM sleep (26.67%), or non-REM sleep periods resulting from REM arousals (6.67%). From a phenomenological perspective, we identified UBEs containing one or more of the following features: (1) Motor-vestibular sensations (n=17 time-marked experiences in N=11 subjects), including out-of-body-like experiences and other sensations such as floating, swinging or spinning; (2) Episodes with a lack of bodily sensations and/or position (n=11, N=6); (3) Episodes involving distortion of the surroundings and/or body (n=7, N=7); and (4) Tactile sensations, such as pressure or warmth (n=9, N=5). Our preliminary results are in line with previous studies associating UBEs with wake-sleep transitions and REM sleep. Additionally, UBEs have been linked to meditative states, suggesting that bodily sensations reported during wakefulness in the present study may have similar characteristics. Further steps in the data collection process and analysis will clarify the sleep stages where UBEs are most likely to appear, as well as any potential associations between the identified sleep stages and the UBE phenomenology.

Select-A-Frame: Constructing Comprehensive and Comparable Metacognitive Behavioral Profiles

Vanessa Ceja (University of Washington), Megan A. K. Peters (University of California, Irvine)

Poster Session 6, Friday July 5th, Ito International Research Center, 4:00PM-5:00PM

Metacognitive bias, particularly positive evidence bias, is a useful tool for studying metacognition since it allows a clear dissociation between confidence behaviors and the accuracy of primary perceptual processes. This metacognitive bias manifests as an overreliance on “positive evidence” (evidence supporting the decision an agent just made) when reporting confidence in that choice. Our motivating question for this study asks to what extent these kinds of metacognitive biases are similar or generalizable across different types of tasks. We have created a novel online library of four 3-Alternative Forced Choice perceptual (PTs) and cognitive/value-based (C/VTs) reaction time behavioral tasks to collect within-subject measures of performance (“T1”) and confidence (“T2”) within 14 distinct conditions that are (a) shared across all tasks and (b) specifically designed to dissociate performance from confidence using the positive evidence bias. We use this library to characterize metacognitive behavioral profiles (BPs) for each subject in each task, i.e. quantitative “fingerprint”-like relationships between performance and confidence. To quantify each BP we first built a choice frequency distribution for each presented choice defining T1-BP for each condition within each task. For T2-BP for each condition within each task, we calculated the average confidence rating conditioned on choice. We computed T1-BPs and T2-BPs in this way for all tasks and for all conditions. Then, we quantified the similarity in BPs (defined by the combination of T1-BPs and T2-BPs) within every condition but across tasks using sum of squared error (SSE) as a dissimilarity metric. To test for systematic differences, we calculated mean SSE1 and SSE2 for all pairs of tasks, across all conditions. Preliminary results show less dissimilarity within PTs T1-BPs and C/VTs T2-BPs and more dissimilarity within PTs T2-BPs and C/VTs T1-BPs. These results suggest that while perceptual tasks produced similar performance behavior, and cognitive/value-based tasks produced similar confidence behavior, the relationship between T1 and T2 behavior may differ significantly across cognitive versus perceptual domains and even between two tasks in the same domain. Ongoing research examines the degree to which these findings will remain stable across a broader cohort of subjects.

Propofol induced burst suppression evokes neuronal firing and local field potential traveling waves in the human brain

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Poster Session 6, Friday July 5th, Ito International Research Center, 4:00PM-5:00PM

Despite the importance of general anesthesia for surgical procedures, a systems neuroscience explanation for how anesthetic drugs cause unconsciousness is lacking. Over the past few decades there has been increasing interest in how propagating synaptic activity across the brain, known as neural traveling waves, can modulate underlying neuronal activity. Ours is the first study to characterize the spatiotemporal dynamics of traveling waves in human action potential and local field potential (LFP) activity during medically induced loss of consciousness (mLOC). I hypothesized that burst suppression evokes brain oscillations that propagate as traveling waves. I examined direct brain recordings during mLOC, from Utah-style microelectrode arrays from two adult patients undergoing monitoring for surgical treatment for medically resistant seizures. Upon identification of burst suppression, I regressed the timing of LFP and neuronal firing against the two spatial dimensions of the microelectrode array. I operationally defined traveling waves as regression models with slopes that significantly differed from zero, assessed via an F-test against a permutation distribution of 500 spatially shuffled LFP or firing times. I fit these models with both L1 and L2 regularization for both signals, and controlled for false positives with permutation testing. I recorded a total of 96 LFPs and 71 single unit recordings for patient one. Out of 93 total bursts in patient one, traveling waves were identified from 30% of LFPs and from 54% of single unit recordings, using the L1 regularization regression model. Using the L2 regularization regression model, traveling waves were identified from 52% of LFPs and from 29% of single unit recordings. I therefore showed that neural activity during burst suppression propagated as traveling waves, suggesting that subsequent research into anesthesia burst suppression evoked traveling waves may identify spatiotemporal signatures of traveling waves that can differentiate among consciousness states at the level of local neuronal populations.

Experimental paradigm for measuring metacognitive awareness of auditory feedback errors during self-produced vocalization

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Poster Session 6, Friday July 5th, Ito International Research Center, 4:00PM-5:00PM

Continuous monitoring of speech auditory feedback is integral to fluent and accurate speech production. Neural control systems compare internal representations of intended speech to actual speech output and, upon mismatch detection, modify speech to compensate for the discrepancy. Although these control systems are often assumed to function automatically, situations such as learning to pronounce foreign phonemes or compensating for a speech impairment require conscious evaluation of auditory feedback. Metacognition is the process that enables individuals to evaluate their performance in different tasks; in this case how well one's speech matches the intended target. How individuals differ in their ability to metacognitively assess errors in auditory feedback, and whether this predicts how they adjust their speech in response to these errors, has not been studied.

We developed a psychophysical experimental paradigm to measure an individual's ability to detect and metacognitively assess auditory feedback errors in self-produced vocalization. We utilized the widely used altered auditory feedback paradigm where speech motor control is studied by perturbing auditory feedback with artificial errors resulting in a perceived mismatch between intended and perceived speech. This perceived mismatch has been shown to lead to an adjustment in speech output in many earlier studies. Our paradigm consisted of a two-interval forced-choice (2IFC) task where participants produced sustained vocalizations of the vowel /u/ for 4 s at a time while their voice was fed back to them in real time through headphones. During each vocalization, the pitch (fundamental frequency, F0) of the auditory feedback was shifted upward for 200 ms during one of two intervals (A or B) displayed on a screen in front of the participants. After each vocalization, the participants evaluated whether the pitch-shift was during interval A or B (perceptual discrimination) and, in addition, reported their confidence in their answer (metacognitive judgement). Pitch-shift magnitudes were individually calibrated for each participant to achieve a constant discrimination accuracy.

We used signal detection theory to estimate participants' (n = 72 healthy adults) discrimination sensitivity (d'), metacognitive sensitivity (meta-d') and metacognitive efficiency (Mratio) regarding the detection of pitch-shifts in their auditory feedback. In addition, we used linear mixed-effects modelling to examine whether discrimination sensitivity, metacognitive sensitivity or metacognitive efficiency predict how participants adjust their vocalization after the pitch-shift. Results revealed individual differences in discrimination and metacognitive awareness of errors in self-produced vocalization, but these factors did not modulate the magnitude of vocal responses. However, confidence level modulated vocal response magnitude within participants: the more confident a participant reported being in their answer on a given trial, the more they had adjusted their vocalization to the opposite direction of the pitch-shift. This result reveals an association between speech motor control, traditionally deemed largely automatic and unconscious, and the conscious evaluation of auditory feedback errors during self-produced vocalization.

Three thinkers' artificial consciousness: Sociology and Neuroscience perspective

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Poster Session 6, Friday July 5th, Ito International Research Center, 4:00PM-5:00PM

The definition of consciousness differs greatly among researchers of different disciplines, such as philosophy, psychology and sociology. Currently, scientific consciousness research is hot topic for biologists and neuroscientists. Computer scientists works as technical supporters and social scientist provides stories of humanity and philosophy to media. Recent years, with advanced in fMRI, patch-clamp, and brain-scanning technologies, neuroscientists are making more and more precise connection map of the human brain, but far from success. The method can't collect signals from every synapse to understand detail neural circuit function. On the other side, the emergence of Large Language models (LLMs), makes "human-like" responses what might be defined as "artificial consciousness". LLMs give sociologists and psychologists opportunities to study "artificial consciousness". A joint team, including sociologist, neuroscientist and computer scientist, started this project to study both sociological and neuroscience properties of "artificial consciousness". The team chose ChatGLM-6B, an open source LLM released by Tsinghua University, as the basic "artificial consciousness". Sociologist provides academic works of Émile Durkheim, Karl Marx, and Max Weber, three most famous and well-studied thinkers of modern sociology. Computer scientist use these textual data as morphemes to fine-tune the basic models and produced three "social artificial consciousness". Neuroscientist and computer scientist implant statistics probe into three "social artificial consciousness" as electrodes commonly used in brain science. The researchers asked "social artificial consciousness" current political issues and got different answers. The results were independently interpreted by sociologists and neuroscientists in their respective fields, and then cross compared the explainable parts to find an understanding of "artificial consciousness". The joint team of social and life science scholars conducted two double-blind back-to-back experiments to study "artificial consciousness" through computer science. Social scientists analyze the results of the answer to determine which sociologist's "artificial consciousness" the answer belongs to, while computer scientists use the output of the "artificial consciousness" probe to analyze the neuron-synaptic differences between the three LLM models. In the comparison of the changes of the statistical and networks of LLM, the differences between the three "artificial consciousness" are explored and cross-verified. This project seeks to create a new approach to studying consciousness and "artificial consciousness".

Unconscious face perception in autism spectrum disorder

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Poster Session 6, Friday July 5th, Ito International Research Center, 4:00PM-5:00PM

Facial perception is ecologically significant in social interactions, yet individuals with autism spectrum disorder (ASD) exhibit impairments in facial perception capabilities, evidenced by neural hypoactivation patterns. Recent findings suggest that facial information processing occurs unconsciously, prompting an empirical investigation into whether ASD impairments under conscious conditions originate from those observed under unconscious conditions. To our knowledge, none of the preceding studies have investigated this issue. Consequently, the present study seeks to investigate whether face processing is different in individuals with ASD compared to healthy controls under unconscious condition. Additionally, our objective is to determine if the observed hypoactivation pattern in conscious conditions is correlated with insufficient neural signals from unconscious stimuli through a comparative analysis. To fulfill our objectives, the current study incorporated three key modifications compared to conventional methods: (1) implementing the dis-continuous flash suppression (dCFS) paradigm for interocular suppression, (2) employing multivoxel pattern analysis (i.e., support vector machine, SVM) for more sensitive functional biomarkers of ASD, and (3) presenting both static and dynamic facial stimuli to enhance/compare signal-to-noise ratios. During the study, a total of 84 participants were recruited and stratified into two groups, namely HAQ (n = 39) and LAQ (n = 45) based on their AQ score, with a cut-off-point of 23. In general, employing the whole brain decoding method, we observed that the HAQ group, mirroring the characteristics observed in individuals with ASD, manifests hypoactivation patterns across multiple areas in both conscious and unconscious conditions. This pattern persists regardless of the method of presenting stimuli, encompassing both static and dynamic stimuli. Furthermore, using ROI analysis, our results demonstrated in the context of perceiving visible facial information (i.e., conscious condition), the distinguishability of facial information in autistic-trait related regions, such as the amygdala (AMYG), and anterior cingulate cortex (ACC) was higher in the HAQ group compared to the LAQ group. Such results are in consistent with prior reports which suggested that individuals with ASD are more sensitive to negative information. Conversely, in the perception of invisible facial information (i.e., unconscious condition), the distinguishability from autistic-trait related areas such and amygdala (AMYG) and insula (INS) as well as face-related areas such as occipital face area (OFA) were lower in the HAQ than in LAQ group. In brief, our results from the study highlight the distinctions between the HAQ and LAQ groups in their proficiency in processing both visible and invisible facial information.

The effect of screen shake on the sense of agency in video games

Yuanhao Lin (University of Washington), Kanji Tanaka (Kyushu University)

Poster Session 6, Friday July 5th, Ito International Research Center, 4:00PM-5:00PM

Sense of Agency (SoA) describes subjective feelings of controlling external events through actions. The multifactorial two-step account model of the SoA divides the emergence of SoA into the non-conceptual 'Feeling of Agency' at the sensorimotor level and the conceptual 'Judgment of Agency' by integrating cues. Previous studies have shown the benefits of playing video games in improving individuals' mental health, perceptual-cognitive functions, and motor skills compared to traditional media. These benefits are likely attributed to the game's unique experience. In the present study, we investigated the influence of game visual effects represented by 'Screen Shake' on player's subjective SoA. For this, we created a game demo using Unity3D, which included two independent variables: delay and Screen Shake. The delay (i.e., the latency between the button press and the start of the attack) strongly influences the sensory feedback of the action. If there is a long delay, people do not feel they have caused the environmental change. Following previous research, we selected three levels of delay (0, 600, and 1200 ms). The Screen Shake (an effect that makes the player feel like the scene is vibrating by rotating the camera rapidly and periodically) is triggered upon an attack hitting an enemy model. Based on the results of the online preliminary experiment, we selected Strong, Medium, Weak, and No-Shake parameters for the levels of Screen Shake. In each trial, participants pressed a button to attack an enemy with a sword. A delay (0, 600, or 1200 ms) was inserted between the button press and the start of the avatar's attack. Upon hitting the enemy, a Screen Shake effect (Strong, Medium, Weak, or No-Shake) was presented, and the enemy went down and disappeared automatically after one second. Subsequently, participants rated their subjective SoA for the attack action or their Sense of Exhilaration (SoE) for the trial. The results showed that the longer delay reduced subjective SoA and SoE, the stronger Screen Shake effect led to higher SoA and SoE, and interaction between delay and Screen Shake was not significant in both SoA and SoE. For the delay, the ratings of both SoA and SoE were highest in the 0 ms condition, followed by the 600 ms condition, and lowest in the 1200 ms condition. Regarding the Screen Shake, the SoE rating was highest in the Strong condition, followed by the Medium, then Weak, with the No-Shake condition rated the lowest. The SoA rating overall showed a similar pattern but no significant difference between the Weak and No-Shake conditions. These findings indicated that the longer delay mainly reduced the FoA at the bottom-up level, and the visual effects represented by the Screen Shake modulated the JoA at the top-down post hoc inferences. As the rating of SoA and SoE shared a similar tendency, the Screen Shake may serve as a positive outcome of actions, and then, the positive outcome might retrospectively modulate JoA. However, the modulation likely requires a certain magnitude of the Screen Shake.

Brain networks underlying formation, maintenance and reporting of confidence during a metacognition paradigm

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Poster Session 6, Friday July 5th, Ito International Research Center, 4:00PM-5:00PM

Subjective confidence associated with the accuracy of one's own decision is a fundamental component of metacognition. However, the brain networks mediating confidence formation, maintenance and reporting have been difficult to disambiguate. In order to unravel these processes, we recorded the blood-oxygen-level-dependent signal while participants performed a metacognition task consisting of different phases and involving three different confidence related processes. Each trial in the metacognition paradigm started with subjects making a decision in a perceptual decision making task. Following this, the subjects estimated the confidence in their decision (formation phase) and maintained an internal mnemonic representation of this confidence estimate during a delay (maintenance phase). At the end of this delay, the subjects reported their confidence by wagering (reporting phase). Additionally, subjects participated in a control experiment, which did not require generation of confidence. Herein, the same primary task as during the metacognition paradigm was followed by a brief presentation of a visual cue, which was kept in memory during the subsequent delay. At the end of this delay, the subjects made a report contingent to the presented cue. Contrasting the activity during the different phases with baseline or the control experiment allowed us to investigate the brain networks underlying confidence formation, maintenance and reporting. A consortium of brain areas were activated during various phases of the task, which included regions within (but not limited to) the prefrontal, insula and visual cortices. In particular, these networks overlapped at the anterior insula/inferior frontal gyrus, suggesting it as a core region relevant to metacognitive processing. Interestingly, the activity of visual cortex and superior PFC correlated with metacognitive sensitivity. Moreover, the two regions displayed stronger functional interaction during the primary task phase in the metacognition paradigm compared to the control task indicating that it may subserve a role in confidence computation. Lastly, the brain network of maintenance of the confidence estimate largely overlapped with that of working memory for a visual cue, indicating shared neural substrates underlying working memory of internally generated abstract concepts and an externally presented visual input. In summary, this study suggests distinct brain networks underlie the discrete steps in a metacognition paradigm.

Introverted Mystical Experience as an empirical case of misrepresentation

Ziqin Zhou (University of Washington)

Poster Session 6, Friday July 5th, Ito International Research Center, 4:00PM-5:00PM

Higher-order thought theory faces the challenge of the misrepresentation problem. Philosophers such as Karen Neander (1998), Joseph Levine (2001), Ned Block (2011), Sam Coleman (2018) and others have criticised David Rosenthal's version of HOT theory (Rosenthal, 1986; 2018) for facing the risk that first-order perceptions may be inconsistently represented. Recently, some scholars have provided some empirical examples for further discussion of the misrepresentation problem, such as synesthesia (Adams & Shreve, 2016), change blindness (Brinck & Kirkeby-Hinrup, 2017), the rare Charles Bonnet syndrome, inattentional inflation, and peripheral vision (Lau & Brown, 2019). I suggested Introverted Mystical Experience as an empirical case of misrepresentation. The term derives from W.T. Stace's (1960) distinction between mystical experiences. After scholars such as Panhke (1963; 1966) and Hood (1975) extended its influence, it has been supported by extensive empirical research in the field of the psychology of religion. I argue that introverted mystical experience can be used as an empirical case of empty higher-order representations (a special case of misrepresentation) because this conscious experience fits the definition that lacks first-order perception as the content of consciousness, which is supported by philosophers such as Forman (1991). And it has similarities with already accepted empirical cases. First, as part of an altered consciousness state, this state is distinct from ordinary states and from obviously pathological states such as schizophrenia. Second, the "ineffability" of introverted mystical experience is also seen in the cases of misrepresentation. Furthermore, introverted mystical experience is a more successful empirical case for the purposes of Lau and Brown's (2019) empirical case. I further note that the misrepresentation problem reflects a fundamental divergence between Rosenthal's version of HOT theory and others (e.g., QHOT theory, the joint determination view, HOROR theory) on the question of the relationship between mental appearances and phenomena. Coleman (2018) has identified two approaches to responding to Block's (2011) critique. I argue that these two approaches reflect Rosenthal's fundamental divisions with others. Coleman (2018) criticizes Rosenthal's proposal for rendering perceptual illusions indistinguishable from real illusions. Brown argues that the advantage of his joint-determination view is that it emphasizes the importance of first-order content being real. These considerations suggest a key question: can mental appearances diverge from reality? Rosenthal supports the idea of divergence, while Kriegel, Neander, Block, Coleman, and others reject the possibility. The two sides appear to have differing fundamental considerations and bear the theoretical consequences of their positions. If introverted mystical experience is accepted , it could provide a way to reconcile the different versions of HOT theory. On one hand, the introverted mystical experience could support Rosenthal's version of HOT theory. On the other hand, it would not directly oppose Coleman's theory of QHOT. In this case, QHOT could still complete the references despite the lack of all sensory qualities. Therefore, the introverted mystical experience offers a hopeful prospect for reconciling the different versions of HOT theory.

Persistent representations of object identity depend on conscious perception

Caroline FMyers (University of Washington), Peter W Mazalik (Johns Hopkins University), Jonathan Flombaum (Johns Hopkins University), Justin Halberda (Johns Hopkins University)

Poster Session 6, Friday July 5th, Ito International Research Center, 4:00PM-5:00PM

What does conscious perception track? In the case of apparent motion, conscious percepts of motion emerge from the brief, successive presentation of two static frames. A staggering example of this is the Ternus illusion: when two discs are shown side by side, and then shifted horizontally, the temporal gap between the successive presentations determines whether observers perceive element-wise or group motion. At long (20 ms) intervals, group motion is perceived: the conscious percept minimizes the distance traversed by each element, resulting in a perceived group-wise leftward shift. At brief (0 ms) intervals, element-wise motion is perceived, and one object appears to “jump” over the other items, taking the longer path. Do early visual commitments pattern with these bistable conscious percepts? Indeed, it is often the other way around - the properties of perceptual objects, or “object files”, are thought to gate conscious perception. Importantly, object files are thought to prioritize spatiotemporal proximity: an object is identified as the same object if it is perceived to take the shortest path. The Ternus illusion would seem to place these in conflict? In the case of perceived element-wise motion, our conscious experience of the “jumping” object does not obey the spatiotemporal proximity law of object files. Will the object index correspond to our conscious percept, or will it prioritize spatiotemporal proximity in the case of element-wise motion? To test these possibilities, we exploit a well-known psychophysical paradigm – the object-specific preview benefit (OSPB)— in which “previewing” information presented on one object results in faster and more accurate retrieval if the information later reappears on the same object relative to another object. If moving objects are defined by spatiotemporal proximity, an OSPB should not follow an object that appears to “jump” when element-wise motion is perceived. However, if the object file system tracks conscious perception, we should expect to see benefits at the “perceived end position” in both motion conditions. Will the OSPB effect act in accordance with the induced conscious percept, or will it obey the principle of minimizing the path between objects, irrespective of (conflicting) conscious percepts? Observers viewed an apparent motion display consisting of three horizontally adjacent discs containing letters. Following a variable blank interval, (0ms or 20ms), the discs reappeared shifted one position rightward, with a probe letter reappearing on either the same or different discs. Observers reported whether the probe contained the same letter shown at the beginning of the trial. Strikingly, observers’ reaction times and accuracy reflected a characteristic OSPB in accordance with the induced percept: participants retrieved the feature faster and more accurately both when the probed object appeared to translate (20 ms intervals), as well as when it appeared to jump (0ms intervals). These results suggest that object identity is mapped across the perceived object motion path induced by the inter-stimulus interval, even if the induced motion path is not the shortest. Thus, representations of object identity across time are dependent on our conscious perception.

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