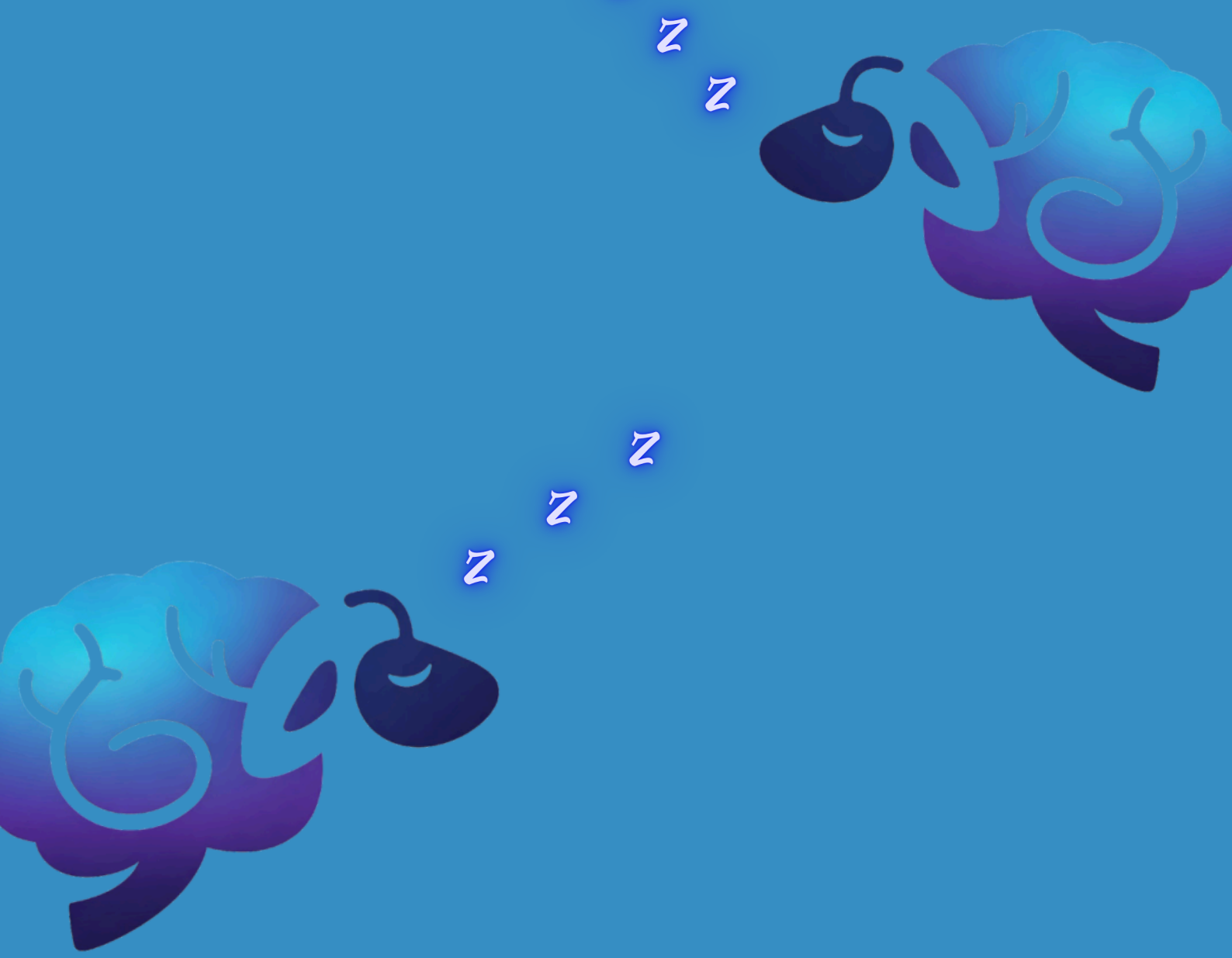

May 31 - June 3 2026 | Marsilius Kolleg, Heidelberg

MEEP

A summerschool on memory and sleep

SUMMERSCHOOL PROGRAM

SUNDAY, 31 MAY

12:30 - 1:00 **REGISTRATION**

1:00 - 1:30 **WELCOME SESSION**

1:30 - 3:30 **LOCAL FACULTY TALKS**

Prof. Andreas Draguhn

Titel: Studying neural network mechanisms of memory

Abstract: Understanding the mechanisms underlying memory formation is a major aim for basic and translational neurosciences, not at least due the enormous societal impact of memory-related disorders. A typical approach for scientific explanations in this realm is to relate a phenomenon at one system level (e.g., spatial memory formation in rodents) to a phenomenon at lower system levels (e.g., activity patterns in temporal networks). In many cases, the underlying logics assumes an upwardly directed ('bottom-up') causality from molecules, cells, small and large networks to large functional systems and the behaving or cognizing organism.

In my presentation, I want to discuss the logics of 'explanations' in biological systems, and highlight some changes and challenges which modern neurosciences are facing. Specific points include the inherently incomplete nature of causal explanations, the problem of complexity, the rise of big science in the biosciences, and the difficulties of translation from basic sciences to clinical applications. The presentation shall foster awareness for the framing of our present approaches and standard flows of arguments. Such reflections may be helpful in a rapidly moving field, notwithstanding the impressive recent progress in the field of memory formation and consolidation.

Prof. Jan Rummel

Titel: Individual Differences in Attention Regulation: The Cognitive Flexibility View on Mind Wandering

Abstract: Mind wandering refers to the shift of attention away from an ongoing task toward task-unrelated thoughts. This talk presents the "Cognitive Flexibility View" of mind wandering, which proposes that individuals with high working memory capacity do not necessarily mind wander less, but rather regulate mind wandering more adaptively depending on situational demands. Drawing on several experimental studies, the presentation demonstrates that the ability to adjust mind wandering to task difficulty is a stable individual difference closely linked to working memory capacity. The findings further suggest that attentional control, and to some extent metacognitive control, are key mechanisms underlying mind-wandering regulation, whereas motivation appears to play a comparatively smaller role.

SUMMERSCHOOL PROGRAM

SUNDAY, 31 MAY

Moritz Plenz

Titel: Where Do Language Models Get Their Facts?

Abstract: Modern language models (LMs) produce fluent, often accurate text across a wide range of topics -- but where does this knowledge actually come from? In this talk, we examine the key stages of knowledge injection into LMs. We distinguish between parametric knowledge, learned during pretraining and encoded into model weights, and contextual knowledge, supplied dynamically at inference time through retrieval-augmented generation (RAG) and agentic tool use. We discuss how each source differs, and why parametric knowledge alone is often insufficient for many applications. We then turn to knowledge graphs -- structured representations of facts -- as a promising alternative to standard text-based RAG approaches, offering greater verifiability and interpretability.

Dr. Magdalena Schlesiger

Titel: From Cognitive Maps to Adaptive Action:
Uncovering Circuit Mechanisms of Context-Sensitive Behavior

Abstract: How do we know to speak openly with friends but remain more measured with colleagues in a professional setting? How do we move between home, work, and public spaces and adjust our behaviour to fit each context? In this talk, I will introduce work from my lab aimed at understanding how the brain encodes, maintains, and updates context-specific representations, and how these representations are used to guide flexible behaviour. I will focus on circuit interactions between the hippocampal–entorhinal memory system, dopaminergic reward signals from the ventral tegmental area, and the striatum, a brain region involved in action selection and goal-directed behaviour. Together, these systems provide a framework for understanding how memories of what happened, where, and under which conditions can guide the right action at the right time, and how context-guided behaviour may become disrupted in conditions such as addiction.

Chair: Juliane Nagel

SUMMERSCHOOL PROGRAM

SUNDAY, 31 MAY

3:30 - 4:00 **BREAK**

4:00 - 5:00 **KEYNOTE**

Prof. Daniel Bendor

Titel: A cortico-hippocampal dialogue governing memory consolidation

Abstract: Hippocampal replay, the spontaneous reactivation of a memory trace, is believed to be critical for memory consolidation, the process by which recent memories are transformed into long-term memories. How an experience is prioritised for consolidation over other competing experiences and selectively strengthened through a coordinated interaction across brain regions, remains poorly understood. Our recent work suggests that replay while awake tags salient experiences prior to sleep, ensuring their prioritisation over competing traces. Consolidating these prioritised memories then requires content-specific, coordinated reactivation across the hippocampus and neocortex. By tracking competing memory representations, large-scale electrophysiology reveals that this distinct cortico-hippocampal dialogue depends on a precise spatio-temporal window. This critical window is defined by the coordination of hippocampal sharp-wave ripples, localized thalamocortical spindles, and cortical slow-oscillation phases. Ultimately, our research indicates that memory consolidation occurs through two distinct stages: awake replay tagging specific memories, followed by sleep-state hippocampal and cortical oscillations guiding their coordinated reactivation across brain areas.

Chair: PD Dr. Gordon Feld

SOCIAL EVENING **PUB QUIZ AT HEMINGWAY'S**

start: 8 pm

location: Hemingway's Heidelberg, Fahrtgasse 1, 69117 Heidelberg

SUMMERSCHOOL PROGRAM

MONDAY, 01 JUNE

8:30 - 9:00 **COFFEE & BREAKFAST TIME**

9:00 - 10:30 **PANEL DISCUSSION**

Prof. A. Draguhn, Prof. D. Bendor, Prof. M. Garvert & Prof. M. Wimber, Prof. T. Staudigl, Dr. S. van Bree, E. Krugliakova & F. Breuer

Title: The future of memory and sleep research

Moderator: PD Dr. Gordon Feld

10:30 - 11:00 **BREAK**

11:00 - 11:30 **POSTERBLITZ**

Brent Vernaillen

Titel: Flexible Statistical Learning Across Modalities: Online and Offline Measures Reveal Different Aspects of Adaptation to Changing Regularities

Abstract: The ability to discern the statistical regularities in our environments has been shown to support key cognitive functions, including attention, prediction and language learning. While most research has focused on stable regularities, real-world patterns often change over time, requiring adaptation. In the context of embedded pattern learning, where continuous input consists of hidden pairs or triplets, prior work showed that learning of an initial structure can hinder learning of an updated one. Alongside post-exposure (offline) learning measures, the current study incorporated online target detection during exposure to gauge real-time learning and adaptation to novel patterns more directly. In three separate blocks, participants were exposed to a stream of embedded pairs that were reshuffled into new pairs halfway through the stream. We administered the same task in both the visual and auditory modality, allowing us to explore modality differences. In the auditory modality, the online target detection measure revealed that participants learned both the initial and updated regularities, but with an advantage for learning the former. In contrast, the offline measure only evidenced recognition of the initial patterns, echoing previously reported primacy effects. In the visual modality, learning was not observed online but was revealed in sensitivity to both sets of regularities in the offline test. I will also discuss plans and some first results of an ongoing fMRI study on updating of neural representations in the Medial Temporal Lobe.

Jialin Zhao

Titel: Assessing the Preferred Breathing Route for Coordinating Sleep Oscillations and Memory Consolidation

Abstract: Beyond regulating cerebral metabolic homeostasis through gas exchange, respiration directly shapes brain activity by modulating rhythmic neural dynamics. Previous research has shown that respiration entrains both the occurrence and coordination of the two hallmark Non-Rapid Eye Movement (NREM) sleep-related oscillations – namely, slow oscillations (SOs) and spindles – which are central to systems-level memory consolidation. However, the mechanisms underlying this modulation remain unclear. It has been proposed that nasal airflow stimulates mechanoreceptors in olfactory sensory neurons, generating breathing-locked oscillations that propagate to regions involved in the emergence of SOs and spindles. Meanwhile, these sleep oscillations may also be modulated by respiratory rhythm generators in the brainstem. To disentangle the contributions of these two pathways in coordinating SOs and spindles, we experimentally manipulated the breathing route during sleep by selectively blocking nasal airflow. After an associative memory task, participants slept either with their mouths taped, such that nasal breathing was maintained, or with the nasal airway blocked, requiring mouth breathing. EEG and respiration were recorded throughout sleep. We will next examine whether the integrity of the nasal route influences the coordination of sleep oscillations and memory consolidation. Slow oscillations and spindles will be detected offline; their coupling to respiratory phase will be quantified. If nasal breathing is critical, its absence should weaken the coupling between respiration, SOs, and spindles. It should also impair the behavioural expression of memory consolidation. This study aims to elucidate how respiration shapes neural dynamics during sleep, contributing to our understanding of brain-body interactions in cognitive and neurophysiological processes.

Sandhya Kumari Pandey

Title: The Impact of Sleep Quality on Memory Consolidation in University Students

Abstract: Sleep plays a crucial role in cognitive processes, particularly memory consolidation. This study aims to examine the relationship between sleep quality and memory performance among university students. Due to academic pressure and irregular routines, many students experience poor sleep, which may negatively affect learning and retention. The study will involve undergraduate students who will complete a sleep quality questionnaire along with simple memory tasks assessing recall and recognition. Based on their responses, participants will be grouped according to sleep quality, and their memory performance will be compared. It is expected that students with better sleep quality and adequate sleep duration will perform significantly better on memory tasks than those with poor sleep habits. The findings aim to highlight the importance of healthy sleep patterns for cognitive functioning and academic success. This research emphasizes the role of sleep hygiene in improving learning outcomes and may provide practical insights for students to enhance their academic performance.

Hedie Zahra Ghanizadeh

Title: Multidimensional Sleep Changes in Major Depressive Disorder

Abstract: Major Depressive Disorder (MDD) is strongly associated with disturbances in sleep, including impaired sleep quality, insomnia symptoms, and altered daytime arousal. However, the extent to which changes in these sleep-related dimensions relate to treatment response remains insufficiently understood.This study investigates the associations between changes in subjective sleep parameters and depressive symptom severity following a 7-week treatment period in patients with MDD. Using a pre–post design within the P4D (Personalized Predictive Psychiatry for Depression) framework at Hannover Medical School, data were collected using standardized self-report measures, including the Pittsburgh Sleep Quality Index (PSQI), Insomnia Severity Index (ISI), Epworth Sleepiness Scale (ESS), and Beck Depression Inventory-II (BDI-II). The primary aim is to examine whether improvements in sleep quality, insomnia severity, and daytime arousal are associated with reductions in depressive symptoms. Secondary analyses explore the relative contribution of different sleep-related dimensions and their potential role as predictors of treatment response. Preliminary aspects of this work have been presented in the form of a scientific poster. By integrating multiple subjective sleep measures, this study adopts a multidimensional approach to sleep in depression, moving beyond single-instrument analyses. The findings aim to contribute to a better understanding of sleep as a clinically relevant factor in depression treatment and to inform future research within personalized and predictive psychiatry.

Francesco Tortora

Title: Context Matters: Dissecting Contextual Representations in Human Threat Learning and Memory under Free Behavior

Abstract: The ability to learn and retain associations between events and their contexts is crucial for survival, particularly in threatening environments. Animal research demonstrates that context modulates retrieval and expression of defensive responses, with contexts represented either as a set of independent features (elementally) or as an integrated configuration (conjunctively). How such contextual representations become integrated into fear learning and memory consolidation in humans is unclear. To address this question, we used a novel virtual reality–based, context-dependent fear conditioning paradigm under free behavior across two days. The virtual environment comprised three distinct offices, each containing two identical lamps (yellow, blue). On Day 1, participants (N = 72) explored two contexts, where one lamp was paired with an aversive electro-tactile stimulation (US) and the other was not. Crucially, contingencies were reversed across contexts. On Day 2, participants were re-exposed to both conditioned contexts and a third, neutral one, allowing us to assess context-dependent retrieval of learned associations. Subjective ratings, autonomic, attentional, and proxemic measures were recorded. Preliminary results show successful context-dependent threat learning reflected in verbal and autonomic responses. Memory performance was strongly modulated by context, consistent with context-dependent retrieval. In the neutral context, US expectancy was reduced for both lamps, consistent with a dominance of configural over elemental representation. Moreover, the strongest memory retrieval was linked to the first acquired contingencies, indicating persistence of early learning. Together, these findings highlight the role of context and its representations in shaping defensive responses and suggest their relevance for clinical interventions targeting maladaptive emotional memories.

Chair: Sianna Grösser

11:30 - 1:00 POSTER SESSION

(1) Brent Vernaillen
(2) Jialin Zhao
(3) Sandhya Kumari Pandey
(4) Hedie Zahra Ghanizadeh
(5)Francesco Tortora
see Posterblitz for title and abstract of contribution

(6) Michaela Kroth

Title: Sleep, Cognitive Control, and Smoking Cessation: Preliminary Observations from a Multimodal Intervention Study

Abstract: Smoking cessation is associated with high relapse rates, emphasizing the need for improved interventions for tobacco use disorder (TUD). Building on prior work suggesting a role of cognitive control in treatment success, this study focuses on cognitive mechanisms relevant for cessation. Sleep, a critical factor in memory consolidation and cognitive function, plays a role in both smoking behavior and cessation. Accordingly, we examine the combined contributions of cognitive training, physical exercise (HIIT, targeting sleep quality), and sleep to smoking cessation outcomes. Participants are recruited toward a target sample of N = 132; however, the present report focuses on preliminary observations from a smaller subset of the sample. The intervention combines chess-based cognitive remediation training (CB-CRT) and high-intensity interval training (HIIT). Sleep is assessed using polysomnography, and wearable fitness trackers to capture both laboratory-based and real-world sleep patterns. Initial descriptive analyses indicate variability in sleep architecture, particularly in NonREM sleep, within the current subsample. Exploratory observations from wearable devices suggest potential changes in sleep parameters in relation to smoking behavior (e.g., before versus after reduction/ abstinence), although these findings are based on limited data and require further validation. Adherence to CB-CRT and HIIT, along with smoking-related questionnaire measures (e.g., dependence, craving, motivation), are being evaluated to assess feasibility and engagement. Ongoing analyses will further investigate whether sleep-related processes may support cognitive improvements and behavioral outcomes. These preliminary findings highlight the importance of considering sleep in the context of smoking cessation and underscore the need for further analyses in the full sample.

(7) Elena Buß

Title: On the trail of memory consolidation - Tracking time-dependent neural representations of complex memory

Abstract: Sleep is thought to support memory consolidation through the reactivation of neuronal engrams. While substantial evidence supports the Active Systems Consolidation Theory and its proposed mechanisms, little is known about the quality and temporal dynamics of consolidated memories over extended periods. Moreover, many previous studies have relied on relatively simple associative learning paradigms, limiting ecological validity. To address these gaps, we will investigate how memory representations evolve across different consolidation intervals using functional magnetic resonance imaging (fMRI) combined with representational similarity analysis (RSA). In the main study (n = 65), participants will complete a complex graph-learning task either 4–6 weeks, 24 hours, or approximately 30 minutes prior to fMRI assessment. RSA will be used to quantify similarities between memory engrams across these consolidation periods. To validate the experimental paradigm and stimuli, two online pilot studies will be conducted. The first pilot (n = 450) will evaluate stimulus characteristics by examining learning curves for disjoint associative pairs across participants. The second pilot (n = 60) will compare learning performance between the graph-structured paradigm and a simple disjoint associative learning task. Together, these studies aim to provide new insights into the long-term dynamics and representational quality of memory consolidation in complex learning environments.

(8) Sianna Grösser

Title: Memory Replay in Humans: Optimizing a Sequence Learning Task with Initial Insights from iEEG

Abstract: Memory replay is a central mechanism for memory consolidation. While clearly characterized in rodents, detecting replay from human non-invasive imaging data remains challenging. Temporally Delayed Linear Modeling (TDLM) is a new approach that detects the sequential reinstatement of stimulus-specific neural patterns. However, recent research suggests that TDLM may not be sensitive enough to reliably capture replay during non-task periods like rest. To address this, we conducted a behavioral pilot to refine a paradigm specifically designed to elicit high replay rates and enhance subsequent detection power. In an online experiment (N=50), participants learned two 14-item linear sequences of images representing distinct conceptual categories. Initially, participants studied overlapping pairs from Sequence 1. To optimize for future replay detection, each learning run was immediately followed by a 5-second "micro-rest" break, at a timepoint where high replay densities are expected. Learning runs were interleaved with retrieval questions requiring participants to infer the underlying sequence structure rather than individual pairs to further encourage replay. In the second phase, a new sequence used novel exemplars of the same categories in a different order. Interleaving both sequences allows investigating how interference modulates sequence replay across different stages of learning. The current dataset validates the behavioral task, providing benchmarks for learning rates and inference performance. Furthermore, we present preliminary iEEG data from a small sample, providing initial evidence of the paradigm's suitability for replay detection. These behavioral and electrophysiological results establish the foundation for a follow-up MEG study to test and refine TDLM-based replay detection in humans.

(9) Samuel Sander

Title: Neural Signatures of Semantic Gradients in False Memory Formation: A 7T fMRI Study

Abstract: Human memory is fundamentally constructive: rather than recording memories exclusively verbatim, the brain extracts and stores semantic representations that can generate vivid recollections of events that never occurred. The Deese-Roediger-McDermott (DRM) paradigm exploits this property, reliably inducing endogenous false memories for semantically related, non-presented words. Two prominent theoretical accounts, the Activation-Monitoring Theory and Fuzzy Trace Theory, converge on the proposal that false memory susceptibility is driven by the degree of overlap between the semantic memory representations of studied material and critical lures. What remains unresolved is whether the temporal pole, the brain's amodal semantic hub, encodes this overlap categorically or as a continuous, graded representational structure. The present study addresses this question directly. Using 7T fMRI (1.5mm isotropic, multi-echo acquisition with TEDANA denoising) and whole-brain RSA searchlights, we will scan 44 participants performing an incidental semantic categorization task on words from 16 German DRM lists. Each list contains three lure types spanning the full associative hierarchy, representing a gradient across associative strength. We predict that temporal pole representational geometry reflects a continuous semantic gradient, and that individual differences in this neural overlap predict idiosyncratic false memory rates at the participant level. Beyond this primary test, we examine brain-model alignment between temporal pole representations and a battery of large language models, from static word embeddings to contextualized transformers and multimodal encoders, to characterize the computational principles underlying semantic memory organization and distortion.

(10) Simon Kern

Title: Non-Invasive Detection of Neural Replay in Humans Using fMRI and MEG

Abstract: Neural replay is well established in rodents and humans via invasive electrophysiology, but remains difficult to study non-invasively. fMRI offers spatial resolution at the cost of temporal precision; MEG provides millisecond-level timing but poor depth sensitivity. Two methods have been proposed to detect sequential replay non-invasively: SODA (Wittkuhn & Schuck, 2021), developed for fMRI, and TDLM (Liu et al., 2021), developed for MEG. To benchmark these approaches, we present FASTIMAGES, a dataset from 70 participants with parallel fMRI (n=40) and MEG (n=30) recordings. Known neural sequences were evoked by fast visual stimulation across four speeds (132, 164, 228, and 612 ms onset-to-onset intervals) using five visual stimuli, alongside functional localizer trials. This controlled design provides ground-truth sequences against which both methods can be evaluated. We find that SODA and TDLM each excel in their native modality with comparable effect sizes under idealized conditions, but cross-modality transfer remains challenging. Beyond this validation, we replicated the SODA paradigm across three acquisition settings: 3T fMRI, 7T fMRI (preliminary) and MEG, to assess replicability and the transferability of multivariate classification techniques across modalities. Together, FASTIMAGES and this cross-modal replication effort aim to establish a robust framework for non-invasive replay detection in humans, clarifying where current methods succeed and where further development is needed.

(11) Dr. Julia Beitner

Title: Reactivating Memory, Replicating Science: Insights From the Ongoing ManyBeds Study of Sleep-Dependent Consolidation

Abstract: Targeted memory reactivation (TMR) proposes that re-exposing sensory cues associated with prior learning during sleep can strengthen memory consolidation. In a seminal study, Rudoy et al. (2009) found that auditory cues presented during slow-wave sleep selectively reduced forgetting for cued image-location pairs, suggesting that sleep-dependent reactivation can help stabilize specific memories. However, the true magnitude and robustness of this effect remain uncertain, as meta-analytic estimates indicate that previously reported effects may be considerably smaller than initially assumed. To address this open question, the ManyBeds project unites more than 13 laboratories across Asia, Europe, and North America in a coordinated, preregistered replication effort. Using standardized behavioral, electrophysiological, and questionnaire protocols, the consortium will collect data from over 600 participants to derive the most precise and transparent estimate of the TMR effect to date. Data collection is currently underway, with participating sites contributing datasets across all three continents. A split-half design will divide the data into exploratory and confirmatory halves, enabling a many-analysts approach in which independent teams preregister, exchange, and validate their analyses on withheld data. By combining large-scale collaboration with rigorous Open Science practices, ManyBeds will not only assess the reliability of TMR during sleep but also illuminate how analytical and theoretical flexibility influence replicability in cognitive neuroscience. The project aims to establish a benchmark for reproducible, collaborative experimental science in human sleep research and to demonstrate how open, theory-driven, and cooperative science can advance confidence in neuroscientific findings.

(12) Juliane Nagel

Title: Reward signals drive encoding of reward item associations during motivated learning

Abstract: Rewards increase our motivation to learn. In their seminal study, Adcock et al. (2006) demonstrated that the anticipation of a reward increased subsequent memory formation. Mesolimbic activity preceding encoding predicted memory performance for high-reward stimuli. Connectivity between mesolimbic areas and the medial temporal lobe was increased for recognized high-reward items. While the work of Adcock et al. has shaped our understanding of motivated memory formation fundamentally, to date, no direct replications exist. We conducted a preregistered replication following the Small Telescope Principle (2.5 times the sample size of the original study; N = 30). Participants studied pictures in the MRI, associated with either a high (2 €) or a low (0.04 €) reward, which was paid out for recognizing the picture in an old/new recognition test 24 h later. While we replicate VTA activity preceding high-reward memory formation, we do not find evidence for the proposed VTA-hippocampal-NAcc circuit that orchestrates selective, motivated learning. We conclude that effects of anticipatory mesolimbic reward activity on high-reward memory formation must be smaller than previously assumed. Furthermore, we demonstrate that the results can also be explained by a different theoretical account: Mesolimbic activity before encoding might not represent preferential memory formation, but instead source memory formation, which is used at retrieval to inform decision strategies.

(13) Dr. Pablo Rojas

Title: Learning Cognitive Maps With Dynamical Systems

Abstract: Learning relational structures from sparse and scarce sequential observations is a hallmark of human cognition, yet its precise mechanistic description remains a challenge. Like other forms of memory, cognitive map learning depends on the hippocampus and its interactions with entorhinal cortex and neocortex, mediated by associative binding and long-term potentiation. Learned maps are subsequently consolidated through experience replay during sleep. Despite substantial progress at molecular, synaptic, cellular, and systems levels, the computational principles underlying the remarkable efficiency of the hippocampus with limited data remain poorly understood. Existing computational models capture important aspects of hippocampal function, yet tend to abstract away biological detail, underrepresent the role of multiple timescales present during both acquisition and consolidation, and often require substantially more data than humans need for equivalent performance. Here we present a critical comparison of existing models along these dimensions, and propose a new architecture that aims at addressing these gaps. Our approach draws on the capacity of recurrent neural networks to learn and reconstruct the dynamics of sequential experience, offering a potential bridge between biological plausibility and computational efficiency.

(14) Li Wei Wei

Title: Does targeted memory reactivation during slow-wave sleep reduces fear generalization?

Abstract: Targeted Memory Reactivation (TMR) uses cues during sleep to modify memories, but its effect on weakening fear memory generalization remains unclear. This study investigates whether TMR during slow-wave sleep (SWS) reduces fear generalization by selectively enhancing memory specificity. Sixty participants will be randomly assigned to a nap group (90-minute SWS) or a wake group (quiet rest). Fear conditioning pairs two geometric shapes (circles and triangles) with distinct odors (leather or metal), fully counterbalanced across participants. Within each set, the most extreme shapes serve as CS+ (partially reinforced with shocks) and CS− (never reinforced). Critically, in the nap group using TMR, one odor is represented during SWS (i.e., the target), while the other remains unreactivated (i.e., the nontarget). Sleep- EEG and fMRI will be used to monitor SWS and evaluate activity in the amygdala, hippocampus, and vmPFC, respectively. We hypothesize that TMR during SWS will selectively reduce generalization only for reactivated stimuli), evidenced by diminished fear responses to non-reinforced, intermediate sizeds shapes, alongside reduced amygdala activation and enhanced vmPFC-hippocampal connectivity for target-related memories. In contrast, nontarget-associated fear of unreactivated stimuli will show comparable generalization in both groups. By disentangling sleep-dependent memory precision from wakeful extinction, this design clarifies how TMR during SWS weakens fear overgeneralization through targeted neural replay, offering a novel strategy to mitigate relapse in disorders where maladaptive generalization persists, such as addiction or PTSD.

SUMMERSCHOOL PROGRAM

MONDAY, 01 JUNE

1.:00 - 2:00 **LUNCH**

2:00 - 2:30 **METHOD SESSION 1**

Prof. Tobias Staudigl

Title:
What can we learn from human intracranial recordings about sleep and memory?

Abstract:

Dr. Sander van Bree

Title:
Encoding Models for Testing Hypotheses about Neural Activity

Abstract:
This workshop introduces encoding models as a practical way to turn hypotheses about neural representations into testable predictions. We will contrast encoding and decoding approaches, and discuss how encoding models can be used to compare competing accounts of neural activity during memory and sleep. The workshop will cover the use of simple predictors in encoding (e.g., experimental conditions, object categories, or behavioral ratings), as well as richer feature spaces (e.g., semantic embeddings or neural network activations).

Chair: Simon Kern

3:30 - 4:00 **BREAK**

SUMMERSCHOOL PROGRAM

MONDAY, 01 JUNE

4:00 - 5:00 **KEYNOTE**

Prof. Mona Garvert

Titel:

Abstract:

Chair: Dr. Pablo Rojas

SOCIAL EVENING **HISTORIC TRAM RIDE**

start at: 5:30 pm

location:

SUMMERSCHOOL PROGRAM

TUESDAY, 02 JUNE

8:30 - 9:00 **COFFEE & BREAKFAST TIME**

9:00 - 10:30 **OPEN SCIENCE SESSION**

In this session, we will cover central aspects of Open Science, including transparency, reproducibility, preregistration, and openly available materials such as data and code. We will first discuss these ideas more generally and then see how they can be implemented in practice through a presentation of the ManyBeds project.

The main part of the session will be an Open Science Hackathon. For this, participants will split into small groups and work on different project ideas related to improving research transparency, robustness, accessibility, or reusability. These projects can take different forms, for example developing a preregistration template for a specific type of study, curating and documenting an open dataset, assessing computational reproducibility, or creating resources that may be useful for the broader scientific community.

The hackathon is meant as a starting point for these projects, rather than as a format in which everything has to be finished within the session. During the session, groups will define the scope of their project, identify concrete next steps, and begin working on a tangible output. After the summerschool, groups can decide whether they would like to continue working on the project and potentially finalize and openly share the resulting resource.

Moderator: Juliane Nagel & Dr. Julia Beitner

10:30 - 11:00 **BREAK**

11:00 - 11:30 **HACKATHON GROUP REPORTS**

SUMMERSCHOOL PROGRAM

TUESDAY, 02 JUNE

11:30 - 1:00 OPEN TALKS SESSION 1

Morgan Whitworth

Title: Sleep-Independent Time Course of Reward-Related Behavioural Tagging

Abstract: Reward can enhance memory for associated events, supporting future adaptive behaviour. Intriguingly, neutral information that initially seems unimportant can later be strengthened in memory when it is followed by a conceptually-related salient event such as reward learning: a phenomenon known as behavioural tagging. While sleep supports memory consolidation, its role in behavioural tagging is unclear. In three separate preregistered experiments, we investigated how sleep and post-encoding delays influence behavioural tagging. In Experiment 1, participants completed two in-lab sessions separated by a 12-hour delay of either overnight sleep or daytime wakefulness. In Session 1, participants completed a learning task with a pre-conditioning phase and a conditioning phase. In the pre-conditioning phase, participants incidentally encoded images of tools and animals. In the conditioning phase, each category of images (i.e., animals or tools) was associated with either a high (£10) or low (£1) monetary reward. In Session 2, participants completed a surprise recognition memory test. Recognition performance was better for high-reward images from the pre-conditioning phase, replicating the behavioural tagging effect. However, there was no benefit of sleep on reward-related retroactive memory enhancement, suggesting that behavioural tagging effects rely on time non-specific to sleep. In Experiments 2 and 3, we investigated if behavioural tagging effects emerge after shorter post-encoding delays. The same design was used except the two sessions were separated by either a 5-minute delay (Experiment 2), or a 3- or 6-hour delay (Experiment 3). We found no retroactive memory enhancement effect when memory was tested immediately after learning, suggesting the effect results from post-encoding consolidation mechanisms. In Experiment 3, we found a retroactive enhancement effect for low-reward images when memory was tested after a 3-hour delay, and no effect of reward on memory after a 6-hour delay. These results suggest that high reward may negatively affect memory during early consolidation. Overall, our findings suggest a long post-encoding consolidation period that is not dependent on sleep is required to observe reward-related behavioural tagging effects.

Xuan Zhang

Title: Effects of Targeted Memory Reactivation on Naturalistic Event Memory Assessed with Free Recall

Abstract: Episodic memory is embedded in the continuous flow of real life, where experiences unfold across time and space and are segmented into meaningful events. This temporo-spatial structure provides a scaffold for retrieval, shaping which units of experience are most accessible and how memories are linked across moments. Here, we investigate how sleep consolidates and reorganizes naturalistic event memories within this temporo-spatial framework, and which features of sleep support the consolidation of event structure. Participants will complete an immersive walking tour in which items are encountered across distinct tour sections. After encoding, memory consolidation will be manipulated using targeted memory reactivation (TMR): auditory cues associated with selected tour items will be replayed during nap. Critically, cues will target items that span event segments, enabling a test of whether sleep preferentially modulates memory organization within events versus across event boundaries. Memory will be assessed after nap using free recall, which can capture both item memory and the organization of recall, including the extent to which retrieval follows temporo-spatial proximity and event-based structure. By combining a naturalistic encoding paradigm with TMR, this study will clarify how sleep architecture supports the consolidation of real-world event representations and the relational structure that binds experiences over time and space.

SUMMERSCHOOL PROGRAM

TUESDAY, 02 JUNE

Nicole Frisch-Payet

Title: Does Acute Cardiovascular Exercise Modulate Sleep-related Motor Memory Consolidation?

Abstract: Acute exercise can enhance motor memory consolidation. Notably, exercise also affects sleep, which is pivotal for memory. However, the interplay between exercise-induced sleep changes and motor memory remains poorly understood. In this pre-registered study, we investigated whether exercise-induced changes in sleep architecture affect motor memory consolidation. Eighty young men were randomly assigned to a WAKE or SLEEP group. Each participant completed two conditions: (i) high-intensity interval training (HIIT: 90%/25% Wmax) or (ii) rest (watching a documentary, REST) immediately after encoding a motor sequence (finger tapping task, FTT). The SLEEP group practiced the FTT in the evening and was retested after a night of sleep, whereas the WAKE group performed the task in the morning and were retested that evening. Sleep was recorded via polysomnography. Analyses revealed a significant group effect, with greater consolidation in the SLEEP compared to the WAKE group ($p=.008$, $\eta^2p=.089$). HIIT did not affect FTT consolidation. Regarding sleep architecture, HIIT reduced REM ($p=.045$, $d=0.37$) and tended to increase NREM sleep ($p=.077$, $d=0.32$). Exploratory analyses further showed that consolidation was positively correlated with NREM sleep only in the HIIT condition ($r=.41$, $p=.020$), reflected by an interaction between condition and NREM sleep with respect to consolidation ($p=.002$). Similar interaction effects emerged at the microstructural level, with significant interactions for sleep spindle number ($p=.022$) and density ($p=.027$). The results confirm enhanced motor memory consolidation through sleep and exercise-induced changes in sleep. Exploratory analyses suggest HIIT may modulate consolidation processes via NREM sleep. Further psychophysiological analyses could help clarify this relationship.

Doan Minh Thu (Martha) Nguyen

Title: REM TMR to modulate negative memories and neuroplasticity

Abstract: Targeted Memory Reactivation (TMR) in REM sleep has been found to habituate negative memories at behaviour and brain functional activity level. As TMR was shown to impact brain structures within the memory system, we hypothesised that the impacts of emotional TMR may be underpinned by neuroplasticity in the amygdala. We tested this using REM TMR of negative videos, followed by diffusion weighted imaging (DWI) at two post-TMR sessions.24 participants (18-35 years old) watched and rated 30 negative videos for valence and arousal before spending the night in the lab. Sounds associated with 15 videos were played for TMR during REM sleep. Participants then underwent MRI scans 48 hours and 15 days post-TMR, repeating the valence and arousal ratings in the MRI scanner. DWI measures were extracted for the amygdala using Soma and Neurite Density Imaging (SANDI) model.

A linear regression was performed to examine whether TMR cueing benefit at session 3 predicted microstructural change in the amygdala. Results showed that TMR cueing benefit predicted left amygdala fsoma ($\beta = 0.02$, $p < .001$), rsoma ($\beta = 0.14$, $p < .001$) and fneurite change ($\beta = -0.01$, $p < .001$); and right amygdala fsoma ($\beta = 0.02$, $p < .001$), rsoma ($\beta = 0.10$, $p < .001$) and fneurite change ($\beta = -0.01$, $p = < .001$).These findings show that microstructural change in the amygdala between 48 hours and 15-day post REM TMR is associated with TMR impacts on emotional habituation at 15-day timepoint.

Dr. Larissa Wüst

Title: Circadian influence on memory-related sleep oscillations – A pilot analysis

Abstract: The sleep homeostatic and the circadian system influence slow wave activity during sleep. Slow oscillations (SO) as a sub-set of slow waves, sleep spindles, and their fine-tuned timely interplay are important factors for overnight memory consolidation, yet slow-wave spindle coupling has not been investigated in the context of circadian science before. In an existing dataset of overnight sleep EEG from 72 male participants, slow oscillation and spindle density as well as SO-spindle-coupling are investigated. Each participant spent 2 nights in the sleep laboratory under different evening light conditions which differentially affected their circadian rhythm, indicated as dim light melatonin onset. SO-spindle-coupling will be indicated through phase angle and coupling strength. Additionally, I will analyze associations of SO-spindle-coupling with after-sleep recall performance in a word-pair learning task. I hypothesize weaker SO-spindle-coupling during the first sleep cycle in the delayed circadian rhythm condition and a positive association of stronger SO-spindle-coupling with performance in the word pair learning task. The results will indicate whether the human circadian timing system can affect memory consolidation during sleep. This will be important for individuals experiencing shift work or required to sleep at non-optimal times of their circadian rhythms, e.g., adolescents required to sleep and rise early for school. Additionally, the information gathered might provide an explanation for variability in previous research between nap and overnight sleep protocols.

Chair: Elena Buß

1:00 - 2:00 **LUNCH**

SUMMERSCHOOL PROGRAM

TUESDAY, 02 JUNE

2:00 - 2:30 METHOD SESSION 1

Dr. Thomas Schreiner

Title:
How Breathing Shapes Brain Rhythms and Memory

Abstract:
Breathing does more than sustain life; it provides a continuous rhythm that shapes brain activity. In this workshop, we will explore how respiration interacts with neural oscillations across wake and sleep, and how this coupling may influence memory consolidation. After a brief conceptual introduction, we will discuss key experimental findings and then move to a practical session outlining analysis pipelines for linking respiratory signals with sleep EEG data. The goal is to provide both a conceptual framework and concrete tools for studying respiration X brain interactions.

Elena Krugliakova & Friederike Breuer

Title:
Hacking the functions of sleep: noninvasive approaches to stimulate sleep neurophysiology

Abstract:
Noninvasive neuromodulation techniques, from sensory to transcranial brain stimulation, offer a promising alternative to pharmacological sleep interventions. We introduce several techniques that have been, or may soon be, used tto modulate the macro- or microstructure of sleep and to investigate effects on related sleep functions, from memory consolidation to brain clearance. We discuss each method's benefits and limitations, showcase relevant sleep stimulation research and offer glimpses into our own sleep-stimulation setups.

Chair: Simon Kern

3:30 - 4:00 BREAK

SUMMERSCHOOL PROGRAM

TUESDAY, 02 JUNE

4:00 - 5:00 **KEYNOTE**

Prof. Maria Wimber

Titel: Retrieval as (fast) consolidation – how remembering actively shapes our memories

Abstract: Memory is not a passive store but a dynamic system continuously shaped by its own use. In this talk, I argue that retrieval is not a read-out of the past but a selective reconstruction that adaptively transforms memories for future use.

First, I present evidence that recalled episodes are far from veridical snapshots, even for simple visual events. Combining behavioural probes with time-resolved decoding of EEG, MEG and fMRI data, we track how retrieval unfolds moment-to-moment. Across studies, memory reconstruction follows a systematic hierarchy that prioritises high-level, semantic information over low-level perceptual detail. I discuss what this prioritisation means for what is retained, lost, and generalised, and how repeated remembering can function as a rapid, consolidation-like event that shifts representations towards more conceptual formats ("semanticisation").

Second, I show how retrieval shapes even memories we do not recall. When reminders co-activate competing memory traces, prefrontal control mechanisms bias processing toward goal-relevant target memories, reducing mnemonic competition. Over repeated retrievals, neural and behavioural evidence indicates that target representations are gradually strengthened while competing representations are attenuated. Retrieval-induced forgetting is thus another mechanism through which retrieval adaptively reshapes memory.

Together, these findings converge on the view that remembering is an active intervention in "memory space": it stabilises useful and prunes interfering information, acting as a highly adaptive consolidation mechanism.

Chair: Dr. Julia Beitner

SUMMERSCHOOL PROGRAM

WEDNESDAY, 03 JUNE

8:30 - 9:00 **COFFEE & BREAKFAST TIME**

9:00 - 10:30 **LOCAL FACULTY TALKS**

Prof. Simon Steib

Title: Exercise as a non-invasive technique to enhance memory across the lifespan

Abstract: Exercise has been shown to enhance cognitive performance, including long-term memory formation. It has been suggested that acute bouts of exercise induce transient effects at multiple levels of the brain, including cellular, molecular, and systems-level changes, thereby providing an optimal environment for neural plasticity and consequently memory formation. Emerging evidence suggests that exercise may also improve motor skill learning and memory; however, findings are mixed and mainly derived from young adult populations using laboratory-based fine motor tasks. In the first part of the talk, I will summarize findings from our lab examining the impact of acute exercise on motor learning in young and older adults, as well as people with Parkinson´s disease. In the second part of the talk, I will then discuss very recent work on the potential role of sleep in the exercise – memory relationship.

Prof. Beatrice Kuhlmann

Title: When, Where, How? How Source Monitoring Allows Tapping Into Multiple Memory and Guessing Processes with a Single Test

Abstract: In this talk, I will give an overview of source monitoring, the set of cognitive processes involved in attributing information to a source such as judging who told you something, where you last saw your glasses or whether you actually heard someone laugh or merely imagined that. I will introduce multinomial modeling as a method to separately measure different source-monitoring processes—familiarity-based item memory, recollection-based source memory, and guessing processes—from the responses of a single source-monitoring test. Finally, I will show how separating these processes is important for examining the influence of sleep (among many other factors) on memory.

Prof. Georgia Koppe
Title: Uncovering Computational Motifs of Memory by Learning Dynamical Systems From Data

Abstract: Memory depends on neural systems that maintain, transform, and retrieve information over time. In this talk, I will discuss how computational motifs underlying memory processes can be inferred from data. I will first introduce a simple recurrent neural network as a toy model and use it to illustrate key dynamical phenomena relevant for memory, such as stable states, transitions, and temporal integration. I will then show how such dynamical systems can be learned from data while remaining sufficiently tractable to analyze their underlying mechanisms. Together, this provides a framework for linking observed neural or behavioral dynamics to interpretable computational principles of memory.

Chair: Dr. Pablo Rojas

10:30 - 11:00 **BREAK**

11:00 - 12:30 **OPEN TALKS SESSION 2**

Dr. Yan Wang
Title: Targeted Memory Reactivation During REM Sleep Modulates Emotional Memory and Affective Persistence
Abstract: Targeted memory reactivation (TMR) during non-REM sleep reliably enhances memory consolidation, whereas REM TMR appears to support emotional regulation by reducing arousal and heart rate responses to negative stimuli. However, the boundary between REM sleep's roles in memory consolidation and emotional processing remains unclear. While slow-wave sleep (SWS) TMR consistently improves spatial memory, REM TMR has been associated with impaired recall for negative content. Whether such effects extend to neutral memories is unknown. This study examined how REM TMR influences memory performance and emotional evaluation (valence and arousal), with a focus on affective persistence. Twenty-one participants completed an image–location task using neutral and negative images paired with sounds. During overnight sleep with 32-channel EEG, half of the cues were replayed during REM sleep. Memory, valence, and arousal were assessed before sleep, after waking, and one week later. Linear mixed-effects models tested TMR effects while controlling for baseline performance and ratings. REM TMR produced a small but significant decline in memory for cued relative to uncued items ($\beta = -0.0022$, $p = .041$). Critically, TMR modulated emotional processing. A TMR-by-emotion interaction for valence ($\beta = -0.001$, $p = .046$) showed reduced differentiation between neutral and negative stimuli. For arousal, a TMR-by-baseline interaction ($\beta = -0.012$, $p = .024$) indicated that the influence of initial arousal on later ratings was attenuated following reactivation. These findings suggest that REM TMR primarily alters emotional processing while subtly affecting memory, reducing affective persistence and reshaping how prior experiences influence later evaluations.

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WEDNESDAY, 03 JUNE

Maria Stella Villa Avila

Title: Memory reactivation during sleep promotes learning-induced neuroplasticity

Abstract: Sleep plays an important role in memory consolidation, during which newly encoded memories are stabilized into long-lasting representations. This process relies on neuroplasticity, enabling functional and structural brain changes after learning, and is thought to be supported by memory reactivation during sleep. However, how such reactivation contributes to neural plasticity and overnight memory consolidation remains poorly understood. In the current study, we aim to investigate the relationship between memory reprocessing during sleep and learning-induced microstructural changes. Eighty-two participants underwent diffusion-weighted MRI (DW-MRI) and overnight high-density 128-channel EEG recordings across three sessions spaced one week apart. Before sleep, participants completed an image localization learning task involving stimuli with scenes and objects. Multivariate pattern analysis will be used to quantify the reinstatement of category-specific representations in wake and sleep, and DW-MRI metrics will assess learning-induced microstructural changes in gray matter. Preliminary findings indicate that category-specific information can be decoded from EEG during the task performance. We expect similar category-specific representations to be detectable during slow wave sleep, where the strength of this content decodability is expected to correlate with overnight memory consolidation. Further analyses are needed to explore whether reactivation strength drives sleep-dependent microstructural changes. Our findings suggest that category-specific neural representations can be decoded during wakeful learning and may also be reinstated during slow-wave sleep. An association between reactivation strength and overnight performance gains would support a role of sleep-related memory reprocessing in memory consolidation. Linking these electrophysiological measures to microstructural changes may provide novel insights into sleep-dependent neural plasticity and improve our understanding of how sleep supports the structural reorganization of memory traces.

Bohdana Ivakhnenko

Title: Modelling Knowledge Conflicts in Large Language Models

Abstract: Over the last couple of years, the topic of knowledge conflicts with Large Language Models (LLMs) has grown significantly. It is one of the unsolved problems of modern machine learning. LLMs are trained on large collections of texts containing facts from different periods, opinions and straightforward disinformation. Some facts become outdated relatively quickly (e.g., who is the current president of a given country), while others coexist with unreliable information (e.g., the origin of the SARS-CoV-2 virus). This results in intra-memory conflicts. Other types of conflicts include clashes with the prompt's context. While humans are generally able to identify such conflicting information and consolidate their memory to encode it along with judgment labels, models are not able to learn continuously and fail to take different views into account because they are focused on predicting the next word. LLMs answer differently when asked the same question in different wordings (e.g., "Who is the president of France?" and "The president of France is..."), since different word sequences lead to different probability distributions over the next word. I am investigating how a model develops conflicts during training by poisoning its training data in a controlled way. After this, I am interested in exploring how one could build a memory-consolidation mechanism for a model.

Öykü Alparsian

Title: Temporal Source Memory Modulation by Discrete Negative Emotions: An Experimental Study Using Emotional Facial Stimuli

Abstract: The planned study investigates how discrete negative emotions, specifically fear and anger, modulate temporal source memory across different retention intervals. While previous research has demonstrated that emotional arousal and valence influence item recognition and memory for perceptual contexts or sources, the interaction between emotion and the temporal organization of episodic memory remains underexplored. Fear and anger, although both threat-related, negatively valenced, and high in arousal, differ in their attentional orientations: fear tends to broaden attention toward contextual cues, whereas anger orients attention toward the source of threat. This divergence may differentially influence how emotional events are temporally bound and later retrieved. In the experiment, participants will view two sequential face lists composed of fearful, angry, and neutral facial expressions presented in randomized order. Following encoding, participants will complete a recognition recognition test for the faces and temporal source attribution test for their list membership simultaneously. We are seeking input on an affective rating tool to ensure and assess active appraisal of the emotional stimuli. Memory data will be modeled using the two-high threshold multinomial processing tree (2HTM) model (Bayen et al., 1996) to disentangle item recognition, source memory, and guessing behavior. This approach enables a fine-grained understanding of how discrete emotions shape temporal binding across different memory delays, making an important contribution to emotion and cognition research.

Xiaoyue Zhou

Title: Systems Consolidation prioritize critical structure in sequential memory

Abstract: Everyday experience unfolds within environments that are richly structured rather than random. To adapt effectively, it is often hypothesised that human brains constructs internal models to capture latent structures of the world, which further facilitate efficient information processing. However, it remains unclear how learned structure, especially those learnt implicitly, are consolidated and shifted in terms of cognitive representations. In this longitudinal behavioural study, we investigated how implicitly learned sparse community structure underlying auditory sequences are consolidated - is pattern integration (extracting mesoscale gist) or pattern separation (sharpening detailed representations) prioritised? The preliminary results support the latter - behaviour patterns reveal successful internalisation of the community property, with the representations for critical structure that contradict community property enhanced. (ongoing work)

Chair: Michaela Kroth

SUMMERSCHOOL PROGRAM

WEDNESDAY, 03 JUNE

12:30 - 1:00 **CLOSING SESSION**

1:00 - 2:00 **LUNCH (TO GO)**

Thank you for your participation.
It was a great summer school.