# 2025 Asia-Pacific Computational and Cognitive Neuroscience Conference (AP-CCN25)

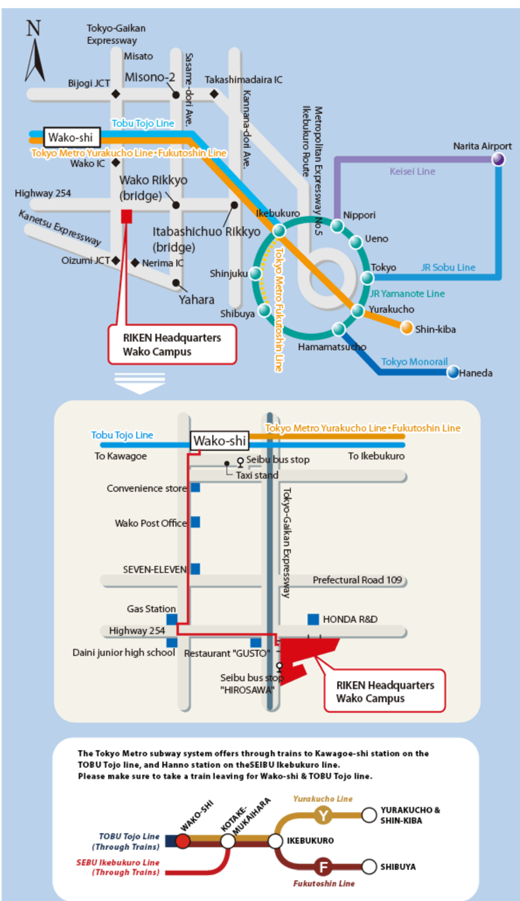
July 21–23, 2025 at RIKEN, Japan

## About AP-CCN25

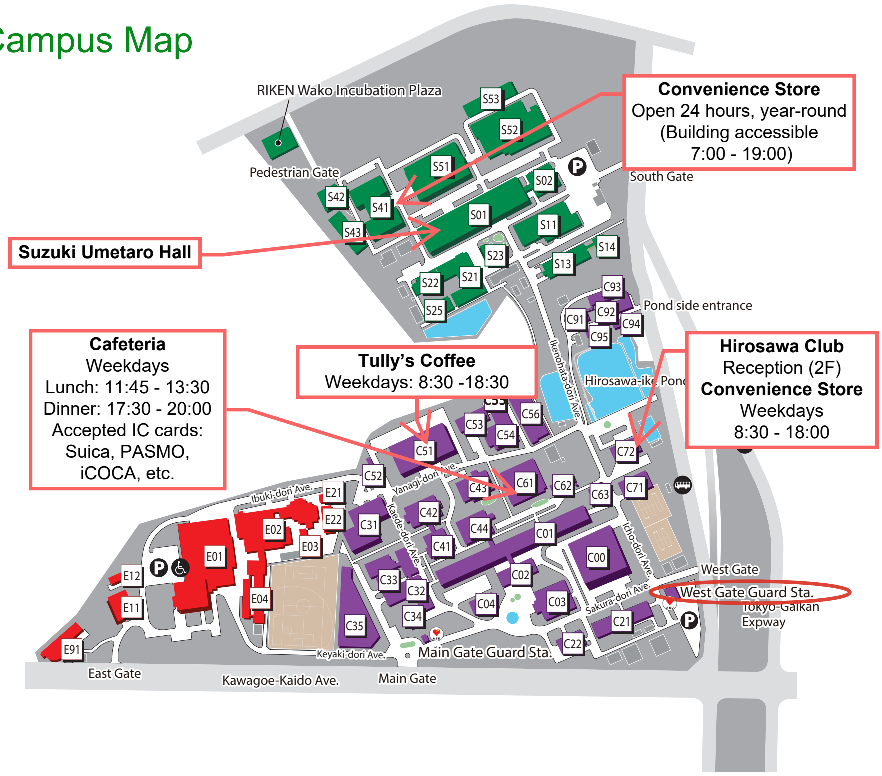
Computational neuroscience has advanced rapidly in recent years owing to the availability of the sheer amount of neural recordings and connectomic data. It is the perfect time for developing a collaborative forum that promotes research in computational neuroscience in the Asia-Pacific area. The mission of the AP-CCN Conference is to promote computational neuroscience, and to facilitate interactions and collaborations between theoreticians and experimentalists.

## Venue

Suzuki Umetaro Hall, RIKEN
2-1 Hirosawa, Wako, Saitama 351-0198, Japan



## Campus Map




## Program

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| July 21 (Mon)<br>13:00-14:00, **Shun-ichi Amari** (RIKEN) [Keynote]<br>14:00-15:00, **Yu-Wei Wu** (Academia Sinica)<br>15:00-15:30, Coffee break<br>15:30-16:30, **James Pang** (Monash)<br>16:30-17:30, **Tianchu Zeng** (NUS)<br>17:30-18:30, Poster presentation |
| July 22 (Tue)<br>09:00-10:00, **Juan Helen Zhou** (NUS)<br>10:00-10:30, Coffee break<br>10:30-11:30, **Yu Takagi** (NIT)<br>11:30-12:30, **James Roberts** (QIMR Berghofer)<br>12:30-13:30, Lunch meeting<br><br>13:30-14:30, **Jun Tani** (OIST)<br>14:30-15:30, **Ching-Che Charng** (NTHU)<br>15:30-16:00, Coffee break<br>16:00-17:00, **Choong-Wan Woo** (SKKU)<br>17:30-19:30, Reception (Invited speakers) |

July 23rd (Wed)
09:00-10:00, **Michael Häusser** (Hong Kong U) [Keynote]
10:00-11:00, **Su Jin An** (KAIST)
11:00-11:30, Coffee break
11:30-12:30, **Liping Wang** (ION)
12:30-13:30, **Xiao-Jing Wang** (NYU)

## Sponsor

SECOM Science and Technology Foundation
RIKEN Center for Brain Science

## Organizing Committee

- Michael Breakspear, University of Newcastle, Australia
- Jaeseung Jeong, KAIST, Korea
- Chung-Chuan Lo, National Tsing Hua University, Taiwan
- Taro Toyoizumi, RIKEN Center for Brain Science, Japan
- Xiao-Jing Wang, New York University, USA
- Juan Helen Zhou, National University of Singapore, Singapore

## Invited talks

### Shun-ichi Amari

Teikyo University

Title: AI, brain and Civilization

Abstract: We have two intelligent systems---AI and the brain. The brain has developed through a long history of evolution, whereas AI has emerged as an engineering product hinted from the brain. We touch upon their histories. The developments of AI are so remarkable, it would change our society and civilization. However, we do not fully understand why it works so well. The scale of AI has been enlarged, but we do not yet fully understand why a large system works so well. Here is lack of theory! Take a deep layered neural network. Its parameter space has singularities, which makes the parameter space so strange. As the number of the parameters increases, the parameter space is covered by a dense net of singularities. We are not yet successful for understanding the performance of its learning. That is, we do not yet understand the empirical power law of its performance nor emergence of a new law as the number of the parameters increases. We finally touch upon the future civilization and the danger as AI develops.

## Yu-Wei Wu

Institute of Molecular Biology, Academia Sinica, Taiwan

Title: Elucidating causal interaction of sensorimotor cortices through neural manifolds during dexterous forelimb movements

Abstract: Sophisticated motor control requires the seamless integration of planning, execution, and feedback adjustment. While studies have illuminated how the motor cortex cooperates with other areas for specific functions, these investigations have largely been limited to interactions between pairs of regions. Here, we introduce a method to map the dynamic signal flow across a network of sensorimotor cortices—the primary motor (M1), premotor (M2), and somatosensory (S1) cortices—to understand how these motor functions interplay on a broader scale. We trained mice to perform a skilled forelimb task, simultaneously recording over 1000 deep-layer neurons across M1, M2, and S1 using a large-scale microwire array. For each trial, we extracted low-dimensional latent factors for each cortical region and aligned their dynamics to a common reference frame for direct comparison. Using a powerful equation-free method, we uncovered the interactions among M1, M2, and S1 at single-trial resolution. Our analysis revealed that aligning the neural data to different behavioral events uncovered distinct temporal sequences of interaction, highlighting the context-dependent nature of cortical communication. Furthermore, we demonstrate a clear link between the dynamics of single neurons and broader population-level coding. In summary, our work provides a robust platform for disentangling the complex, high-speed interactions across multiple brain regions, offering new insights into the distributed network that enables sophisticated motor control.

## James Pang

Monash University

Title: Geometric influences on brain function and regional organization

Abstract: In this talk, I will highlight the previously underappreciated role of brain geometry in influencing brain function and regional organization. I will show that geometric eigenmodes derived from the brain's cortical and subcortical geometry accurately capture diverse experimental human functional magnetic resonance imaging (fMRI) data from spontaneous and task-evoked recordings. I will then show that the close link between geometry and function is explained by a dominant role of wave-like activity, and that wave dynamics can reproduce numerous canonical features of functional brain organization. I will also show that geometric eigenmodes can be used to develop a simple, hierarchical approach that mimics a putative generative process for regional organization. The approach can effectively parcellate any brain structure in any species, defining regions with more homogeneous anatomical, functional, cellular, and molecular properties than most existing

parcellations in use today. Finally, I will show that the approach captures the essence of reaction-diffusion mechanisms that play an important role in shaping the foundations of regional organization through neurodevelopment.

## Tianchu Zeng

National University of Singapore

Title: Optimizing Biophysical Large-Scale Brain Circuit Models With Deep Neural Networks

Abstract: Biophysical modeling provides mechanistic insights into brain function, from single-neuron dynamics to large-scale circuit models bridging macro-scale brain activity with microscale measurements. Biophysical models are governed by biologically meaningful parameters, many of which can be experimentally measured. Some parameters are unknown, and optimizing their values can dramatically improve adherence to experimental data, significantly enhancing biological plausibility. Previous optimization methods – such as exhaustive search, gradient descent, evolutionary strategies and Bayesian optimization – require repeated, computationally expensive numerical integration of biophysical differential equations, limiting scalability to population-level datasets. Here, we introduce DELSSOME (DEep Learning for Surrogate Statistics Optimization in MEan field modeling), a framework that bypasses numerical integration by directly predicting whether model parameters produce realistic brain dynamics. When applied to the widely used feedback inhibition control (FIC) mean field model, DELSSOME achieves a 2000× speedup over Euler integration. By embedding DELSSOME within an evolutionary optimization strategy, trained models generalize to new datasets without additional tuning, enabling a 50× speedup in FIC model estimation while preserving neurobiological insights. The massive acceleration facilitates large-scale mechanistic modeling in population-level neuroscience, unlocking new opportunities for understanding brain function.

## Juan Helen Zhou

National University of Singapore

Title: Integrating Brain Imaging and AI: Applications in Neurological Disorders

Abstract: Advances in brain imaging and AI provide an unprecedented opportunity to explore the human mind and develop new approaches for treating neurological disorders. Each neurodegenerative disorder affects distinct large-scale brain networks. This talk will focus on brain network phenotypes in neurological disorders such as Alzheimer's and cerebrovascular disease. Specifically, how these network phenotypes relate to pathology, help identify at-risk groups, and predict cognitive decline. Our recent work on AI-driven models for brain decoding and interpretable brain foundation models with efficient adaptation strategies will also be discussed. Moving forward, integrating AI with brain

imaging paves the way for improved early diagnosis and treatment strategies for neuropsychiatric disorders.


## Yu Takagi

Nagoya Institute of Technology


Title: Bridging Minds: Human Brain, Generative AI, and Foundational Models


Abstract: Generative AI is advancing rapidly, displaying impressive abilities to understand complex environments, follow intricate instructions, and even interact with the physical world—approaching near-human proficiency in some domains. Yet systematic work on how the internal representations of these models align with, or can be used to model, the human brain is only just beginning. Studying this link benefits both sides: AI offers new methods for probing neural function, and neuroscience insights help us keep AI understandable and aligned with human goals.

In this talk, I will introduce studies that place human and artificial “brains” side by side to deepen our understanding of both, and I will showcase ongoing efforts that leverage cutting-edge AI techniques to accelerate—and fundamentally reshape—cognitive and systems neuroscience research.



## James Roberts

QIMR Berghofer


Title: Modelling brain activity on long time scales


Abstract: Brain activity unfolds on an extremely wide range of time scales, though most effort to date has focused on studying relatively short time scales of milliseconds to minutes. In models, different brain states often map to different sets of parameter values, but then questions remain on how models parsimoniously explain transitions between different states, and how brain activity matures and ages. This talk will present work on modelling “slow” variables beyond the traditional neuronal ones. For example there are slow changes on the order of hours in metabolic and ionic availability, and circadian and homeostatic processes, and on longer time scales still these dynamics evolve across the lifespan. Applications include transitions in and out of seizures, recovery from hypoxic injury, and the maturation of sleep patterns. Many possibilities remain to be pursued, discussion of which will hopefully inspire new models explaining dynamics on time scales of hours, days, months, and years.

## Jun Tani

Okinawa Institute of Science and Technology

Title: How can higher cognitive mechanisms develop through iterative sensorimotor interactions with the world? Insights From Neurorobotics

Abstract: This talk presents two recent neurorobotics studies that extend the active inference framework. The first study [1] explores how out-of-distribution generalization (ODG) can emerge during the learning of goal-directed object manipulation tasks. Robotic experiments demonstrated that a form of ODG can be achieved through the emergence of content-agnostic information processing at the executive control level during learning. The second study [2] builds on this by investigating how compositionality in action and language can be acquired through sparse interactive learning. Results showed that generalization of compositional structures improves when a wider variety of compositional elements are included in training examples. Finally, I will discuss how these findings provide insights into potential neural mechanisms underlying higher-order or meta-level cognition, as revealed through emergent phenomena in neurorobotics experiments.
[1] Queißer, J. F., Jung, M., Matsumoto, T., & Tani, J. "Emergence of Content-Agnostic Information Processing by a Robot Using Active Inference, Visual Attention, Working Memory, and Planning." Neural Computation., 2021
[2] Vijayaraghavan, P., Queißer, J. F., Verduzco-Flores, S., & Tani, J. "Development of compositionality through interactive learning of language and action of robots." Science Robotics, 10, eadp0751., 2025

## Ching-Che Charng

National Tsing Hua University

Title: Hybrid Olfactory Encoding Network Forms an Olfactoscape across Neuropils in the Drosophila Brain

Abstract: Olfactory perception in Drosophila melanogaster emerges from the coordinated activity of neural circuits distributed across multiple brain regions, yet the organizing principles of these circuits remain incompletely understood. Here, we present a comprehensive analysis of large-scale connectomics dataset revealing a hybrid organizational structure in the projection neuron (PN) to Kenyon cell (KC) network. This structure forms an L-shaped connectivity pattern, wherein food-related PNs diverge to multiple KC classes, while pheromone-sensitive PNs converge specifically onto γ KCs. From the input perspective, γ KCs receive widespread input from all PN clusters, whereas α/β and α′/β′ KCs preferentially receive input from food-related PNs, positioning them as key players in appetitive processing. These wiring motifs are supported by the spatial distributions of PN axons and KC dendrites and extend beyond the mushroom body to the antennal lobe (AL) and lateral horn (LH), collectively forming a structured olfactory landscape, or "olfactoscape," across neuropils. Functional calcium imaging and

computational modeling further reveal that distinct KC classes exhibit different odor response strengths, which align with behavioral valence—approach or avoidance—demonstrating a correspondence between connectivity, encoding, and preference. Moreover, simulations confirm that this hybrid architecture enhances both odor discrimination and detection sensitivity, highlighting its computational advantages for robust and flexible olfactory processing.

## Choong-Wan Woo

Sungkyunkwan University

Title: Understanding pain: Insights from the brain and artificial intelligence

Abstract: One in five adults suffers from chronic pain, yet we do not fully grasp the mechanisms of pain. In addition, despite 30 years of using fMRI to study pain, robust brain models of pain are still lacking. In this talk, I will present our previous findings from a decade of modeling pain in the brain, highlighting the limitations of current models. Subsequently, I will introduce new research directions emerging from recent advances in personalized brain mapping and artificial intelligence, with the aim of developing better neurocomputational models of pain to help individuals suffering from chronic pain.

## Michael Häusser

University of Collage London / Hong Kong University

Title: Using all-optical interrogation to constrain the neural code

Abstract: Understanding how the patterns of activity in neural circuits underlie the neural code driving behaviour is one of the fundamental questions in neuroscience. Addressing this problem requires the ability to perform rapid and targeted interventions in ongoing neuronal activity at cellular resolution and with millisecond precision. I will describe results of experiments using a powerful new "all-optical" strategy for interrogating neural circuits which combines simultaneous two-photon imaging and twophoton optogenetics. This enables the activity of functionally characterized and genetically defined ensembles of neurons to be manipulated with sufficient temporal and spatial resolution to enable physiological patterns of network activity to be reproduced. We have used this approach to identify the lower bound for perception of cortical activity, probe how brain state influences the role of cortex in perception, provide causal tests of the role of hippocampal place cells in spatial navigation. I will also discuss how closed-loop interventions can be used to dynamically control neural circuit activity in real time.

## Su Jin An
KAIST


Title: Learning About Learners: Real-Time Task Optimisation for Human Causal Reasoning


Abstract: Traditional experiments assume a fixed task structure, overlooking how human reasoning dynamically adapts to context and experience. We present the Deep Neural Experimenter (DNE), a closed-loop framework that models and guides human causal inference in real-time. Combining an LSTM-based cognitive profiling module with an adaptive task control module, DNE continuously estimates latent cognitive states and adjusts cue–outcome schedules to enhance learning efficiency.

In a behavioural study (N = 56), participants interacting with DNE demonstrated a 42% improvement in one-shot inference accuracy and faster convergence compared to a non-adaptive control group. These findings demonstrate how adaptive experiment design can actively reshape reasoning, offering a new paradigm for cognitive neuroscience and human–AI co-adaptation.



## Liping Wang
Institute of Neuroscience, Chinese Academy of Sciences


Title: Multiple Routes to Metacognitive Judgments of Working Memory in the Macaque Prefrontal Cortex


Abstract: The ability to evaluate one's own memory is known as metamemory. Whether metamemory is inherent to memory strength or requires additional computation in the brain remains largely unknown. We investigated the metacognitive mechanism of working memory (WM) using two-photon calcium imaging in the prefrontal cortex of macaque monkeys, who were trained to memorize spatial sequences of varying difficulties. In some trials, after viewing the sequence, monkeys could opt out of retrieval for a smaller reward, reflecting their confidence in WM (meta-WM). We discovered that PFC neurons encoded WM strength by jointly representing the remembered locations through population coding and their associated uncertainties. This WM strength faithfully predicted the monkeys' recall performance and opt-out decisions. In addition to memory strength, other factors—trial history and arousal—encoded in baseline activity predicted opt-out decisions, serving as cues for meta-WM. We identified a code of meta-WM itself that integrated WM strength and these cues. Importantly, WM strength, cues, and meta-WM were represented in different subspaces within the same PFC population. The dynamics and geometry of PFC activity implement metacognitive computations, integrating WM strength with cues into a meta-WM signal that guides behavior.

**Xiao-Jing Wang**
New York University

Title: Distributed coding and functional modularity in a multiregional brain

Abstract: With technological advances in connectomics and neurophysiology, studies of whole-brain circuits have come to the fore. Recent observations of widespread information processing and memory storage have raised questions about functional specialization in the brain, which I will address using large-scale modeling of cortex based on connectomic data for monkeys and mice. I will highlight macroscopic gradients of synaptic excitation and inhibition as a general principle of the cortical organization; and discuss findings ranging from a hierarchy of timescales to distributed working memory and simple decision-making. This line of work suggests that a new concept dubbed "bifurcation in space" can explain functional modularity compatible with distributed neural representations in the neocortex that is made of repeated canonical local circuits à la Kevan Martin and Rodney Douglas.

## Poster presentations


### Poulomi Adhikari

Academia Sinica


Title: Motor learning stage-dependent dendritic spine remodeling in cognitive learning vs movement refinement


### Pin-Ju Chou

Institute of Systems Neuroscience, College of Life Science, National Tsing Hua University, Taiwan


Title: Unique Asymmetry in Dendritic Morphology and the Computational Properties of Drosophila Central Neurons


Abstract: Neuronal morphology directly influences the arrangement of synaptic inputs, outputs, intrinsic electrical properties, and consequently, the computation performed by a neuron. The diverse morphology of fruit fly neurons raises questions about the underlying structural rules. We perform data mining on the neuronal skeleton data provided by FlyCircuit. We conduct statistical analyses on the overall structural complexity and examine how morphological properties, lengths, and distributions of branches relate to their centripetal properties, using the Strahler ordering system. Later, we delve into analyzing dendritic structural symmetry using a new metric, the balance ratio, by averaging the balancing information of each node concerning the centripetal ordering system. We wonder why most dendritic structures have a balance ratio within a narrow range. To understand this, we propose two distinct computational scenarios: spatial and temporal computation. Spatial computation is defined as the efficiency of inhibition usage by neurons to dissect spatial input patterns, while temporal computation is defined as the variation in output spike trains with shuffled order inputs. Eventually, we found that most dendrites have a balance ratio indicative of non-biased computational ability. This provides a reason for the observed distribution of the balance ratio of dendritic structures.

## KunLin Hsieh

RIKEN CBS


Title: Breathing-Central Amygdala Coupling Drives Dynamic Transitions Between Aversive and Reward-Seeking States


Abstract: The relationship between physiological responses and emotional states remains a fundamental question in neuroscience. Previous studies have shown that bodily feedback can modulate emotional states. However, the precise neural mechanisms underlying this connection remain unclear. Here we investigated how breathing-brain coupling in the central amygdala mediates dynamic emotional state transitions.

We trained animals on a reward-seeking task in an open arena. We then introduced aversive loud noise stimuli during testing while simultaneously recording breathing patterns and central amygdala local field potentials (LFP). Following the first aversive stimuli, animals exhibited distinct behavioral changes from the pre-aversive period. These changes included reduced reward-seeking behavior, decreased locomotion, and increased corner-staying behavior.

We identified three distinct physiological-behavioral states. The first was Passive Aversive states with low speed, low breathing rate, and no neural coupling. The second was Active Aversive states with high speed, high breathing rate, and strong 7Hz breathing to 90Hz LFP coupling in central amygdala. The third was High Arousal Non-Aversive states with high speed, high breathing rate, but no coupling. Last state is usually seen when animals travel from one reward port to the other.

The emergence of strong cross-frequency coupling between 7Hz breathing and 90Hz central amygdala LFP specifically marked active aversive processing states. This coupling predicted faster recovery to reward-seeking behavior. The coupling was absent during both passive freezing and non-aversive high-arousal states. This indicates its specificity to emotional regulation rather than general arousal.

Our findings reveal a dynamic model of aversive state processing where animals transition from passive threat assessment to active emotional regulation and eventually return to reward seeking states. The breathing-amygdala coupling represents a neural mechanism that enables flexible emotion regulation by modulating threat prominence. This coupling allows animals to recover from aversive states and return to normal behavior. This work demonstrates the dynamic process of emotional state transitions and the critical role played by breathing-neural interactions. These findings provide new insights into the physiological basis of emotional flexibility and resilience.



## Sunil Kim

KAIST


Title: Decoding the Neural Vocabulary of Seizures: A Zero-Shot Analysis of Canine iEEG Using a Generalist Time Series Model

Abstract: This study introduces a novel, zero-shot approach for analyzing canine intracranial electroencephalography (iEEG) to differentiate between ictal (seizure) and interictal (non-seizure) brain states. Our core contribution lies in leveraging TOTEM, a generalist VQ-VAE model pre-trained exclusively on non-medical time series datasets, to convert complex iEEG signals into discrete tokens without any domain-specific fine-tuning. We then analyzed the statistical properties and temporal predictability of these token sequences. Our analysis reveals two key findings: First, the token distributions of ictal and interictal states are statistically distinct, indicating that each neurological state possesses a unique "neural vocabulary." Second, ictal sequences exhibit significantly higher predictability and lower complexity than interictal sequences, suggesting that pathological brain activity during a seizure undergoes a loss of dynamical complexity. This explorative study demonstrates that generalist, token-based models can robustly discriminate between brain states, addressing common challenges in EEG analysis like noise and hyperparameter sensitivity. By discretizing neural dynamics, our work opens a promising avenue for applying well-established discrete state-space models, potentially unlocking a deeper understanding of complex neurological data.

**Hildelith Leyser**

RIKEN CBS/ McGill Univeristy

Title: Revealing Social Strategies in Monkeys with Inverse Reinforcement Learning: Embodied Decisions Beyond Optimality

Abstract: Understanding how primates make decisions in social contexts requires moving beyond standard reward maximization frameworks. In this study, we combine a 3D embodied choice task with multi-agent inverse reinforcement learning (IRL) models to dissect the decision-making strategies of macaques across social and individual conditions. Each trial required monkeys to choose between a variable (exploratory) and a known (exploitative) reward capsule, with sessions conducted solo or in the presence of other monkeys varying in social rank. Our IRL models incorporate public, private, and personal reward valuations, revealing that subordinate monkeys shift away from reward-optimal choices in social contexts, instead adopting context-sensitive policies aligned with social dynamics. These behaviors are not merely suboptimal; they reflect strategic adaptation to dominance hierarchies. Our results demonstrate that optimality and exploration are orthogonal, and that social variables reshape the reward landscape itself. This work introduces a computational framework for modeling social cognition in nonhuman primates and opens new avenues for decoding embodied, socially mediated learning.

## Chen Chieh Liao

National Tsing Hua University

Title: Sensory integration in Drosophila navigation: unravelling the role of lateral accessory lobe in sensorimotor transformation

Abstract: The Drosophila melanogaster's head direction (HD) system is crucial for navigation, with neurons in the ellipsoid body (EB) encoding visual cues for spatial orientation. Recent research highlights E-PG neurons in the EB and FC2 neurons in the fan-shaped body as encoding head direction and goal angles, respectively. PFL3 neurons integrate these signals for navigation, transmitting steering commands to interneurons and descending motor neurons (DNs) in the lateral accessory lobe (LAL), influencing turning behaviors. Despite detailed connectomic data revealing a complex LAL network, its precise function in the sensorimotor transformation pathway remains unclear. In our study, we employed computer simulations to explore the role of the lateral accessory lobe (LAL) in Drosophila navigation. By incorporating LAL circuitry into neural simulations, we revealed that the LAL goes beyond signal relay, emphasizing turning signals from PFL3 neurons and preventing overshooting during head-turning behaviors. Specifically, we identified two neurons that inhibit contralateral motor neurons and play a crucial role in the turning process. We also discovered an anti-goal circuit that causes the body to turn away from the target. In conclusion, our study elucidates the multifaceted role of the lateral accessory lobe (LAL) in Drosophila navigation, highlighting its intricate circuitry and contributions to precise turning behaviors and adaptive response dynamics to the goal.

## Hsiu-Hau Lin

National Tsing Hua University

Title: Sparse Edge Encoder (SEE) for natural images

Abstract: Vision is fundamental for all animals to interact with their environment. In humans, visual perception is governed by intricate mechanisms spanning from the eyes to the brain. Visual recognition, therefore, emerges from the dynamic interplay between external stimuli and the neural systems that process them. Our recent patent, Sparse Edge Encoder (SEE), draws inspiration from principles in physics and neuroscience to uncover hidden statistical structures in natural images, optimizing both image encoding and decoding. The core mechanism of the SEE algorithm is grounded in the physical laws of image formation. By encoding images using Laplacian charges, natural scenes often yield sparse representations due to the prevalence of diffusive reflections. Remarkably, these sparse representations can be decoded with minimal information loss. A compelling demonstration is lossy image compression: using SEE, images are compressed while maintaining a peak signal-to-noise ratio (PSNR) greater than 30 dB by retaining less than 27% of the original information—outperforming traditional discrete cosine transform methods.

## Henrique Oyama

Okinawa Institute of Science and Technology (OIST)

Title: Modeling Autonomous Shifts Between Focus and Mind-Wandering Mental States Using a Predictive-Coding-Inspired Variational RNN

Abstract: Mind-wandering (MW) reflects a complex interplay between focused attention and off-task mental states. Various studies have investigated the psychological and systematic mechanisms underlying the shifts between MW and focus state (FS). However, the current models have not yet provided an account for the underlying neural mechanisms for autonomous shifts between the two states.

Recent works investigated mind-wandering mechanisms using the Predictive Variational Recurrent Neural Network (PV-RNN), a hierarchically organized model rooted in the Free Energy Principle (FEP). The PV-RNN's dynamic behavior is governed by a meta-level parameter, the meta-prior w, which balances the complexity term against the accuracy term in free energy minimization. While these current computational studies provide critical insights into macroscopic neural mechanisms, the transition from FS to MW has been caused by manual resetting of the meta-prior from a low to a high setting, leaving the mechanism for autonomous FS-MW shifts unexplored.

Motivated by the above, we propose an online adaptive mechanism for w, modulated by the average reconstruction error over a fixed length time window in the past. A simulation experiment is presented to showcase the proposed framework. In particular, using PV-RNN, we trained the model to predict sensory patterns generated by probabilistic transitions among cyclic trajectories. Simulation results demonstrate that autonomous shifts between FS and MW emerged as w switched dynamically: high w enhanced top-down predictions, promoting MW, while low w emphasized bottom-up sensory perception, favoring FS. Finally, this work explores how our experiment results align with existing studies and highlights their potential for future research.

## Tomasz Rutkowski

RIKEN AIP

Title: Title: Passive Brain-computer Interface for Dementia Prediction Using Path Signature and Deep Learning Models

Abstract: Abstract: Passive brain-computer interface (pBCI) offers potential for assessing brain health, detecting neurodegenerative processes, and monitoring non-pharmacological interventions. However, like active BCI, pBCI faces challenges due to EEG noise and non-stationarity. This study introduces a novel application of the path signature, a tool involving iterated integrals of multidimensional paths, to address the issue of noisy EEG. The path signature, invariant to translation and time reparametrization, provides a robust feature for

analyzing multichannel EEG time series. We explore its combination with the geometric structure of symmetric positive definite (SPD) matrices and deep learning regressors. Preliminary results from experiments targeting mild cognitive impairment (MCI) in elderly individuals, a key predictor of dementia, demonstrate the potential for creating digital biomarkers. Specifically, we model underlying neurodegenerative brain mechanisms and investigate lead-lag relationships using path signatures. Our initial findings involve exploring geometric features of the negative square of the lead matrices constructed from the second-level signature, and employing a regularization term to derive SPD matrices as features for subsequent machine learning models.


## Hosana Tagomori

RIKEN


Title: Title: Thalamic Analysis of Inhibitory Control in Sensory Inference


Abstract: Abstract:
In order to establish coherent perceptions of ambiguous sensory environments, the internal model of the world must be updated. However, the mechanisms underlying this process have yet to be fully elucidated.

• Higher-order thalamic nuclei may play a key role in stabilizing short-term sensory history representations in the posterior parietal cortex (PPC; Schmitt et al., 2017).
• Using optogenetics, we found that the thalamus' pulvinar nucleus (PUL) is crucial for forming inferences based on sensory history.
• The thalamic reticular nucleus (TRN) is the main source of inhibitory input to the thalamus (Campbell et al., 2024) and has connections with the PUL. Consisting of entirely GABAergic neurons, it may inhibit the PUL when change is detected, serving as a comparator between the current sensory environment and past sensory history, facilitating sensory history updating.
• Leveraging the chloride sensor SuperClomeleon to determine GABAergic inhibition, we found greater inhibition in the PUL when there was a mismatch between the current sensory stimulus and past sensory history.
• Consistent with this engagement optogenetic activation of the TRN destabilizes representations of sensory history.
• These findings suggest that TRN-PUL interactions facilitate the inhibitory control of sensory inference, enabling appropriate sensory history updating with sensory change.

**Kensuke Yoshida**
RIKEN Center for Brain Science

Title: A theoretical model of schema learning during sleep

Abstract: Reorganizing learned knowledge into a generalized structure is an essential aspect of cognition, known as schema formation. Sleep is considered to facilitate this process by promoting memory reorganization. Previous studies have suggested that sleep plays a crucial role in acquiring transitive inference—inferring non-adjacent relationships (e.g., ‘A>C’) from adjacent ones (e.g., ‘A>B’ and ‘B>C’)—enabling the generalization of directly learned relationships to novel ones. However, the neuronal mechanisms underlying this process remain unknown.
Here, we develop a theoretical model of schema formation. In our framework, learning during wakefulness is modeled as rote memorization of input patterns, while learning during sleep is formulated as a Hebbian t-SNE, a previously proposed biological nonlinear dimensionality reduction. This process reorganizes high-dimensional input patterns into low-dimensional representations that preserve input structures. The model reproduces the acquisition of transitive inference during sleep by building transitive structures via Hebbian t-SNE. These findings suggest that the proposed model provides a mathematical explanation, unifying the previous findings related to schema learning during sleep.