NATURALISTIC NEUROSCIENCE:

FROM PERCEPTION TO ACTION AND BACK

ABSTRACTS

SYMPOSIUM AT THE UNIVERSITY OF BONN

28-29 MAY 2026

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KEYNOTES & TALKS

(IN CHRONOLOGICAL ORDER)

Thursday, 28 May 2025

SESSION 1: SPATIAL NAVIGATION

Neil Burgess (Institute of Cognitive Neuroscience, University College London)

Using VR in Mice and Humans to Examine the Neural Integration of Environmental and Self-Motion Information

In real-world situations with unreliable or ambiguous information, understanding where you are and which direction to go in requires the integration of self-motion and environmental information. The cognitive map of spatial cells in and around the hippocampal formation is thought to perform this function, but many details are unknown.

I will present work using virtual reality (VR) in mice and humans aimed at answering how these two types of information are integrated; how the direction to move in is represented; the role of theta rhythmicity and directional information; and how this function is affected early in Alzheimer's disease.

Neil Burgess *is Professor of Cognitive and Computational Neuroscience at the Institute of Cognitive Neuroscience, University College London (UCL). His computational, behavioural, neuroimaging and electrophysiology experiments with both humans and rodents bridge the gap between neuroscience and behaviour, shining a light on the neural representations and computations supporting spatial cognition. His basic research in spatial and episodic memory is now being applied to artificial intelligence, and neurological and psychiatric conditions. Neil Burgess is a Wellcome Trust Principal Research Fellow, and a Fellow of the UK Academy of Medical Sciences and the Royal Society.*

<u>Lukas Kunz (Department of Epileptology, University Hospital Bonn)</u>

Theta-Phase Locking of Human Neurons During the Encoding and Retrieval of Spatial Memories

Numerous studies in rodents and other non-human animals have shown that the hippocampus and surrounding brain structures implement neural mechanisms for spatial navigation and spatial memory. In my talk, I will discuss recent attempts to translate these mechanisms to the human brain using single-unit recordings in epilepsy patients performing virtual-reality tasks. This includes the investigation of classical spatial cell types, such as place cells; the search for other forms of spatial tuning, including spatial view cells; and the study of spike-phase relationships that may support memory processes.

<u>Dyutika Banerjee</u>

Probing How the Temporal Structure of Odour Plumes Informs Mouse Navigation Behaviour

Dyutika Banerjee [1], Amirreza Gholivand [1], Anantha Padmanabhan [1], Tobias Ackels[1]
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Understanding how mammals use olfactory information for navigating their environment is key to uncovering their natural behaviours. Crepuscular and nocturnal rodents, in particular, rely on odour cues for locating food and potential mates, and avoiding predators. Odour plumes in nature are both temporally and spatially dynamic, with high-frequency concentration fluctuations carrying spatial information, such as distance to the source. However, despite their importance, there is limited research on how mammals interpret these complex temporal odour signals. Our study investigates how mice use dynamic olfactory cues for navigation, by combining behavioural tasks with respiratory and neural measurements. For this, we designed a large open-field arena with a multichannel odour delivery system that simulates natural conditions, providing various odour sources and complex airflow patterns. Mice are trained to navigate to one of four odour sources using a reward-conditioning paradigm. Once trained, we monitor multiple behavioural and physiological parameters. Besides assessing the performance during the odour source localisation task, mouse movements are tracked in 2D and 3D with high spatial and temporal resolution, enabling quantification of kinematics like speed, velocity, head and body orientation, path taken to source, spatial occupancy, and exploratory strategies. Respiratory dynamics are monitored using an implanted thermistor probe, while real-time odour encounters are recorded with a custom miniature odour sensor. We further aim to assess neural activity in key olfactory regions, including the olfactory bulb and lateral entorhinal cortex, using silicon probes. Together, this study aims to identify which features of naturalistic odours inform mammalian behaviour and guide navigation.

SESSION 2: NEUROTECHNOLOGY & MODELLING

Gareth Barnes (Department of Imaging Neuroscience, University College London)

Wearable magnetic field sensors for neuroimaging

Traditionally we have used cryogenically cooled magnetic field detectors to image human brain function non-invasively at a millisecond time-scale. Optically Pumped Magnetometers provide an alternative to these cryogenic systems as they are small (LEGO-brick sized) and wearable. These new sensors allow us to build custom imaging systems, shaped like helmets, that allow natural participant movement. The flexibility of these sensors also allows us to look at other sections of the neuroaxis (such as the spinal cord) and how they interact with the brain and muscle. I will talk about some of the challenges and advances we have experienced with the new technology.

***Gareth Barnes** is Head of Magneto-encephalography (MEG), Imaging Neuroscience, Institute of Neurology, University College London, London, UK. Most of his research has been the on the development of methods to estimate brain activity based on these measurements and the verification that these methods work through simulation, or comparison with what we know about brain anatomy and function from techniques such as MRI and fMRI and direct invasive recordings from the cortical surface. The main aim of his work is to provide a millisecond by millisecond picture of the electrical activity changes in the human brain.*

<u>Jason Kerr (Max Planck Institute for Neurobiology of Behavior – caesar)</u>

What the brain sees during predator-prey interactions of sky and ground-based animals

During mortal behaviours such as predator/prey interactions, where the motivation for success is high, the fidelity of the information encoded by the senses is critical for survival as this must contain both the opponent's location as well as the changing relationship to the environment during the chase. This poses potentially opposing requirements on the visual system for the predator and the prey, and raises the question of how the different visual systems enable a successful behavioural outcome.

Our lab is primarily interested in the neural circuity activity and behavioural strategies underlying predator prey interactions for a variety of animal species. To measure, reconstruct and quantify sensory information during prey capture and prey detection, we have developed a number of high-resolution techniques that allow motion of the environment and objects, such as prey, to be measured in the visual systems of freely moving animals, both in the laboratory and wild.

By combining these behavioural quantification approaches with anatomical reconstructions of visual pathway componentry we have been able to quantify both the behavioural and common visual system strategies that a number of ground-dwelling and airborne animals employ during predator prey interactions to ensure either avoidance or capture.

Lastly, we have started to image neuronal activity simultaneously from all visual cortex layers during these freely moving behaviours and have started to unravel a mechanism of how the visual cortex enables detection of environmental features in very low light levels.

Jens Tillmann

Modeling Neuro–Behavioral State Dynamics from Longitudinal Multimodal Recordings

Jens F. Tillmann [1], Tobias Schmidt [2], Ziyan Huang [1], Amine Bahlouli [1], Steffen Schneider [2], Jan Gründemann [1,3]

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[2] Helmholtz Munich, Neuherberg, Germany

[3] University of Bonn, Medical Faculty, Bonn, Germany

Continuous advances in neurotechnology enable large-scale recordings of neuronal activity, complemented by markerless pose estimation and wearable sensors capturing behavior and physiology. These multimodal approaches produce synchronized datasets spanning neural and bodily dynamics. Recent machine learning methods extract structure from neuronal and behavioral data at scale (e.g., Schneider et al., 2023; Weinreb et al., 2024), yet models that jointly predict behavioral and neural states and their transitions remain limited. Here, we present a longitudinal multimodal dataset of freely behaving mice (>400 recording hours over several weeks), combining calcium imaging, multi-site EEG, video tracking, ambient audio, and head-mounted motion sensors. Animals were recorded in a homecage-like environment, expressing diverse self-paced behaviors including exploration and sleep. From these data, we derived synchronized representations of pose trajectories, behavioral motifs, and sleep states, yielding an integrated, ML-ready dataset linking neural, behavioral, and physiological signals. Using this dataset, we established a scalable framework for multimodal neural state modeling that enables the prediction of state transitions and delivers interpretable insights into the dynamics of state encoding. Our final goal is the deployment of a real-time neuro-behavioral state inference system to facilitate closed-loop state-dependent perturbations. This framework will facilitate the systematic study of neuronal state dynamics across learning, aging, and disease states and serve as a foundational step toward real-time, multimodal brain– machine interfaces in preclinical research.

SESSION 3: SENSORIMOTOR PROCESSING

Katja Reinhard (Scuola Internazionale Superiore di Studi Avanzati – SISSA)

Light and time shape innate behaviours

Avoiding danger is one of the most essential and conserved set of behaviours. To optimize an animal's survival, avoidance responses need to be fast and reliable, but also flexible and adaptable to the current context. However, how this flexibility in behavioural output is implemented in the brain is largely unknown. The goal of my lab is to identify how information about the environment and state can adapt behavioural decision making.
We approach this by using a highly standardized assay where we compare innate reactions and neural circuit activity while changing selected contextual elements, with the aim to identify principles of behavioural flexibility that are conserved (or not) across contexts and species. During this talk, I will focus on how ambient light and circadian time shape innate behaviours, how this modulation is implemented in the brain and how it has evolved across different rodent species.

Katja Reinhard *is an Associate Professor in Neurobiology at SISSA in Trieste, Italy. She studied Biomedical Sciences at the Universities of Fribourg and Bern in Switzerland, after which she joined the lab of Thomas Münch in Tübingen to investigate retinal processing across several species and disease models. As a postdoctoral fellow with Karl Farrow at NERF in Leuven, Belgium, she then studied how retinal information is sampled by the superior colliculus to guide innate behaviours a lucky encounter with Hopi Hoekstra triggered Katja's interest in ethological and ecological aspects of neuroscience, which has since become a key aspect of her work. Since 2022, she has been leading a team at*

SISSA, which, using a variety of rodent species, focuses on how contextual information can be integrated to modulate innate behaviours.

Friday, 29 May 2025

SESSION 4: PERCEPTION

Georg Keller (Friedrich Miescher Institute for Biomedical Research – FMI Basel)

A Cortical Circuit Approach to Psychosis

The cortical dynamics underlying changes in conscious perception are largely unknown. By screening for common effects of diverse psychoactive drugs, we identified cell-type-specific activity patterns consistently altered by these substances. The primary effects were observed in spontaneous activity patterns spanning the dorsal cortex, rather than in sensory or movement-related activity. While the functional significance of these large-scale changes requires further investigation, distinct patterns emerged for antipsychotics, psychedelics, and anesthetics. Critically, all drug classes modulated functional communication within the layer 5 cortical network, supporting the hypothesis that this layer plays a key role in conscious processing.

Georg Keller *is a research group leader at the Friedrich Miescher Institute (FMI) for Biomedical Research in Basel, Switzerland. He received his PhD in physics in 2009 and moved to the Max Planck Institute for Neurobiology in Munich for postdoctoral studies before starting his own group at the FMI in 2012. The first decade of the lab was devoted to studying the circuitry for predictive processing in cortex. In 2022 the group discovered a cell type specific effect of antipsychotic drugs in cortex. This discovery shifted the research direction of the lab* *towards investigating the functional effects of consciousness altering substances. The hope is that this will allow for the development of novel therapies for schizophrenia.*

Tobias Rose (Institute of Experimental Epileptology and Cognition Research, University Hospital Bonn)

Stability and Stabilization of the Neural Code in Sensation and Action

The visual system faces a dual challenge. It must process stable features of the environment despite variation in circuits and behavior, yet remain robust to continual changes in retinal input caused by eye, head, and body movements. We use closed-loop approaches to study these two aspects of visual stability in mice during passive and active vision.

In passive vision, we study long-term representational stability in head-fixed mouse primary visual cortex. Apparent representational drift may reflect genuine changes in feature encoding, but it may also arise from changes in behavioral state and gaze-related geometry. Using longitudinal two-photon calcium imaging, modular deep encoding models, and closed-loop tests of model-derived hypotheses, we dissociate feature, state, and gaze contributions to natural image responses over weeks. We find that a substantial fraction of apparent drift is explained by gaze-related variation rather than by changes in feature encoding or state-dependent modulation. These results suggest that mouse visual cortex is more functionally stable than previously thought.

In active vision, we study how orienting, pursuit, and decision-making shape visual processing and spatial behavior in freely moving mice. Using closed-loop tasks with precise stimulus control, dense 3D tracking of behavior and gaze, and miniature two-photon imaging in freely moving animals, we examine how task demands shape head-eye coordination and visual processing under natural conditions.

Cem Uram

Behavioral and Learning Signatures of Predictive Thalamocortical Dynamics

Cem Uran [1,2,3], Georgios Spyropoulos [2,3], Martin Vinck [3]

[1] Department of Epileptology, University Hospital Bonn
[2] Ernst Strüngmann Institute (ESI) for Neuroscience in Cooperation with Max Planck Society
[3] Donders Centre for Neuroscience, Radboud University

Predictive processing posits that the neocortex operates as a continuous, self-supervised learning algorithm, extracting spatiotemporal regularities from the natural visual stream. However, the extent to which subcortical processing follows these predictive principles remains largely uninvestigated. Here, we address this gap by investigating the role of thalamocortical loops in predictive processing. We specifically test whether internal predictions dominate neural firing more strongly than actual sensory input, and whether they primarily drive immediate behavior or facilitate ongoing learning. We first evaluated a novel spatiotemporal predictability measure—derived directly using video joint-embedding predictive architectures (V-JEPA)—against the open-source Allen Institute Neuropixels dataset to map the functional hierarchy of these predictions. To directly interrogate these mechanisms in vivo, we conducted highly parallelized recordings in six mice using four simultaneous 4-shank Neuropixels v2 probes targeting the primary visual cortex (VisP), lateral geniculate nucleus (LGN), and higher-order thalamus (LP). Building on this high-yield electrophysiology, we introduce a novel closed-loop methodology utilizing online receptive field mapping and dynamic stimulus selection to actively manipulate sensory expectations in real time. By integrating both local field potentials (LFP) and single-unit spiking activity, we reveal how corticothalamic neural dynamics negotiate the balance between expected and actual sensory streams, isolating the localized computational signatures that distinguish immediate behavioral drive from long-term predictive learning.

SESSION 5: HUMAN NEURAL RECORDINGS

<u>Matthias Stangl (College of Engineering, Boston University)</u>

The Social Brain in Action: Cognitive Maps of Self and Others in the Real World

As we move through the world, the human brain continuously constructs and updates a cognitive map that supports spatial navigation and memory. This map integrates information about our location, movement, orientation, and the structure of the surrounding environment. In everyday life, navigation is also fundamentally social: we move through shared spaces while monitoring where other people are and how their actions relate to our own. How the human brain builds and updates these cognitive maps — and integrates information about both the self and others on the fast timescales of movement, gaze, and decision-making — remains poorly understood. In this talk, I will describe a multimodal "neuroscience in the wild" approach that combines intracranial electrophysiological recordings with wearable sensing of real-world behavior, including movement dynamics and visual sampling of the environment. I will present evidence that medial temporal lobe activity reflects key components of the cognitive map, including one's current location, movement dynamics, environmental features, and the locations and movements of other individuals. These neural representations are flexibly reconfigured as behavioral goals shift during continuous, natural behavior. Together, these findings reveal fast-scale coupling between deep brain activity and natural actions, and provide mechanistic insight into how the human brain builds, updates, and uses an integrated "social" cognitive map during real-world navigation.

Matthias Stangl *is an Assistant Professor of Biomedical Engineering, Psychological & Brain Sciences, and Neurosurgery at Boston University. Trained in electronics, computer science, and brain–computer interface research, he earned his PhD at the German Center for Neurodegenerative Diseases, where he investigated the neural mechanisms of spatial navigation and the sources of age-related decline in navigation abilities. As a postdoctoral scholar at the University of California, Los Angeles, he developed and applied neuroengineering approaches* *for mobile intracranial recordings and stimulation of human deep brain activity, enabling pioneering studies on how the human "cognitive map" operates during natural movement and behavior in real-world settings. He then launched his lab at Boston University in 2024, where his team combines invasive human electrophysiology, non-invasive neuroimaging, and computational methods to investigate how the human brain supports spatial navigation, memory, and other cognitive functions in everyday life — and how these functions are disrupted in aging and neurodegeneration. Matthias is an elected member of the Memory Disorders Research Society, a faculty member of BU's Center for Systems Neuroscience, Cognitive Neuroimaging Center, and Neurophotonics Center, and a co-organizer of the annual Neuroscience of the Everyday World Conference.*

<u>Alana Darcher</u>

Decoding Movie Content From Neuronal Population Activity in the Human Medial Temporal Lobe

A. Darcher [1*], F. Gerken [2*], P. J. Goncalves [3,4,5,6], R. Rapp [3], I. Elezi [2§], J. Niediek [1,7], M. S. Kehl [1,8], T. P. Reber [1,9], S. Liebe [3,10,11], J. H. Macke [3,12†], F. Mormann [1†], L. Leal-Taixé [5,§§†]

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Neurons in the human medial temporal lobe (MTL) exhibit highly-selective, sparse, and modality-invariant responses to stimuli depicting specific people, landmarks, or objects. Since these neurons have largely been studied using static and isolated stimulus presentations, it remains unclear how neurons in the MTL process content-rich stimuli such as movies and to what extent dynamical stimulus features can be retrieved from neuronal population spiking activity. To address this gap, we studied single-unit responses from 2,286 neurons recorded from the amygdala, hippocampus, entorhinal cortex, and parahippocampal cortex of 29 intracranially implanted patients during the presentation of an 83-minute movie. We found only a few individual neurons that exhibited a classic selective response to semantic features such as characters and setting. Despite the absence of stimulus-selective responses for most features on the single-unit level, we successfully decoded the presence of main characters, setting, and the occurrence of visual transitions from the activity of the neuronal pseudo-population aggregated across subjects. We compared decoding performance between recurrent and linear models and found that visual transitions rely on the temporal information in neural sequences while character-related information does not. We then examined which neuronal subsets contributed most to the decoding performance and found that the relevant information varies across regions depending on the feature category. Our results demonstrate an approach for reliably decoding movie features in the human MTL, and suggest that the brain uses a population code when representing character and location features.

<u>**Philip Sulewski**</u>

Fixation Duration on Natural Scenes Is Explained by Memory Encoding Not Processing Demand

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Prior to each of around 200 thousand eye movements we make each day, the brain decides how long to fixate before shifting gaze to new information. Here we investigate this process using a large-scale scene-viewing experiment (4,080 natural scenes, 5 participants) that combines magnetoencephalography (MEG), eye tracking, and a semantic captioning task. Using multivariate analysis of MEG source-space patterns, behavioural analyses and artificial neural network (ANN) modelling, we show that longer fixations do not reflect prolonged visual processing but relate to downstream memory encoding. First, temporal variability of ventral stream representational dynamics did not explain variability in fixation duration. Second, fixation durations were anti-correlated with ANN-estimated patch classification difficulty. Third, fixation durations correlate positively with ANN-predicted patch memorability and caption-inclusion, and co-occur with increased theta-gamma phase-amplitude coupling, particularly in frontal and hippocampal regions. These results indicate eye-movement timing decisions are shaped by memory-encoding demands rather than by perceptual processing limits.

Pierangelo Nicolas D'Onofrio Pacheco

Distinct Neural Signatures of Tactile Bias and Sensory Uncertainty During Movement

P.N. D'Onofrio Pacheco[1], E. Zimmermann[1]
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When we move, tactile stimuli on the moving limb are perceived as less intense, a phenomenon known as somatosensory gating. However, it remains unclear whether movement affects perceptual precision, and which neural mechanisms underlie these effects. We combined psychophysics and EEG in 29 participants performing a vibrotactile discrimination task across four conditions: Control, Active, Passive Predictable, and Passive Unpredictable movement, replicating and extending our prior work. All movement conditions reduced perceived intensity relative to rest, and somatosensory ERPs were attenuated irrespective of whether movement was self-generated or externally driven, consistent with a movement-related modulation of tactile processing. Discrimination precision, however, followed a pattern: it was highest during Active movement, intermediate during Passive Predictable movement, and lowest during Passive Unpredictable movement. Oscillatory dynamics distinguished these effects. Beta and gamma power differentiated active from passive movement, reflecting movement-related neural processes, whereas oscillatory power did not differ between Predictable and Unpredictable conditions. Instead, increases in trial-to-trial gamma variability from Predictable to Unpredictable movement predicted the corresponding reduction in discrimination precision. Together, these findings indicate two independent processes: a movement-related reduction in perceived intensity and predictability-related changes in perceptual precision, supported by distinct neural mechanisms. While the reduction in perceived intensity occurs across movement conditions, changes in precision depend on how predictable the sensory consequences of the movement are. In natural settings, this may reflect the need to separate externally generated tactile input from the sensory consequences of our own movements, for example when judging surface texture while moving the hand across it.

SESSION 6: STRESS-RELATED BEHAVIOUR

Karin Roelofs (Donders Institute for Brain, Cognition and Behaviour, Radboud University Nijmegen)

Fear Behaviour from Lab to Clinic

For a long time, ecological validity —and the naturalistic quality of experimental design— has been assumed to depend primarily on the external properties of visual environments. In neuroscience, this has often meant shifting from simplified stimuli, such as smiley faces, toward more realistic photographs or videos in an effort to increase naturalism. However, this approach still has limitations, and, somewhat paradoxically, our work with virtual reality (VR) has shown that greater visual realism can sometimes distract from the core processes under investigation.

In this talk, I propose a different perspective. I argue that ecological validity depends less on precise visual detail and more on the internal state of the actor—specifically, their action readiness and psychophysiological condition. I will illustrate this by showing how we target autonomic nervous system (ANS) states associated with threat anticipation and decision-making under threat. I will then describe our efforts to translate these insights into a closed-loop VR-based intervention for professionals and youth at risk. Finally, I will discuss how fundamental neuroscientific findings can be applied in clinical settings.

Karin Roelofs *is Professor of Experimental Psychopathology at Radboud University and Chair of the Affective Neuroscience group at the Donders Institute for Brain, Cognition and Behaviour. Her research focuses on the neural mechanisms of stress vulnerability and resilience, combining behavioural and autonomic phenotyping with advanced neuroimaging (fMRI, MEG) and neuromodulation techniques, including transcranial ultrasound stimulation (TUS). She leads prospective longitudinal studies on emotional action control and decision-making in both typical and at-risk populations, translating resilience markers into targeted interventions.*

Roelofs is a member of the Royal Dutch Academy of Sciences (KNAW) and serves on the board of ALLEA (All European Academies); she is also a former president of the International Resilience Alliance (INTRESA). In 2026, she joined the Scientific Council of the ERC. She has received numerous national and international awards, including an ERC advanced grant (2025), and was awarded the Evens Science Prize in 2020 for her contributions to stress resilience and cognitive neuroscience.

<u>Dominik Bach</u>

The Computational Grammar of Human Behaviour in a Biological Environment

Ulises Daniel Serratos Hernandez[1], Uzay Gökay[2], Lukas Kornemann[2], Yonatan Hutabarat[2], Debadrita Sen[2], Dominik R. Bach[1-2]

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[2]University of Bonn, Transdisciplinary Research Area Life and Health, Centre for Artificial Intelligence and Neuroscience, Bonn, Germany.

Human behaviour unfolds as extended, goal-directed streams of actions shaped by environmental demands and internal states. The organisation of these actions — situated between abstract goals and concrete movements — remains poorly characterised. In particular, it is unclear whether the sequence of these actions is planned a priori or selected on the fly, as has been suggested in rodents. Here, we introduce DynaClade, an unsupervised temporal action segmentation algorithm for full-body motion capture data, and apply it to freely moving participants navigating biologically realistic risky foraging environments. DynaClade identified discrete actions whose kinematic characteristics and spatial distributions closely corresponded to task demands, validating the approach. Among these actions, we discovered a previously undescribed movement pattern, defined by increased body sway without locomotion and suggestive of information sampling. The sequences of these actions exhibited a highly non-random structure with clear evidence for history dependence beyond first-order Markov structure, but mostly explained by a second-order prediction model. This structure was well captured in a hidden Markov model in which distinct latent states associated with different task contexts map onto the same observed action. Individual differences in action transition patterns predicted trait anxiety scores, accounting for 21.5% of cross-validated variance. These findings demonstrate that human behavioural sequences possess rich sequential structure, and establish a framework for investigating the organisation of naturalistic human action.

Jan Gründemann (German Center for Neurodegenerative Diseases – DZNE):

Distributed Neuronal Circuits for Aversive Learning

Growing evidence supports the view that first- and higher-order sensory thalamus is an active participant in adaptive behavior rather than a solely passive sensory relay. The auditory thalamus (medial geniculate body, MGB) is necessary for auditory fear conditioning and we have identified state-dependent plastic MGB neurons whose responses are selectively reshaped during high fear states and fear extinction. This plasticity is mediated by cholinergic control. In addition to classical auditory fear conditioning, which results in passive freezing behavior, MGB activity patterns are furthermore changed during learned escape and active avoidance. These dynamic changes in MGB activity are accompanied by changes in inhibitory regulation from the thalamic reticular nucleus, suggesting circuit-level control of thalamic plasticity across behavioral states."

SESSION 7: CLINICAL NEUROSCIENCE

Jennifer Faber (University Hospital Bonn & German Center for Neurodegenerative Diseases – DZNE)

Leveraging AI-Informed Motion Capturing for Digital Video-Based Movement Analysis in Neurodegeneration

Neurologists are classically trained in visual pattern recognition and identify movement disorders such as Parkinson's disease, post-stroke syndromes, or cerebellar ataxias by observing patients in everyday environments and daily living tasks such as walking. While ataxias are characterized by distinct impairments of balance and coordination resulting resulting in highly recognizable in irregular gait patterns, parkinsonian gait is typically characterized by slowed walking with short steps, reduced arm swing, and difficulty initiating movement or turning. Although skilled in recognizing such characteristic patterns, human visual assessment remains qualitative and limited in its sensitivity to subtle or presymptomatic alterations.

Recent advances in computer vision and artificial intelligence provide an opportunity to translate this long-standing but coarsely graded clinical expertise into scalable, objective, and highly granular digital biomarkers. Our research explores the potential of simple monocular camera systems for markerless motion capturing and video-based movement analysis in neurodegenerative disorders. Pose-estimation-based frameworks enable extraction of spatiotemporal movement trajectories from standard video recordings without the need for specialized hardware or wearable sensors. Combined with subsequent AI-informed feature ranking and selection, we aim to move beyond replicating clinical scales and leverage machine learning approaches for data-driven identification of the most impactful parameters capturing subtle early alterations in oligo- or presymptomatic disease stages and longitudinal changes in neurodegenerative movement disorders. These examples illustrate how digital biomarkers derived from easy-to-deploy and thus, a highly democratizable, technology may support earlier quantification, disease monitoring, and telemedicine applications.

Jennifer Faber *has a background in Mathematics and Medicine. She is a senior neurologist at the Department of Parkinson's Disease, Sleep and Movement Disorders, University Hospital Bonn, where she heads the first European "Ataxia Center of Excellence". She leads the Clinical Ataxia Network at the German Center for Neurodegenerative Diseases (DZNE) coordinating national patient registries. Following a research stay at Stanford University, her work has focused on structural MR imaging at high and ultra-high magnetic field strengths (3T, 7T) and digital biomarkers. Her research particularly centers on the development of AI-informed automated approaches for biomarker discovery, data-driven disease modeling, and image-based severity quantification, with the overarching goal of advancing clinical translation to improve patient care and treatment. Dr. Faber is a Fellow of the Hertie Network of Excellence in Clinical Neuroscience and serves on several international steering committees, including the Movement*

Disorder Society Ataxia Study Group and the Ataxia Global Initiative (https://teamcerebellum.de).

<u>**Melissa Steininger**</u>

Toward Interpretable Cognitive Screening in Epilepsy: Eye Tracking in a VR Trail Making Test

Melissa Steininger [1], Anna Jansen [1], Johannes Müllers [1], Randi von Wrede [1], Björn Krüger [1,2,3]

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Cognitive screening is central to epilepsy care, yet standard Trail Making Test (TMT) outcomes mainly provide completion times and therefore offer limited insight into the visual search and executive-control processes that shape performance. We present an eye-tracked virtual-reality version of the TMT designed as a controlled research tool for process-level cognitive assessment. By synchronizing continuous gaze recordings with task events and gaze-to-area-of-interest annotations, the system enables analysis of attention allocation, search strategy, and set switching during TMT-A and TMT-B. This allows cognition to be examined at both the whole-task level and the level of individual node-to-node search episodes, supporting interpretable measures of how participants orient to relevant, potentially relevant, and irrelevant information. In a feasibility pilot with healthy adults (n=8), synchronized gaze, event, and AOI recordings were obtained in all sessions, usability ratings were favorable, and self-reported cybersickness was low. The next step is to apply this framework in epilepsy cohorts and test whether eye-movement markers provide information beyond completion time in relation to established screening outcomes such as EpiTrack categories. This approach aims to move cognitive screening beyond summary scores toward a more mechanistic account of executive dysfunction and visual search in epilepsy.

POSTERS

(IN CHRONOLOGICAL ORDER)

Continuous behavioral dynamics in mice under self-paced and socially embedded conditions in the IntelliCage

Fabrizio Musacchio[1], Sophie Crux[1], Felix Nebeling[1], and Martin Fuhrmann[1]

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Naturalistic neuroscience seeks to understand behavior in settings where perception, decision-making, and action are continuously coupled. In such closed-loop environments, animals actively determine which information they sample and how they act, giving rise to temporally extended behavioral policies rather than discrete trial-based responses.

Here, we use the IntelliCage system as a semi-naturalistic framework to study continuous behavior in group-housed mice. Animals live in social groups and freely interact with an automated environment in a self-paced, reward-driven manner, enabling the observation of ongoing action selection within a stable social context. Within this framework, a broad range of established behavioral paradigms can be implemented without imposing trial structure. As examples, we present spatial learning experiments probing reward-based memory, as well as stress paradigms assessing depression-like phenotypes via changes in hedonic behavior. These paradigms allow us to quantify how internal states shape behavioral policies over extended timescales, reflected in systematic changes in exploration, activity patterns, and reward-related behavior. The continuous nature of the data further enables the analysis of behavior as trajectories through state and action space, rather than isolated responses.

Compared to classical assays, this framework enables high-throughput, long-term recording of multiple animals in parallel with minimal experimenter intervention. This provides a scalable platform for linking experimentally controlled manipulations to adaptive behavior under conditions that approximate natural environments and support quantitative analysis of decision-making and learning.

An integrated virtual reality platform for naturalistic neuroimaging with magnetoencephalography

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Advancing our understanding of the neural mechanisms that support natural behaviour requires imaging methods that work under conditions of movement and realistic sensory input. Wearable magnetoencephalography (MEG) with optically pumped magnetometers (OPMs) offers millisecond temporal and millimetre spatial resolution in freely moving participants. Yet, combining OPMs with virtual reality (VR) - a tool for delivering immersive in fully controlled environments - has been limited by electromagnetic artefacts from conventional head-mounted displays (HMDs). Here, we introduce and validate a new OPM-compatible VR platform that enables naturalistic neuroimaging without compromising signal quality.

We designed an HMD built from low-noise LCD panels and open-source electronics, achieving magnetic interference levels below those of commercial systems. The device integrates seamlessly with optical motion capture and standard VR development environments (Unity, Unreal Engine), supporting interactive behavioural paradigms. We validated the system through a combination of hardware-level tests and seven experimental tasks across perceptual and cognitive domains.

Our findings demonstrate that the headset introduces negligible magnetic artefacts and preserves source localisation precision. In experimental tests, the system robustly reproduced canonical neural signatures: alpha-band increases with eye closure, lateralised visual responses to flickering checkerboards, beta-band suppression and motor-cortex activation during grasping, and theta-band engagement of medial frontal gyrus and hippocampus during N-back and imagination tasks.

These results establish that our platform enables reliable, whole-brain OPM-MEG recording in immersive VR environments. Its open-source design provides a flexible, scalable foundation for investigating embodied cognition and naturalistic behaviour in human neuroscience.

Audiovisual integration of speech: evidence for increased accuracy in “talk” versus “listen” condition

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Processing of sensory stimuli generated by our own actions differs from that of externally generated stimuli. However, most evidence regarding this phenomenon concerns the processing of unisensory stimuli. A few studies have explored the effect of self-generated actions on multisensory stimuli and how it affects the integration of these stimuli. Most of them used abstract stimuli (e.g., flashes, beeps) rather than more natural ones such as sensations that are commonly correlated with actions that we perform in our everyday lives such as speech. In the current study, we explored the effect of self-generated action on the process of multisensory integration (MSI) during speech. We used a novel paradigm where participants were either listening to the echo of their own speech, while watching a video of themselves producing the same speech (“talk”, active condition), or they listened to their previously recorded speech and watched the prerecorded video of themselves producing the same speech (“listen”, passive condition). In both conditions, different stimulus onset asynchronies were introduced between the auditory and visual streams and participants were asked to perform simultaneity judgments. Using these judgments, we determined temporal binding windows (TBW) of integration for each participant and condition. We found that the TBW was significantly smaller in the active as compared to the passive condition indicating more accurate MSI. These results support the conclusion that sensory perception is modulated by self-generated action at the multisensory in addition to the unisensory level.

Beyond the button press: free-movement VR for studying approach and avoidance in anxiety

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Maladaptive avoidance is considered a hallmark of anxiety disorders, yet laboratory studies have struggled to reliably demonstrate it, hampering investigations into underlying mechanisms as well as treatment development. Two factors plausibly contribute: existing tasks typically reduce behavior to abstracted responses (e.g. button presses) to simple stimuli, and clinical samples are usually characterized by DSM categories that group heterogeneous phenotypes. We address both in an ongoing patient study that combines a free-movement immersive VR task, in which participants forage for fruit under predator threat, with the HiTOP-SR, a dimensional, transdiagnostic measure of psychopathology. The task manipulates two motivational pressures within a single naturalistic episode.

Two within-subject manipulations are crossed on every trial. The starting fruit stash (0, 1, 2, or 3 fruits) sets appetitive pressure: a smaller stash imposes greater pressure to forage, since participants must accumulate enough fruit to avoid virtual starvation. The trial context (0%, 25%, 50%, or 75% probability of predator attack) sets threat. Conversely, higher attack probabilities predict shorter exposure at the fruit bush. The two manipulations vary fully orthogonally across trials, dissociating approach drive from threat-driven avoidance/escape within trials and enabling joint analysis.

The protocol also includes two further VR phases probing safety learning and extinction learning, plus two optional modules: collection of genetic and epigenetic samples, and a measure of intrusive memories.

Preliminary data from healthy controls, collected prior to opening clinical recruitment, show both manipulations producing the expected behavioral signature: foraging effort scaled monotonically with appetitive pressure (more fruit picked when starting with fewer), and time at the fruit bush decreased monotonically with predator-attack probability. Moreover, they showed clear behavioral signs of both safety learning and extinction learning. Therefore, the key manipulations of this paradigm elicit the intended behaviors, supporting the move to the clinical phase.

Enhanced Alcohol-Specific Pavlovian-to-Instrumental Transfer is Associated with Alcohol Use Disorder

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The Pavlovian-to-instrumental transfer (PIT) paradigm assesses how environmental cues influence ongoing instrumental behaviour. Our previous work has linked PIT to high-risk drinking and alcohol use disorder (AUD), but used monetary rewards during learning. We therefore developed a PIT paradigm delivering trial-by-trial alcohol and juice rewards alongside monetary rewards, directly assessing the alcohol-specific PIT effect that may better reflect real-life alcohol-seeking behaviour.

Seventy-five participants with AUD and nighty-five controls completed the task during fMRI. Alcohol-specific PIT was defined as more alcohol choices during presentation of alcohol-associated versus juice-associated cues. General PIT was defined as increased response vigor during display of positively-valenced cues (€10) versus negatively-valenced cues (€-10). The AUD group showed enhanced alcohol-specific PIT effect compared to controls ($p < .001$; $r = 0.295$). Alcohol-specific PIT effect was also associated with the Alcohol Use Disorder Identification Test (AUDIT; rho = 0.287; $p < .001$). In contrast, general PIT effect showed no associations with groups ($p = .698$; $r = 0.030$) or AUDIT (rho = -0.143; $p = .075$). At the neural level, alcohol cues elicited stronger anterior insula responses. Region of interest (ROI) analysis showed a greater left-amygdala alcohol>juice response in AUD than in controls ($p = .043$; Cohen'd = 0.323). For general PIT, gain>loss engaged putamen, amygdala, and ventromedial prefrontal cortex responded, and these ROI responses correlated with behavioural general PIT.

These findings indicate that alcohol cues exert a greater influence on alcohol-seeking in AUD, potentially linked to elevated amygdala responses to alcohol relative to alternative rewards.

NN2026 abstract

(Title)
Estimating task structure by maximizing similarity between task-state and resting-state functional connectivity

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(Text)
The brain flexibly reconfigures in response to task demands. Task designs induce time-locked changes in the blood oxygen-level dependent (BOLD) response. Removing variance of the task's structure yields strong associations between task-removed and resting-state functional connectivity (trFC, rsFC) (Cole et al. 2015). Capitalizing on this, we investigated whether the task structure can be identified in a data-driven way.

Data from the first and second phase-encoding runs of 100 subjects from the Human Connectome Project (HCP-YA) were analyzed separately. Spearman correlation between trFC and rsFC was used as the optimization target for genetic algorithm (GA) to estimate task onset times of a working memory paradigm. The GA-derived optimal task structure was used as task regressor to estimate the explained BOLD signal variance and was compared to results from the known task structure.

GA-derived trFC's correlation to rsFC surpassed the correlation derived from the baseline of known structure removal to rsFC. The GA-derived task onsets aligned well with known onset times in the first run. For the second run, GA-derived onsets were not temporally aligned with known onsets. Task activation analyses using GA-derived task structures identified clusters comparable to those derived from the known task structure in both runs.

These findings suggest that maximizing the similarity between task-removed and resting-state FC can decipher task structure. Precise temporal alignment with ground truth may not be necessary to recover meaningful activation patterns, possibly reflecting sensitivity to task-related network reconfigurations that are not time-locked to the task onset.

Generation and Real-Time Detection of High-Fidelity Odour Plumes

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Olfactory navigation is crucial for survival-related behaviours in animals, including locating food sources, evading predators, and selecting mates. In natural environments, odours are transported in turbulent plumes, generating highly intermittent and rapidly fluctuating concentration signals rather than smooth gradients. These fluctuations contain rich temporal information about the structure and origin of odour sources. Reproducing these naturalistic stimuli in a controlled lab environment remains a significant challenge. Capturing their real-time dynamics in freely behaving animals adds further complexity.

We introduce the temporal Odour Delivery Device (tODD), capable of generating complex, temporally structured odour stimuli with sub-10 ms resolution. tODD precisely reproduces stochastic "whiff–blank" sequences and arbitrary patterns that mimic natural plume structures.

For detection, while Photoionisation Detectors (PID) offer high sensitivity, their size and cost preclude head-mounted use. We instead utilise a miniature metal oxide-based Micro-Chemical Sensor (MiCS), which detects diverse odorants. However, their slow dynamics limits their ability to resolve rapidly fluctuating odour concentrations in turbulent environments. To address this limitation, we designed a high-dynamics signal processing framework using a WaveNet-based deep learning architecture. This model learns the non-linear mapping between raw MiCS responses and high-fidelity PID references, effectively restoring the temporal resolution lost to sensor inertia.

The sensor has been optimised as a chronic, lightweight implant and integrated into behavioural experiments in freely moving rodents. This integrated system enables the precise generation and accurate, real-time measurement of naturalistic odour dynamics.

Head-eye coordination across visual orienting contexts in freely moving mice

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Abstract

During natural behavior, animals continuously move through and interact with the environment, requiring visual stabilization and flexible gaze shifts toward behaviorally relevant targets. These demands are met through coordinated eye and head movements. In foveate species, such as primates, the gain and timing of head–eye coupling strongly depend on behavioral context. In afoveate mice, by contrast, eye movements are thought to be largely compensatory with little evidence so far for similarly rich context dependence. However, a systematic quantitative characterization of head–eye coordination in freely moving mice across defined task contexts has been lacking.

To address this gap, we developed a closed-loop behavioral framework in which mice orient toward or pursue head-orientation-aligned visual projections in an open-field arena. Inspired by classic primate fixation and saccade paradigms, the framework includes discrete target orienting, continuous pursuit, and competitive decision-making between two targets under varying reward contingencies. It combines ecological validity with experimental control, enabling craniotopically defined stimuli, high trial counts, and reproducible stimulus dynamics compared with complex natural tasks such as prey capture, while avoiding the limitations of head-fixed methods.

Using simultaneous tracking of binocular eye movements and high-resolution 3D head kinematics, we quantified head–eye coordination across contexts. We identify various head–eye coupling patterns that extend beyond simple compensation. Critically, the paradigm is compatible and tested with miniature two-photon calcium imaging, providing a versatile platform to link neural dynamics with visuomotor strategies that support visual stabilization and active vision in freely moving rodents.

Investigating Spatially Modulated Neurons with Virtual Navigation

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Spatial navigation is integral to our everyday life, allowing us to interact with the world and remember spaces around us. Multiple cell types have been discovered that may support this ability. A well-known example is the place cell, which was first discovered in rodents and represents a subject's position in space. However, studies in monkeys have also focused on a different cell type, termed 'spatial view cells', which show activity in response to the space that is looked at, irrespective of the subject's location. While place-like cells have also been found in the human brain through intracranial recordings in epilepsy patients, the role of spatial view cells is less explored. Here, we investigated the relative contributions of both functional cell types in humans using an immersive virtual navigation paradigm. Twelve epilepsy patients with intracranial electrodes navigated to object locations in the virtual environment, while we simultaneously recorded eye movements and neural data from major medial temporal lobe (MTL) regions. Recording sites included the hippocampus, entorhinal cortex, amygdala, and parahippocampal cortex. We then quantified the number of neurons, whose firing rates were modulated either by the participants' virtual location or by 3D gaze position in the environment. Our preliminary findings indicate the presence of both cell types, with firing rates modulated by either spatial location or gaze position. Our findings further suggest that while both are most prevalent in the parahippocampal cortex, there is little overlap between them. Together this work improves our understanding of spatial representations in the human MTL.

Area: Experimental research in naturalistic neuroscience

Poster title:

Multifractal dynamics of brain–input tracking during naturalistic audiovisual perception

Abstract:

The brain's ability to process naturalistic audiovisual stimulation depends on tracking stimulus dynamics, or temporal structure. Such stimulation often exhibits fractal properties in which the spectral exponent varies over time, producing irregular temporal structure known as multifractal dynamics. A central open question is whether the brain's multifractal dynamics during naturalistic audiovisual inputs merely reflect intrinsic brain fuctuations, or whether they continuously track the multifractal structure of ongoing naturalistic inputs in a modality-specifc manner, such that auditory and visual regions track the dynamics of their respective sensory inputs. To address this question, we applied a novel analysis pipeline to the 7-T functional magnetic resonance imaging (fMRI) Human Connectome Project movie-watching dataset, jointly analyzing audiovisual stimulus dynamics and brain activity. We found that multifractal dynamics in early auditory and visual regions, but not higher-order association areas, closely tracked those of the corresponding sensory inputs. These findings were replicated in two independent movie-watching datasets. In one replication, the strength of visual input tracking correlated with participants' foreground–background perceptual reports. Together, these results identify brain–stimulus tracking through multifractal dynamics as a mechanism supporting subjective perception under naturalistic conditions.

Authors:

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Title

Language, event perception, and decision-making: A crosslinguistic and neurocognitive approach for forensics

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Abstract

Naturalistic neuroscience conceptualizes cognition as emerging from dynamic interactions between brain, body, and environment [1]. Within this framework, one of the most central higher-order cognitive processes of humans, Language, is largely considered to actively interact with perceptual and action-related processes, shaping for instance how events are perceived, encoded, interpreted, and remembered [2]. Although language and thought are often considered independent, converging evidence indicates that linguistic representations can modulate reasoning and decision-making, particularly under conditions of ambiguity or increased cognitive load [3-4].

The present study examines whether and when crosslinguistic variation influences event perception and decision-making, with direct relevance for forensic contexts. Building on classic findings demonstrating that subtle lexical variations affect event evaluation and memory-based testimony reports [5-6], and on typological and forensic approaches to language use [7-8], we investigate whether languages function as filters to thought, allowing only partial access to key event components such as manner (e.g., speed) and path (goal-directedness/intentionality), and assess whether linguistic (semantic and syntactic) differences impact both *online* processing (reaction times, eye-movement patterns) and *offline* judgments [8-9].

Behavioral and eye-tracking data were collected from monolingual and bilingual participants exposed to naturalistic event scenes paired with systematically varied linguistic descriptions. Offline judgments reveal systematic shifts in perceived intentionality and event structure, with similarity assessments depending on specific semantic and syntactic language profiles. Eye-tracking results further show early attentional modulation, indicating that linguistic cues guide perceptual encoding in real time. These crosslinguistic differences lead to systematic interpretative biases with potential consequences in legal contexts, particularly in eyewitness testimonies.

To extend this approach, we propose an ERP paradigm focusing on the N400 component to examine neural responses to semantic ambiguity and mismatch. This multimethod framework integrates behavioral, perceptual, and neural measures within ecologically valid yet controlled settings.

Overall, our findings highlight the cognitive impact of linguistic diversity on event representation and decision-making, with important implications for forensic practice.

References

[1] Barsalou, L. W. (2008). Grounded cognition. *Annual Review of Psychology,* 59: 617-645.
[2] Pulvermüller, F., Hauk, O., Nikulin, V. V., & Ilmoniemi, R. J. (2005). Functional links between motor and language systems. *European Journal of Neuroscience*, 21(3), 793–797.
[3] Lupyan, G., Abdel Rahman, R., Boroditsky, L., & Clark, A. (2020). Effects of language on visual perception. *Trends in Cognitive Science*, 24(11): 930–944.
[4] Deldar, Z., Gevers-Montoro, C., Khatibi, A., & Ghazi-Saidi, L. (2021). The interaction between language and working memory: A systematic review of fMRI studies in the past two decades. *AIMS Neuroscience*, 16: 8(1), 1-32.
[5] Loftus, Elizabeth F. & Palmer, John C. (1974). Reconstruction of auto-mobile destruction: An example of the interaction between language and memory. *Journal of Verbal Learning and Verbal Behavior*, 13, 585-589.
[6] Boroditsky, L. (2012). How the languages we speak shape the ways we think: The FAQs. In Spivey, M. J., McRae, K., & Joanisse, M. F. (Eds.), *The Cambridge handbook of psycholinguistics* (pp. 615–632). Cambridge University Press.
[7] Shuy, R. W. (1996). *Language crimes: The use and abuse of language evidence in the courtroom.* Oxford: Wiley-Blackwell.
[8] Filipović, L. (2022). From the Crime Scene to the Language Lab and Back: Cross-linguistic Empirical Research on Language and the Law and its Practical Applications. *International Journal of Language & Law*, 11: 104–120.
[9] Soroli, E. (2024). How language influences spatial cognition, categorization of dynamic motion events and gaze behavior: a crosslinguistic comparison. *Language and Cognition*, 16(4): 924-968.

Title: Navigation of non-Euclidean spaces reveals the key role of movement in the flexible re-organisation of spatial memory

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Format: Poster

Abstract: Spatial information from different sources is integrated into a coherent memory that guides navigation. The format of spatial memory is debated, however. A cognitive map that features a globally consistent reference frame and uses a Euclidean metric is the dominant theory. A cognitive graph labelled with metric information is a popular alternative, which does not assume a Euclidean metric or global consistency between different spatial relations. To contrast these theories, we tested 100 participants with 128-channel EEG recording on a non-Euclidean route memory task either in a mobile VR setup or a static desktop setup. The task involved learning and subsequently reproducing routes. Routes were manipulated in a 2x2 design where either the path distances or turning angles were possible or impossible given the route topology. Route reproductions were classified according to the predictions of map or graph theories and showed a mix of behaviours. Manipulation of angles resulted in more map-like responses whilst manipulation of distances produced more graph-like behaviours. Importantly, this effect was only present in the mobile condition, highlighting the key role that active movement plays in forming flexible spatial representations. Spectral analyses of EEG data revealed variations of frontal theta and posterior alpha power depending on the environmental geometry and the representational format used, showing that cortical activity during navigation is dynamically changing and that cognitive systems are flexibly deployed during spatial learning and recall. Together, the data from this study supports a multi-representational perspective where spatial memory is adaptively reorganised in different formats during navigation.

Skeleton Motion Words for Unsupervised Skeleton-Based Temporal Action Segmentation

Segmenting continuous behaviour into meaningful actions is a central step in the quantitative analysis of animal and human behaviour. In practice, this segmentation has often relied on manual annotation by human observers, which is time-consuming, subjective, and difficult to scale to long recordings and large behavioural datasets. These challenges have motivated the development of unsupervised behavioural segmentation methods. However, existing approaches often impose explicit models of behavioural state dynamics and are primarily applied within individual recordings, rather than to identifying consistent actions across datasets and subjects.

To address these limitations, we present Skeleton Motion Quantization (SMQ), an unsupervised framework for segmenting long, untrimmed skeleton recordings into globally consistent action segments across multiple sequences and subjects. SMQ encodes joint-level temporal dynamics using a dilated temporal convolutional autoencoder, while keeping information from different joints disentangled to avoid dominance by a subset of joints. The resulting latent sequences are divided into short, non-overlapping temporal patches and discretized via vector quantization, yielding a set of prototypical skeleton motion words that capture recurring patterns of movement. Assigning each patch to its closest motion word directly produces a temporally coherent segmentation of behaviour.

We evaluate SMQ on multiple human motion datasets spanning wearable sensors and full-body motion capture. Across datasets, SMQ consistently outperforms existing unsupervised action segmentation approaches, producing less fragmented and more coherent segments. By identifying action segments directly from kinematic data, SMQ provides a scalable and objective alternative to manual annotation, with potential applications in behavioural neuroscience and human movement analysis.

Keywords : Behavioural analysis, Action segmentation, Unsupervised learning

Single-Neuron Odor Representations in the Human Brain During Olfactory Behavior

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The olfactory system provides a uniquely powerful model for investigating naturalistic behavior beyond vision and audition. With its well-defined and comparatively direct circuitry, the olfactory system offers a rare opportunity to reveal how neuronal activity transforms sensory input into perception and behavior. We present the first neuronal recordings from the human primary olfactory cortex and medial temporal lobe during an odor-rating and identification task. We discover odor-modulated neurons in the human piriform cortex, amygdala, entorhinal cortex, and hippocampus. Neurons in these regions precisely encode odor identities. Our odor-rating and identification task links human olfactory processes, such as semantic odor identification and reported odor valence, to neuronal activity along the olfactory pathway, allowing us to identify region-specific functions. We find that amygdala neurons encode personal valence ratings, whereas hippocampal neurons predict odor-identification performance. Notably, we reveal that individual neurons in the human piriform cortex precisely encode the identities of odor-related images, highlighting multimodal sensory coding in the human piriform cortex. Presenting semantically related images and odors, we find significant cross-modal coding, especially in the amygdala and the piriform cortex. Most strikingly, we discover individual neurons firing in response to both odors and semantically related images, suggesting concept-like neural coding schemes in olfaction. By bridging the gap between animal models and human research, our results provide insights into human olfactory processing, revealing neural odor coding principles, regional functional specificity, and cross-modal sensory coding.

Processing mechanisms of temporally complex odours across olfactory circuits

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Olfactory stimuli in natural environments often occur as turbulent plumes with varying temporal structures. Although the mammalian olfactory system can access these temporal features with surprisingly high resolution, the cellular and circuit mechanisms that encode, transform, and refine this information remain poorly understood. Here, we investigate how temporally complex odour plumes are represented and processed across multiple stages of the olfactory system. We perform extracellular recordings in awake and anesthetized head-fixed mice to characterize how projection neurons in the olfactory bulb (OB) encode temporally complex odours. To examine the role of local interneurons in shaping the representation of dynamic sensory input, we use optogenetic perturbations of local inhibitory neurons. We further aim to investigate how these representations are transformed in higher olfactory regions, including the lateral entorhinal cortex and piriform cortex, using simultaneous multi-site extracellular recordings combined with silencing of feedback projections to the OB. Together, we investigate how temporally structured sensory information is encoded in the olfactory bulb, transformed across cortical circuits, and modulated by cortical feedback.

Human avoidance: Canonical Learning Phenomena In Naturalistic Settings

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Avoidance learning is essential for survival, yet excessive avoidance is a central feature of anxiety-related disorders. Human avoidance has often been studied using simplified laboratory tasks with discrete responses, limiting the ecological validity and dimensional characterization of avoidance behavior. Here, we developed an immersive virtual reality paradigm that measured avoidance continuously as participants' distance from threat-related cues and outcomes. Using this task, we systematically tested 12 canonical associative learning phenomena in avoidance learning across six pre-registered experiments in healthy humans (N = 599). We observed acquisition, spontaneous extinction, stimulus competition, and retrospective revaluation, but did not find evidence for partial reinforcement extinction, signalled US omission, or CS pre-exposure effects. By combining immersive VR with continuous measures of avoidance, this work offers an ecologically grounded characterization of key phenomena relevant to theory-building in human avoidance learning. Our findings suggest that avoidance behavior is predominantly inference-based, while potentially intermingled with hard-wired Pavlovian influences.

Sleep and Wake Differentially Shape Navigation and Strategy Use

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Navigation relies on distinct strategies, namely response learning and place learning, which can be described through model-based (MB) and model-free (MF) reinforcement learning. The balance between these strategies is shown to change over time, but the effect of sleep on this change is unknown. We investigated the effect of sleep on behavioural metrics of navigation, including goal finding, orientation, and path length, as well as strategy changes between MB and MF learning, using a hybrid successor representation model with one arbitration weight per session.

We developed an aversive virtual reality navigation task using an omnidirectional walking platform. 23 participants completed two sessions of the task, 12 hours apart and were assigned to either sleep or wake condition, with sessions scheduled at different times of day. Results showed improvements in goal finding and orientation across sessions in the wake group, with no evidence for an effect of time or sleep on path length. Computational modelling identified a significant change in arbitration weights towards more MF strategies in the wake group. However, arbitration weights did not predict behavioural outcomes.

Together, these findings show that sleep and wake differentially influence navigational outcomes. In addition, changes between MF and MB strategies can occur over shorter timescale than previously reported. More broadly, the results highlight the importance of integrating reinforcement learning models with conventional behavioural analyses to capture changes in both navigational outcomes and underlying strategies.

Poster contribution

Small Brain, Great Performance: Cognition in Inbred Cichlid Fish

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Inbreeding has been shown to affect fitness-related traits in animals. However, the impact of inbreeding on cognition is less well understood. Here, we examined how multigenerational inbreeding shapes cognitive abilities and brain size in *Pelvicachromis taeniatus*, a cichlid fish with pronounced social behaviour and kin-mating preference. We compared 5th-generation inbred and outbred fish as well as hybrid fish derived from crosses of different 4th-generation inbred lines. Although outbred fish had larger brains than inbred fish and hybrid fish – suggesting inbreeding as well as outbreeding depression – this difference was not reflected in basic cognitive abilities as all 3 groups showed similar associative learning abilities. Inbred fish even outperformed outbred and hybrid animals in reversal learning, an arguably more complex learning task. Generally, hybrid fish took longer to make a decision than outbred and inbred fish. Our findings highlight that inbreeding effects might be overlooked when considering specific output alone. Integrating measures of behaviour, brain morphology, and the neural processes underlying cognition may uncover genetic effects that would otherwise remain undetected. Accordingly, the effects of inbreeding and hybridization cognition are complex and may involve compensatory mechanisms or neuroplastic changes that preserve or even enhance certain cognitive functions.

We also present some preliminary data on the relationship between inbreeding, gut microbiome diversity and cognition to evaluate the potential role of the microbiome in shaping cognitive behaviour. Overall, our study highlights that the relationship between genomic diversity, brain size, and cognition warrants further transdisciplinary investigation across taxa and contexts.

19

Aperiodic Neural Activity During Encoding Tags Cortical Networks for Spindle-Mediated Memory Consolidation

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Abstract

Memory formation depends on initial encoding and subsequent consolidation of new experiences. How do these processes interact to determine which experiences ultimately persist? Sleep plays an active role in memory consolidation, particularly through neural oscillations such as sleep spindles. Previous work suggests that sleep spindles are preferentially expressed at sites of prior cortical excitation, however, the neural signatures during wake that tag these sites for later spindle-mediated consolidation remain elusive. We therefore examined whether aperiodic activity during encoding—thought to reflect levels of neural excitation—predicts trial-by-trial memory success and marks neural sites later recruited by sleep spindles to support memory consolidation. During pre-sleep learning, participants encoded a sequence of 50 images, followed by a two-hour nap and post-sleep retrieval, while we recorded high-density electroencephalography. Spectral parameterization revealed that flatter aperiodic slopes and decreases in alpha/beta power during encoding predicted subsequent memory success. Flatter aperiodic slopes, which have been shown to index increased neuronal excitation, emerged at temporoparietal electrodes, with source localization suggesting medial temporal lobe involvement. Further, the topographic correspondence between encoding-success-related aperiodic activity and fast sleep spindle expression during the subsequent nap predicted memory retention across participants. These findings indicate aperiodic dynamics as a neural marker of effective memory encoding and suggest that sleep spindles recruit tagged learning networks to promote consolidation.

Keywords: memory encoding, memory consolidation, sleep, EEG, aperiodic activity, alpha oscillations, sleep spindles, subsequent memory effects

A Virtual Reality Paradigm to Measure Human Avoidance Learning

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Avoidance learning involves behaviours that enable individuals to evade or withdraw from potentially harmful stimuli. Previous work mainly employed lab-based experimental procedures, which arguably lack ecological validity and ignore human movements. In current work, we addressed these limitations by developing a virtual reality paradigm to investigate human avoidance learning. We refined the original paradigm through five iterations. All experiments involved different combinations of the following phases: a fear conditioning phase, where participants learned to associate one stimulus (CS+) with an unpleasant loud noise (US), but did not associate the other stimulus (CS-) with the US; an avoidance phase, where participants learned that walking away from the CS+ reduced US intensity; a transfer task assessing whether avoidance learning can be transferred to different contexts; an extinction phase assessing reduction in avoidance responses; and finally, a reinstatement phase measuring renewal of avoidance behaviours. Participant movements, positions, and psychophysiological responses (SCR, HPR) were tracked throughout. Results across five experiments validated our paradigm's effectiveness in eliciting measurable avoidance learning. Participants consistently showed stronger avoidance response for CS+ (vs. CS-). Moreover, this avoidance behaviour was subject to extinction and renewal. Our study provides robust evidence supporting the efficacy of our paradigm to study avoidance learning in conditions of high ecological relevance. This paradigm also offers a robust tool for future human avoidance learning research.

Blink-related brain activity – a pathway to study cognition in ecological valid settings

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Studying the use of navigation assistance systems and their neural correlates in a laboratory environment with restricted movement only allows conclusions to be drawn about cognition in this artificial setting. To overcome these limitations, the present study focused on cognitive processes in the real world, allowing natural movement in a complex and dynamic environment. Using mobile electroencephalography (EEG), we analyzed the neural dynamics during pedestrian navigation to investigate incidental spatial learning during the use of landmark-based navigation instructions.

We compare incidental spatial learning performance measures between a video-based seated and a real-world pedestrian navigation setting. To further investigate this incidental spatial learning during navigation, we used eye-blink related potentials of the EEG as indicators of changes in visual information processing during natural motion in an uncontrolled environment. Blinks are powerful events because they serve as a partitioning tool of the visual information stream.

The results showed that meaningful blink-related potentials can be extracted from EEG data of moving participants in uncontrolled real-world protocols, and that blink-related brain activity measures allow the investigation of cognitive processes during ongoing tasks in ecological valid settings.

Disorder-Specific Cerebello-Cerebral Resting-State Functional Connectivity of Neurological Soft Signs: Evidence from A Clinical and Subclinical Samples

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Abstract

Traditional diagnostic systems may obscure heterogeneity and shared mechanisms across schizophrenia (SCZ), bipolar disorder (BD), and major depressive disorder (MDD). It remains unclear whether neurological soft signs (NSS), a potential transdiagnostic phenotype, reflect shared or disorder-specific connectivity, and whether such patterns extend to subclinical participants.

We recruited clinical (SCZ, BD, MDD, healthy controls [HC]; N = 201) and subclinical (high schizotypy [HST], bipolar traits [BIP], subthreshold depression [SD]; N = 201) samples. NSS and cerebellar-cerebral resting-state functional connectivity (rsFC) were assessed using the abridged Cambridge Neurological Inventory and seed-based analyses, respectively.

NSS were elevated in SCZ and BD patients but not MDD patients. In SCZ patients, NSS were positively associated with sensorimotor cerebellar–inferior frontal gyrus rsFC and fully mediated its association with avolition. In BD patients, executive cerebellar–supplementary motor area rsFC was positively associated with NSS and negative symptoms, whereas executive cerebellar–middle occipital gyrus rsFC was negatively associated with both. MDD patients showed restricted NSS-related rsFC at the middle frontal gyrus. HC showed sparse patterns.

In subclinical groups, HST participants showed executive cerebellar rsFC alterations without elevated NSS, whereas BIP participants showed elevated NSS without rsFC changes. In SD participants, sensory integration fully mediated executive cerebellar rsFC associations with depressive and social anhedonia scores, mirroring the MDD pattern.

These findings suggest disorder-specific cerebellar rsFC patterns associated with NSS. Despite cross-diagnostic elevation, NSS may represent an SCZ-specific marker at the cerebellar-frontal circuit level, with BD showing executive cerebellar involvement and MDD minimal engagement, while subclinical patterns reflect differential compensatory processes along the continuum.

GABAergic Modulation of Saccades across Tasks and Contexts

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One of the most reliable findings in psychopharmacological research is the decrease in saccadic peak velocity following benzodiazepine administration. Notably, past research has only examined this in highly controlled settings, assessing horizontal saccades during standardised prosaccade tasks. The spectrum of saccadic eye movements, however, is much larger, including different saccade directions, microsaccades, and saccades to naturalistic stimuli with more complex visual input. Here, 1mg lorazepam or placebo was administered (within-subjects, double-blind, randomised) to healthy adults (N=30). Participants performed a prosaccade task that included vertical saccades and different stimulus eccentricities, a sustained fixation task eliciting microsaccades, and a free-viewing task. Results from the prosaccade task confirmed established effects of benzodiazepines but additionally showed that the effect on peak velocity is independent of saccade direction. Remarkably, in the free-viewing task peak velocities and other metrics of large saccades were unaffected by the drug. Furthermore, exploration patterns in the free viewing task did not change after lorazepam administration. In microsaccades, lorazepam, in comparison to the placebo, led to a decrease in amplitude-adjusted peak velocity during both sustained fixation and free-viewing. Additionally, drug effects appeared to be more pronounced during sustained fixation than free-viewing. Overall, findings demonstrate that saccadic peak velocity is exquisitely sensitive to benzodiazepines, an effect which generalises to microsaccades. However, results also suggest that benzodiazepine effects may be compensated in tasks more closely resembling natural gaze behaviour, possibly via the additional involvement of neurophysiological processes related to top-down influences and fixational eye movements.

Human escape behaviour reveals a constrained action space shaped by threat and context

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Abstract

Escaping imminent danger requires rapid action under extreme time pressure, yet the space of movements available to the human body is vast. In non-human animals, escape strategies are shaped by neural, biomechanical, and ecological constraints, resulting in species-specific patterns. In humans, ethical and practical constraints have until recently hindered the investigation and quantification of escape movements, such that their organising principles are commonly extrapolated from other, mostly quadruped, species. Here, using immersive freely moving virtual reality (fm-VR) in a large physical space, we capture unconstrained whole-body kinematics of human escape from biologically relevant threats. We discover that human escape behaviour is organized within a constrained action space shaped by threat and context. The dominant kinematic pattern includes head orientation toward the threat, body rotation until facing away, and escape with the ipsilateral foot first. Alternative variants include turning away from the threat, backward movement, and misdirected flight. Certain escape patterns and kinematic features reduce success, whereas specific preparatory adjustments enhance it. Our findings provide a quantitative foundation for linking defensive behaviour to neural control, informing the design of biologically-inspired controllers, and enabling the investigation of potential disruptions, such as motor deficits in clinical conditions.

Improving Immersion in VR Threat Simulations through Interaction and Behavioral Design

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We present a set of targeted design improvements to enhance immersion in virtual reality (VR) threat simulations based on the VRThreat Toolkit for Unity. Our work is motivated by the observation that immersion in VR critically depends on the plausibility of agent behavior, interactions, and environmental responses, which together drive the sense of presence.

We observed limitations in the VRThreat Toolkit in agent behavior, user interaction, environmental responsiveness, and visual design that reduced perceived realism. To address these issues, we introduced (1) more expressive threat agent behavior, including reactive attack cycles and animation-based feedback, (2) a two-step object interaction task to increase user engagement, (3) dynamic environmental elements that respond to nearby threats, and (4) visual refinements to strengthen threat perception. In addition, we evaluated performance across environments to ensure stable frame rates, a key requirement for maintaining immersion in VR.

We conducted a pilot user study (n = 6) using a within-subjects design, where participants experienced both the original and modified scenarios. Participants rated the immersiveness of individual components (e.g., interaction, agent behavior, environment, and threat response) on a 5-point Likert scale. Results indicated a consistent preference for the modified scenario, with participants rating every component as more immersive than its original counterpart. The mean immersion score across all components increased from 2.37 (original) to 3.43 (modified). Qualitatively, observations and participant feedback suggested that participants felt more threatened by the more immersive threat agent.

Human fight-or-flight decisions are shaped by threat imminence and follow a sigmoidal function

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Abstract:
The decision to fight or flee in the face of an approaching threat is a fundamental choice observed across the animal kingdom. For humans, the underlying factors driving this decision remain underexplored. Freely moving Virtual Reality (FM-VR) offers a controllable environment where these choices can be tested with high ecological validity. Participants (N = 35) completed a fruit collection task in a naturalistic FM-VR setting. During habituation, they learned they could either flee to a nearby safehouse (0.5 m) or attempt to fight by retrieving a torch (8 m). They were informed that a bear would charge them from behind a grass border in front of them. Threat imminence, a non-quantitative concept, was operationalised as time-to-impact, signalled to the participant by the distance of the grass border (4-30 m). We classified behavior as fight, escape, hesitation, or aborted escape across 11 attack trials. Our results show that fight probability followed a sigmoidal function of time-to-impact, with an inflection point at ~3.91 s. Decision initiation time was invariant across threat imminence, whereas escape speed increased. Fear sensitivity (Fear Survey Schedule-III) was negatively correlated with fight probability. A normative model based on participant-specific speed predicted behavior with 71.7% accuracy, with 14.8% of trials being overly cautious and 14.1% overly risky. These findings indicate that fight or flight decisions depend on threat imminence and are partially captured by a normative speed-based model. Deviations are associated with fear sensitivity.

Keywords:

- Freely moving Virtual Reality
- Decision Making
- Defensive Behavior
- Fight vs Flight
- Threat Imminence

Title: Naturalistic Brain and Body Imaging During Urban Stress: A Multimodal Study in Virtual Environments

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Abstract:

Previous work has shown that city dwellers have an increased risk of developing stress-related mental illness (Peen et al., 2010). Neuro-Urbanism leverages neuroscientific methods and novel data analysis to quantify human subjective experience, aiming to better understand and improve urban conditions to minimize stress. However, current research focuses on stationary unimodal neuroimaging, rather than naturalistic recordings (Gramann, 2024), failing to depict the impact of active behavior on people interacting with the environment.

In this planned study, we will simultaneously record 64-channel EEG, fNIRS, ECG, PPG, NIBP, EDA, and eye tracking, in standing and walking participants inside the lab. Participants will be presented three 2D virtual environments depicting a city model, with systematically-manipulated building-street ratios, revealing increasing stress levels with increasing built density (Trossman-Haifler & Fisher-Gewirtzman, 2022). Participants will observe each environment while standing or walking on a treadmill, and report their subjective experience. In total, sixteen 5-minute trials will be collected. For data analysis, we will implement a symmetric, data-driven source decomposition method, such as mSPoC – ideal for naturalistic recordings (Codina et al., 2025). Furthermore, we will also study power changes in alpha band, and time-domain analysis of natural events, across all stressfulness levels. Peripheral physiology will provide additional insights into stress-modulated responses, including heart rate variability and changes in skin conductance.

The current planned study is the first to employ a robust multimodal neuroscientific framework for naturalistic data collection with fully controlled environmental manipulations, aiming to investigate the effects of urban density on human experience.

Social dilemmas under threat in virtual reality: to flee or not to flee?

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Social dilemmas or coordination games like the prisoner's dilemma (PD) and the stag hunt game (SHG) are situations in which two or more people choose independently between a cooperative and a selfish option. If everyone selects the cooperative option the group gets the most positive outcome but if one selects the selfish option then the other players suffer a big loss. Because of the uncertainty about the other players' choice, one may choose the selfish (but safe) option instead of the cooperative (but uncertain) one. Social dilemmas are generally investigated in the lab, where people either respond hypothetically to vignettes or play with other participants via computers. In both cases, the setting is artificial, participants are isolated, and there is no actual perceived loss for participants. In order to investigate behavior in social dilemmas in a naturalistic way (including the potential for subjective perception of loss and the ability for participant interaction), we have developed a Virtual Reality game in which two participants play an adaptation of PD and SHG. The players collect fruits from two bushes and at some point they are approached by an aggressive dog that may attack them. In this case, they lose their collected fruits and experience a bright red screen and a loud white noise. The dog only attacks one of the players if the other player flees toward their safe house. If both players stay, they can keep collecting fruits while if they both flee they lose half of their collected fruits. Half of the participants receive a fixed participation reward while the other half are paid according to their performance (total collected fruits). This project is composed of two sub-projects: a single-player with a Non-Player Character (NPC) as the counterpart and a multi-player where two participants play the game in VR from two different rooms. I will present preliminary results from the single player sub-project with fixed reward.

Representation of temporally complex odours in the mouse olfactory bulb

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In natural conditions, odours often occur as dynamic plumes whose temporal profiles carry information about the environment. Recent studies have shown that the mouse olfactory system can access high-frequency information from such temporally complex odours (TCOs), despite limitations in sampling rate and signal transduction kinetics. However, an understanding of the relevant temporal features, as well as the local and centrifugal circuit motifs involved in processing them, remains incomplete.

Here, we investigate how TCOs are represented in the mouse olfactory bulb (OB), the first odour-processing centre in the mammalian olfactory system. To this end, we perform two-photon Ca^{2+} imaging in transgenic mice expressing GCaMP6f or GCaMP3 in olfactory sensory neurons, which provide input to the OB at the glomerular layer. Neural activity in the OB is known to be linked to the breathing rhythm. Using a fast odour delivery device of millisecond precision, we present stimuli at fixed phases of the breathing cycle and probe the neural correlates of specific temporal features.

We find that for paired odour pulses with intervals spanning a single sniff cycle, the response magnitude depends on the sniff phase of each pulse. Further exploring how the encoding mechanism changes in the presence of multiple odours, we show that the sequence of paired pulses of different odours can be predicted from the glomerular population responses. Combined with future recordings from OB output neurons, our findings will provide a deeper insight into which temporal odour features are encoded in the OB and how this dynamic information is further transformed for downstream processing.

The relation of facial expression to overt behaviour in naturalistic risky foraging

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Abstract

Facial expression is thought to subserve social communication about one's internal state across many mammal species including humans. While classic emotion theories posit that emotional states jointly organise overt actions, feelings, and facial expression, recent evidence suggests that feelings and actions have a relatively weak concurrent relation and evolve at different time scales: actions responding to the immediate environment, and feelings integrating over longer time scales of minutes. This raises the question of whether facial expression reflects the immediate context, either reflexively or in a goal-directed fashion, or integrates a slowly-evolving state.

Here, we seek to address this question by using a freely-moving virtual reality (fm-VR) in which participants navigate repeated epochs of a naturalistic foraging task under risk of biologically relevant threats, such as aggressive humans, apex predators (e.g., big cats and bears) and self-defending animals (e.g., dogs and snakes). Threat conditions varied by predator identity, distance, attack behavior, and contextual factors such as day versus night environments. Additional "magic shield" and cage trials assessed physiological responses when threat is present but action outcomes are altered or constrained, in order to investigate whether facial expression is reflective (i.e., goal-directed) or reflexive. We recorded facial electromyography (fEMG) from muscles relevant to the facial expression of emotions, as well as general indices of autonomic arousal, namely pupil size, skin conductance, and ECG.

Using these data, we will analyse how facial expression relates to environmental variables and to instrumental actions, and how it evolves over time. The design will also allow us to investigate how autonomic arousal relates to escape initiation, monitoring behaviour, and risk-taking. Exploratory analyses will address habituation across repeated threat exposure, the modulation of bradycardia when escape is impossible, and whether physiological markers can index the moment of threat detection.

By integrating psychophysiological measures with dynamic VR-based behavior, this work seeks to clarify how covert defensive states shape overt threat responses. The findings may improve theoretical models of defensive behaviour and contribute to understanding individual differences in threat sensitivity, action thresholds, and adaptive decision-making under stress.

Neural representation of spatial distance to another person in the human medial temporal lobe

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Navigation and social interaction in dynamic environments rely on estimating spatial distances to objects or conspecifics—an essential variable for planning actions such as approach, avoidance, and social interaction. In non-human animals, specific cell types—such as goal-vector and vector-boundary cells—encode egocentric or allocentric distances to relevant objects. However, how spatial distance is represented in the human medial temporal lobe (MTL) remains poorly understood.

To address this, we recorded single-neuron activity from the MTL of 13 epilepsy patients undergoing intracranial monitoring. Across 18 recording sessions, we recorded 890 single and multi-units in a semi-naturalistic social distance task. During two experimental conditions, participants either viewed an individual standing at one of four distinct distances for two seconds (static condition) or fixated on an individual moving continuously toward or away at a constant speed (dynamic condition).

We found that neurons in the parahippocampal cortex encoded the distance to another person under both static and dynamic conditions. These responses were stable over time and spanned the full range of presented distances. Using Naïve Bayes classifiers, we decoded the experimenter's spatial position from unit activity and found higher decoding accuracy in parahippocampal and entorhinal cortices than in the amygdala or hippocampus. These findings indicate that the human MTL contains a cellular representation of spatial distance to others. More broadly, these results provide new insights into the neural basis of spatial coding and its role in social perception in humans.

Title:
Multimodal Correlates of Environmental Experience in Real and Virtual City Environments

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Abstract:
Previous research has shown that the built environment profoundly impacts both physical health and mental wellbeing. While natural elements are robustly linked to restorative effects (Ferreira et al., 2025), and some evidence associates built density with higher stress (e.g. Trossman-Haifler & Fisher-Gewirtzman, 2022), the mechanisms behind the negative influence of urban environments remain poorly understood. Most existing studies rely on 2-D visual stimulus presentation in stationary paradigms, comparing starkly different environments (e.g. forests vs. busy downtown areas), thereby neglecting the complexity of real urban environments. Additionally, previous studies mostly investigated effects on one single physiological outcome (e.g. electroencephalography (EEG), or electrocardiography (ECG), or electrodermal activity (EDA), etc.). The planned study will take n= 70 participants on an approx. 1h walk through Berlin while collecting continuous 64-channel EEG, ECG, EDA, and eye-tracking data. We will use models based on digital twins of the city (Yosifof & Fisher-Gewirtzman, 2024), as well as semantic segmentation of individual POV-video footage to quantify the composition of the city environment and understand what objects participants direct their attention to. In a following experiment, 360° video and ambisonics audio recorded at selected locations along the route will be presented to participants via head-mounted virtual reality (VR) to compare subjective and physiological responses to the same environments in VR vs. the real world. The poster presentation will present and discuss planned analyses of the collected data and seek to gain feedback and develop new ideas on potential analysis avenues to address the study research questions.

Probing how the temporal structure of odour plumes informs mouse navigation behaviour

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ABSTRACT :

Understanding how mammals use olfactory information for navigating their environment is key to uncovering their natural behaviours. Crepuscular and nocturnal rodents, in particular, rely on odour cues for locating food and potential mates, and avoiding predators. Odour plumes in nature are both temporally and spatially dynamic, with high-frequency concentration fluctuations carrying spatial information, such as distance to the source. However, despite their importance, there is limited research on how mammals interpret these complex temporal odour signals.

Our study investigates how mice use dynamic olfactory cues for navigation, by combining behavioural tasks with respiratory and neural measurements. For this, we designed a large open-field arena with a multichannel odour delivery system that simulates natural conditions, providing various odour sources and complex airflow patterns. Mice are trained to navigate to one of four odour sources using a reward-conditioning paradigm. Once trained, we monitor multiple behavioural and physiological parameters. Besides assessing the performance during the odour source localisation task, mouse movements are tracked in 2D and 3D with high spatial and temporal resolution, enabling quantification of kinematics like speed, velocity, head and body orientation, path taken to source, spatial occupancy, and exploratory strategies. Respiratory dynamics are monitored using an implanted thermistor probe, while real-time odour encounters are recorded with a custom miniature odour sensor. We further aim to assess neural activity in key olfactory regions, including the olfactory bulb and lateral entorhinal cortex, using silicon probes.

Together, this study aims to identify which features of naturalistic odours inform mammalian behaviour and guide navigation.

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