ESPP Symposium proposal: Cognition in Action

Speaker information

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Speaker 2

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General abstract

Symposium title: Cognition in Action

This symposium brings together cutting-edge theoretical and experimental work from philosophy and psychology, exploring how action plans and bodily constraints shape cognition. While most modern thinkers reject Cartesian dualism, its traces continue to linger in the study of brain and cognition. Cognitive brain function still tends to be studied in isolation from the rest of the body and the outside world, treating participants as passive receivers of stimuli and overlooking their role as goal-driven agents whose intentions and actions fundamentally shape how they filter, perceive, and use information. However, the brain does not operate in isolation: it is situated in a body, shaped and constrained by physiological needs, motor capabilities and the affordances for action in the world. Recognizing this is not just a philosophical refinement: adopting a 4E (embodied, embedded, enactive, extended) perspective fundamentally changes how we understand and experimentally study the brain and human cognition, as will become apparent through the talks in this symposium. Although 4E ideas are well-developed philosophically, they have long remained at the periphery of mainstream empirical psychology. This symposium helps bridge this gap and illustrates the value of strong theoretical grounding in cognitive science. Using work from a range of fields and methods, it also offers methodological insights into how the role of action can be studied in cognition. This includes interactive paradigms that incorporate bodily engagement, as well as strategies for adapting more traditional techniques, like fMRI, which does not permit movement, to address action-related questions through thoughtful experimental design.

In this symposium, Dr. Kiverstein will begin by making the case for an action-oriented cognitive ontology based on findings from cognitive and affective neuroscience. This is followed by a presentation by Dr. Groen of experimental findings from combined human neuroimaging (fMRI and EEG), behavior and AI modeling studies, which show that visual brain regions long thought to encode purely perceptual aspects of natural scenes represent their locomotor affordances (e.g., whether you can climb, swim or walk in the scene), contrary to commonly used, passively trained deep learning models of visual perception. Next, Moonen's presentation calls for a reconsideration of mental imagery, classically considered a purely internal process, as fundamentally action-oriented. Finally, Prof. Slagter will discuss findings from a series of studies showing that action plans tune working memory representations, biasing future performance, demonstrating that working memory does not simply serve perception beyond the immediate, but also serves adaptive future behavior. Together, the presentations in this symposium emphasize that even high-level cognitive processes are deeply rooted in sensorimotor processes and should be understood as such.

This symposium reflects the growing momentum across philosophy, psychology, and neuroscience toward approaches that recognize the central role of the body, action, and the world in shaping cognition. It emphasizes the reciprocal relationship between empirical psychological research and its philosophical foundations, calling upon philosophers and psychologists to work together to advance understanding of how even high-level cognitive processes depend on the body's action systems and the affordance structure of the environment.

Talk 1: "Making sense of multi-functionality in the brain: an action-oriented cognitive ontology"
Talk 2: "Gibson's neural reality: locomotive affordances in the human brain and AI models"
Talk 3: "Toward a functional, action-oriented approach to visual mental imagery"
Talk 4: "Visual working memory for action"

Individual abstracts

<u>Talk 1:</u>
Presenter: Dr. Julian Kiverstein
Title: Making sense of multi-functionality in the brain: an action-oriented cognitive ontology
Abstract:
Much of cognitive neuroscience has been concerned with the mapping of specialised cognitive and affective functions onto regions and circuits of the brain. Brain-imaging techniques such as fMRI are used to map task-specific patterns of brain activity to behaviour and cognitive functions. What does it mean to claim that a brain region has a specialised cognitive, affective or behavioural function? This talk will take up the recent arguments of Luis Pesoa (2023) that the units of function in the brain are not individual areas or regions but networks of regions (cf. Anderson 2014). Pessoa has argued that brain regions dynamically assemble into coalitions and populations that realise complex cognitive-emotional behaviours. Functional relationships between regions fluctuate based on cognitive, emotional and motivational demands. The same regions can belong to different networks at different times and thus be recruited to perform multiple cognitive functions (Anderson 2010, 2014; Klein 2012; Viola 2017; McCaffrey 2023). The function a region performs changes on the timescale of seconds depending on the coalitions and relationships it forms with other regions. That is to say, by the structure of the whole network.

I will consider the implications of Pessoa's argument for the question of cognitive ontology – the psychological categories that guide investigation in cognitive neuroscience and psychology more generally. First, I will argue for a bottom-up approach to cognitive ontology that seeks to derive cognitive categories from neural categories. By studying the variety of functions brain regions can perform, we can answer the cognitive ontology question of which cognitive categories can productively guide research in cognitive neuroscience and psychology. Second, I will argue that the cognitive categories required to make sense of how brain regions can perform a variety of functions relate to action control and planning and thus cut across traditional distinctions between cognition, affect and motivation (Hurley 2008; Anderson 2014; Pessoa 2023). According to this action-oriented perspective, the nervous system originally evolved for sensorimotor coordination and these action-oriented biases have been preserved in the human brain. For example, basal ganglia-cortical loops bidirectionally connect cortex with sub-cortex allowing cortex and subcortex to work in close coordination. Basal ganglia-cortical (BG-C) loops have been found to be preserved across vertebrates – reptiles, fishes, birds and mammals. BG-C loops are an example of a functionally integrated network that serve an action control function. However, the BG-C loops that form in birds and mammals are more elaborate suggesting that a functionally integrated circuit that originally served an action control function can be recruited to support more elaborate and complex cognitive behaviours. I will argue on this basis for an action-oriented cognitive ontology.

<u>Talk 2:</u>
Presenter: Dr. Iris Groen
Title: Gibson's neural reality: locomotive affordances in the human brain and AI models
Abstract:
To move, traverse or transport ourselves in the world around us, we can use different actions, such as walking, swimming, or climbing. Ecological psychologist Gibson (1979) famously proposed that *affordance recognition*, i.e. the process of determining which actions are possible given the current environment, fundamentally shapes visual perception in visual organisms, including humans. The neural basis of this process in the human brain has remained mostly elusive, however. Excitingly, the advent of modern neuroimaging technology allows us to now look 'inside' the brain and to identify

brain areas and neural computational cascades that may underlie our ability to recognize environmental affordances.

I will present neuroimaging evidence for neural computation of affordances in the context of natural scene perception, as measured with functional magnetic resonance imaging (fMRI) and electro-encephalography (EEG) in humans. We operationalized affordance perception as a simple multiple choice task, in which participants were shown a picture of an unfamiliar, real-world environment (e.g., a mountain trail; a bridge crossing; a bouldering hall) - and asked to indicate which actions they would undertake to move in such a scene. We then measured their brain activity to assess, when confronted with each visual scene, how the brain knows what to do – which brain responses reflect the locomotive actions the environment affords?

Via careful comparison of the measured neural activation patterns with various models of scene information, we show that specific cortical regions and temporal processing stages uniquely reflect locomotive action affordances. We find that multivoxel fMRI responses in regions of visual cortex known to be involved in scene perception represent perceived locomotive affordances, and do so independently from other scene properties such as objects, surface materials, scene category, or global properties, and independent of the task performed in the scanner. Similarly, analysis of millisecond-resolution time-courses of EEG responses evoked by the visual scenes reveal that locomotive action affordance representations emerge within 200 ms of visual processing, with again independent unique contributions at temporally distinct time-points from other properties. These empirical observations uncover novel evidence for neural representations in the human brain that reflect locomotive affordances.

Finally, AI has seen tremendous progress in recent years through machine learning on large corpora of pictures or text. However, when engineering real-world interfacing AI in e.g. robotics, incorporating affordance recognition has been difficult. To understand why, we compared a suite of AI models to the behavioral and brain responses from our human participants. We demonstrate that commonly used models of visual processing in human brains, namely deep neural networks trained on scene understanding tasks, do not adequately capture the unique representations of affordances we observed in humans. We propose that this discrepancy reflects human embodiment, which allows affordance representations to emerge in the brain, but which current architectures of scene understanding AI models lack.

Together, these findings suggest that human locomotive affordance recognition relies on specialized neural representations different from those used for other visual understanding tasks, and different from common AI models.

<u>Talk 3:</u>
Presenter: Lydia Moonen
Title: Toward a functional, action-oriented approach to visual mental imagery
Abstract:
Visual mental imagery is commonly thought to be experienced in the mind's eye, without any overt behavioural responses. Accordingly, cognitive neuroscience on visual mental imagery has predominantly focused on capturing sensory representations, rather than incorporating behavioural paradigms to explore its functional role in guiding our actions. This emphasis stands in stark contrast to how cognitive processes, such as memory and decision-making, are studied, which are typically operationalized through behaviour. We argue that prioritizing sensory content over behavioural effects in visual mental imagery research has led to visual mental imagery being conceptualized as a passive

mental process that operates independently of other cognitive processes, thereby isolating it from the broader cognitive architecture. This focus hinders significant progress in leading debates within visual mental imagery research, which largely concern the relationship between visual mental imagery and other cognitive processes. Specifically, we propose that a functional, action-oriented account of visual mental imagery can help clarify (1) whether mental imagery is similar to perceptual processing and visual working memory, and (2) whether visual mental imagery can be unconscious. Including behavioural paradigms in visual mental imagery research is therefore crucial for providing a functional account of mental imagery, supporting meaningful advances in current debates, and enabling a genuine integration of this mental process within the cognitive neurosciences.

Talk 4:

Presenter: Prof. dr. Heleen Slagter

Title: Visual working memory for action

Abstract:

Philosophers and psychologists have long proposed that perception is organized around action: that we selectively process sensory features that matter for what we can do next. Empirical research increasingly supports this selection-for-action view for objects currently in sight, though it remains underappreciated in many standard accounts that still consider perception and action independent processes. An open question, however, is whether action planning similarly structures the representations we maintain in mind, in working memory. This is the question my talk addresses. Traditionally, visual working memory has been approached as a temporary storage system for previously seen information. In my talk, I will present convergent evidence from behavioral, eye tracking and EEG studies showing that representations in working memory are tuned by what we plan to *do* with that information next, emphasizing that visual working memory fundamentally serves future behavior. In a first set of studies, we found that when participants planned actions on an object held in mind, this strengthened their sensory representation, as reflected in enhanced attentional capture on an intermittent visual search task (shown with eye tracking) and a larger Ppc, an ERP component associated with visual saliency (shown with EEG). In a second set of studies, we manipulated whether two oriented bars held in working memory were associated with the same action plan or two different action plans. We found that action similarity affected the extent to which the two bars, when similarly oriented, were reported as more visually distinct. Moreover, a follow-up study showed that consistent object-action relationships, learned over many trials, amplified these perceptual biases, suggesting that action planning structurally warped "visual" feature space in working memory. Together, these findings indicate that working memory representations are tuned to the actions we intend to perform. They show that visual working memory does not simply serve perception beyond the immediate, as traditionally assumed, but is geared towards adaptive interaction with the world. More broadly, they highlight the deep interdependence of action and cognition.