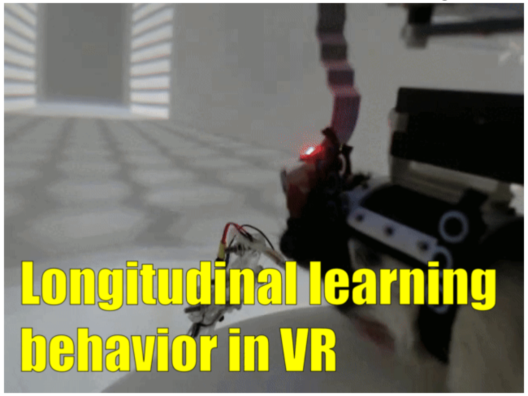
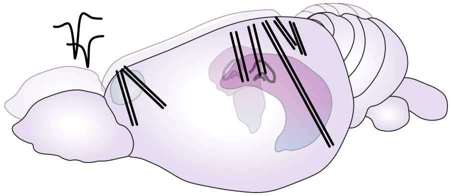
Decoding longitudinal learning of behaving rats in VR with a 1024 channel BMI from 9 brain regions



longitudinal +
electrophysiology data



How is learning orchestrated across brain regions?

+ animal experiments + data analysis
+ software development

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Master Thesis Project

Decoding longitudinal learning of behaving rats in Virtual Reality
with a 1024 channel BMI from 8 brain regions

Motivation

Understanding how neural populations change their coding during learning is a central question in systems neuroscience. This project aims to shed light on how changes in the low-dimensional subspaces of population activity across brain regsions facilitate learning [1]. We want to understand what kind of trajectory does learning follow in behavioral and neural space? How do changes in behavioral strategy manifest in neural population coding? How do higher-order areas such as the medial prefrontal cortex (mPFC) differ from primary and secondary sensory cortices in terms of plasticity during learning and reversal learning? Can we identify features of neural population dynamics that facilitate learning? And how are these features coupled to changes in behavior?

Approach

Learning moderately complex tasks unfolds over extended timescales. To observe how populations of neurons across multiple brain regions adapt, it is essential to track neural activity longitudinally.
We are uniquely positioned to address these questions using our flexible electrode technology, which enables long-term, stable recordings across brain regions [2]. Our latest brain-machine interface (BMI) system allows simultaneous acquisition of high-density neural data—up to 1278 electrodes spanning 8 distinct brain areas. This cross-regional perspective is crucial for capturing the distributed nature of learning in the brain.

In parallel, we have developed a virtual reality (VR) setup that enables highly controlled behavioral experiments with synchronized neural recordings. The behavioral paradigm is inspired by a recent study [3] that showed how CA1 pyramidal neurons become successively decorrelated in alignment with discrete behavioral strategy states. Our VR task similarly induces transitions in behavioral strategies, which we aim to relate to changes in neural population structure across multiple regions.

Project Scope for the Master Student

We have successfully established the behavioral paradigm and acquired two months of neural data from a single rat performing the task. For the next phase of the project, we are seeking a motivated master's student to join the team. The thesis will involve:

> Conducting animal experiments and managing behavioral training
> Acquiring and curating longitudinal neural data from multiple brain areas
> Analyzing neural population dynamics, with a focus on changes in neural geometry during learning and strategy shifts
> Exploring the relationship between behavioral states and neural representations across brain regions

Candidate Profile

The ideal candidate is enthusiastic about experimental neuroscience, enjoys working with animals (rats), and is curious about how complex behavior emerges from coordinated activity in large neural populations. Prior experience with electrophysiology, data analysis (Python/MATLAB), or behavioral neuroscience is beneficial but not strictly required.

[1] Averbeck, B., Latham, P. & Pouget, A. Neural correlations, population coding and computation. Nat Rev Neurosci 7, 358–366 (2006). https://doi.org/10.1038/nrn1888
[2] Yasar, T.B., Gombkoto, P., Vyssotski, A.L. et al. Months-long tracking of neuronal ensembles spanning multiple brain areas with Ultra-Flexible Tentacle Electrodes. Nat Commun 15, 4822 (2024). https://doi.org/10.1038/s41467-024-49226-9
[3] Sun, W., Winnubst, J., Natrajan, M. et al. Learning produces an orthogonalized state machine in the hippocampus. Nature 640, 165–175 (2025). https://doi.org/10.1038/s41586-024-08548-w