

by Morten Overgaard

Human consciousness can be defined as the inner subjective experience of mental states such as perceptions, judgments, thoughts, intentions to act, feelings or desires – all of which are observable from a so-called first-person perspective only.

Several of the past, ongoing, and planned experiments focus in particular on how consciousness relates to brain activity, and how this question can be systematically investigated while taking into account that consciousness seems to be observable by introspection only.

We have explored this question in a multitude of ways over the last two decades using a variety of methods for subjective reports and neuroimaging methods. Repeatedly, we have found that the neural correlates of consciousness (NCC) are not localizable in any particular brain area or brain process, and seem to be dependent on several factors, including reporting method and the cognitive task at hand. Conscious experience, and thus the NCC, appears robust in the sense that it seems related to all faculties of cognition, and is likely an integral part of a large variety of neural and cognitive processes rather than a separate type of state or module.

To arrive at this conclusion, we have investigated how different kinds of higher order reports about experimental participants' own performance (using e.g. confidence ratings and subjective awareness scales) are differently related to the performance itself. As one example, we found that negative feedback to subjective ratings directly influence perceptual sensitivity (d' in signal detection theory), whereas a similar manipulation of confidence ratings does not have the same type of influence. Other experiments have revealed that variations in instructions, changing the task relating to the same stimuli and same methods of reporting, affect the neural correlates of consciousness in the sense that different levels of subjective clarity relate to different neural processes depending on the task.

Results from these and several other experiments suggest that consciousness is most likely an inherent part of the cognitive system as a whole. Nevertheless, we have only scratched the surface to arrive at an understanding of consciousness and not least its neural counterparts.

Most theories of the neural correlates of consciousness (NCC), however, are modelled on one specific sensory

modality, almost always vision, while consciousness in most cases has an integrated content relating to more than one sensory modality. Studies of sensory integration are becoming increasingly common in the cognitive neuroscience literature. Although the list of effects showing that one sense may influence another is already long, it is much less clear how we are to understand the nature of such integrations. Nevertheless, if conscious perceptions are integrated after the content of each sensory modality is processed, it would suggest that consciousness is a late process that reasonably can be expected to involve prefrontal areas. However, if perceptions are integrated at an early stage, so that conscious perception is "already integrated" without a secondary, higher-order integration process, it suggests that consciousness occurs early, and may (also) relate to primary sensory areas.

In one experiment, we investigated spontaneous neural oscillations that have been identified as key predictors of perceptual decisions to bind multisensory signals into a unified percept. Research links decreased alpha power in the posterior cortices to attention and audiovisual, suggesting that controlling alpha oscillations would be a way of controlling audiovisual binding. We used MEG-neurofeedback to train one group of subjects to increase left/right and another to increase right/left alpha power ratios in the parietal cortex. Our data suggests that the relation between parietal alpha power (which is sometimes considered an index of attention) and its effect on audiovisual binding is dependent on the learned causal structure in the previous stimulus. The present results suggest that low alpha power biases observers towards audiovisual binding when they have learned that audiovisual signals originate from a common origin.

We have initiated both experimental and theoretical analyses to investigate how multimodal perception works and what it may inform us about consciousness in the years to come.

Whereas our methodological work on action on perception is intended to make an important scientific contribution in itself, the underlying purpose is the development of a metaphysical model of consciousness. Over the last years, we have worked in collaboration with a series of partners, especially The Copenhagen based UCN group, to create a model of neural and cognitive function that includes consciousness as a natural, inherent aspect rather than leave it as a mystery. Our models – REF and its extensions as REF-CON and REF-GEN basically describes connectionist network in which, however, the "unit" is not a neutral and functionally

"indifferent" "neuron" – but information processing modules called elementary functions (EFs). The EF does not have any functional specificity beyond its basic information processing. This model is able to account for both localization and non-locality of functions (in e.g. recovery after brain injury). According to the original version of the REF model, the surface level of task solution – be it in the form of overt behavior or mental representation – is achieved via two underlying levels: the lower level of the EFs and the level of the Algorithmic Strategies (ASs). EFs perform basic information processing and are localized within restricted subdivisions of neural structures. In contrast, ASs consist of numerous interacting EFs and are distributed in the sense that the neural substrate of an AS includes both the neural substrates of the individual EFs and the neural connections mediating the complicated interaction between these EFs. Thus, an AS is the totality of a given set of EFs and their interactions. A given surface phenomenon (e.g., behavioral pattern/task solution) may be achieved via different ASs. Focal brain injury will deprive the individual of a substantial number of EFs and thereby all ASs including those EFs. Thus, injury will lead to behavioral impairments of tasks previously achieved via activation of those ASs. However, the model suggests that a different organization of underlying strategies, using different EFs, may realize "the same" surface phenomenon.

In the REF-CON model, consciousness is fundamentally seen as related to a particular kind of AS – that is the Situational Algorithmic Strategy, or SAS, representing the "current now". As elaborated in the REF-GEN model, this "current now" is constantly compared with a representation of the expected future, and SAS is accordingly constantly updated. Consciousness is here considered as "fundamentally related" to information that is available to action (or access) by a kind of "natural law" that does not have an independent further cause or explanation.

On the basis of this line of thinking, we have over the last years published other models, of e.g. how to understand gradedness of consciousness. Our work in these regards is not to be seen as "final theories" but rather a continued work in progress that is continuously revised and developed as our research progresses.

FACTS

Group members:

- Morten Overgaard
- Peter Fazekas
- Thomas Alrik Sørensen
- Asger Kirkeby-Hinrup
- Timo Kvamme
- Martin Dietz
- Janice Wang

Selected invited talks:

- "Perceptual consciousness", UCN, Copenhagen, November 2021
- "Sensory interplay: Causation, fusion, or deep integration?", Videnskaberne Selskab, Sept 2021
- "Consciousness and Access", Consciousness, Mindfulness, Compassion. Research Webinar, March 2021
- "Consciousness and Access", Aarhus Institute of Advanced Studies, April 2021
- "Consciousness: From theory to practice", Neuroscience School of Advanced Studies, Venice, May 2020

Aarhus Institute of Advanced Studies (AIAS)

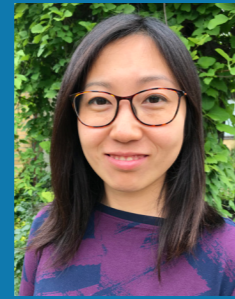
Morten Overgaard, Peter Fazekas – and former CNRU researcher Lau Møller Andersen - have all been involved at AIAS in 2020 and 2021. AIAS is an interdisciplinary research institution, and as such, a natural place to seek collaborations and interactions for CNRU researchers.

In 2020, Morten Overgaard received a Jens Christian Schou Professorship at AIAS, and he continues as a Fellow at AIAS. His project at AIAS proposed a new approach to one of the hardest and most controversial scientific questions: Why are we conscious, and how does consciousness relate to neural counterparts. Some previous projects have attempted to compare theories of consciousness and its neural correlates directly but without any increased consensus or progress in the consciousness research field. In this project, a number of assumptions are identified that divide the waters between theories of consciousness, and which makes direct comparisons difficult. More specifically, these assumptions regard: 1) Whether consciousness is rich or sparse, 2) whether it is gradual or dichotomous, 3) whether neural correlates of consciousness are specific or universal, and 4) whether they are stable or dynamic. Through a series of experiments and theoretical development, the project will target and attempt to falsify and validate these underlying assumptions, thus informing the collective body of theories of consciousness. The project will be realized based on already existing collaborations, and will create new interdisciplinary collaborations as well as attract younger researchers interested in the field. The project will lead to new large-scale applications to e.g. ERC and the Lundbeck Foundation.

In 2021, Peter Fazekas received an AIAS co-found fellowship to investigate spontaneous thoughts, or mind-wandering. Mind-wandering, although quite common, has only recently gotten into the forefront of scientific investigations, and philosophical reflection is lagging behind. Combining philosophical analysis and psychological experimentation this project proposes a new model of mind-wandering and develops it into a general framework of all kinds of self-generated mental phenomena. Major predictions are tested via exploring links between mind-wandering, dreaming and hypnotic dreams (induced by instructions to 'have a dream' in a hypnotic state). It is also investigated if hypnotic dreams could serve as hypnotic analogues of mind-wandering and dreaming. An affirmative answer could revolutionise how features of mind-wandering and dreaming — which are

notoriously hard to study due to their spontaneous nature — could be examined in a well-controlled manner.

NEW FACE at CFIN

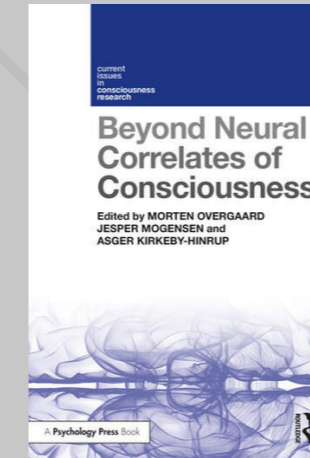


Qian Janice Wang joined AU in August 2018 as a tenure-track assistant professor in the Food Quality Perception and Society Group at the Department of Food Science. Janice takes an interdisciplinary approach to the investigation of multisensory flavour perception

and preference, combining behavioural methods with neurophysiological approaches. She focuses on studying the role of the brain sensory system and its connection with eating behaviour, in order to gain a deeper understanding of why people eat what they do, and to encourage behaviour change for a healthier, more sustainable lifestyle. To achieve this goal, she works to develop new ways to evaluate the consumer experience - from opinion mining to virtual reality to biometric measurements.

Janice received her PhD in Experimental Psychology from the University Oxford in 2017 under the supervision of Prof. Charles Spence. Her thesis investigated different mechanisms behind the phenomenon of "sonic seasoning", whereby listening to sounds congruent with specific tastes while eating could alter people's taste evaluation.

New book: Beyond neural correlates of consciousness



In 2020, Morten Overgaard, Jesper Mogensen, and Asger Kirkeby-Hinrup published the book *Beyond neural correlates of consciousness*.

Drawing on neuroscientific research and metacognitive theory, this volume examines the theoretical implications that are elicited when neural correlates of consciousness (NCC) are identified.

The relationship between consciousness and the brain has concerned philosophers for centuries, yet a tacit assumption in much empirically minded consciousness research seems to be that if we can only develop a map of correlations, no further questions remain to be asked. *Beyond Neural Correlates of Consciousness* starts where others stop, by asking what these correlations may tell us about the nature of consciousness. The book contains chapters considering the upshots of finding the neural correlates of consciousness in light of the most prominent contemporary theories in the field. This illuminates the theoretical consequences of succeeding in the quest for the neural correlates of consciousness from the perspective of global workspace theory, higher-order thought theory, local recurrency theory, and REFCON models, in addition to considering how this quest is shaped by different conscious phenomena, such as dreaming, altered states of consciousness, and different levels of consciousness.

FACTS

Selected publications:

1. Skóra, Z. Cipińska, K. Del Pin, S.H. Overgaard, M. & Wierzbón, M. (2021): Investigating the validity of the Perceptual Awareness Scale – The effect of task-related difficulty on subjective rating, *Consciousness and Cognition*, 95, 103197, 1-16
2. Overgaard, M. & Sandberg, K. (2021): The Perceptual Awareness Scale – recent controversy and debate, *Neuroscience of Consciousness*, 7, 1, 1-8
3. Skewes, J. Frith, C.D. & Overgaard, M. (2021): Awareness and confidence in perceptual decision making, *Brain Multiphysics*, 100030
4. Del Pin, S. Skóra, Z. Sandberg, K. Overgaard, M. & Wierzbón, M. (2021): Comparing theories of consciousness: Why it matters and how to do it, *Neuroscience of Consciousness*, 7, 2, 1-8
5. Kirkeby-Hinrup, A. & Overgaard, M. (2021): Finding the neural correlates of consciousness will not solve all our problems, *Philosophy and the Mind Sciences*, 2, 5, 1-17
6. Overgaard, M. (2021): Insect consciousness, *Frontiers in Behavioral Neuroscience*, 15, 1-6
7. Overgaard, M. (2021): Assumption and metaphysics in empirical consciousness science, *Psychology of Consciousness: Theory, Research and Practice*, 8, 88-91
8. Overgaard, M. & Kirkeby-Hinrup, A. (2021): Is learning the cognitive basis of consciousness? SOMA and consequences *Trends in Cognitive Sciences*, 25, 1, 8-9
9. Fazekas, P. Nemeth, G. & Overgaard, M. (2020): Perceptual representations and the vividness of stimulus-triggered and stimulus-independent experiences, *Perspectives on Psychological Science*, 15, 5, 1200-1213
10. Mogensen, J. & Overgaard, M. (2020): Avian prefrontal cortex and conscious experience, *Science, eLetter*, 369, 6511, 1626-1629
11. Del Pin, S. Skóra, Z. Sandberg, K. Overgaard, M. & Wierzbón, M. (2020): Comparing Theories of Consciousness: Object position, not probe modality, reliably influences experience and accuracy in an object recognition task, *Consciousness and Cognition*, 84, 102990, 1-10
12. Overgaard, M. Kirkeby-Hinrup & Mogensen, J. (2020): Introduction, in: M. Overgaard, A. Kirkeby-Hinrup & J. Mogensen: *Beyond neural correlates of consciousness*, Routledge
13. Overgaard, M. & Mogensen, J. (2020): Will we explain consciousness when we find the neural correlates of consciousness? in: M. Overgaard, A. Kirkeby-Hinrup & J. Mogensen: *Beyond neural correlates of consciousness*, Routledge
14. Mogensen, J. & Overgaard, M. (2020): An integral view of the neural correlates of consciousness (NCC) – Reorganization of the connectivity between Elementary Functions as a common mechanism of mental processes, in: M. Overgaard, A. Kirkeby-Hinrup & J. Mogensen: *Beyond neural correlates of consciousness*, 153-176, Routledge
15. Overgaard, M. & Mogensen, J. (2020): Strategies for mind, brain and culture – a cure for the replication crisis? *Nature Research: Behavioural and Social Sciences*