"Large scale interactions in the cortico-hippocampal network during memory consolidation."

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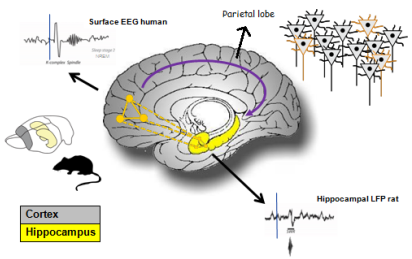
Overview

Background: Sleep-related Memory consolidation

Short-term –> Long-term memories

- Replay of neural pathways on NREM sleep.
- Electrical signal oscillations (Sharp Wave Ripple (SWR))



Memory-related areas:

1. Hippocampus
2. Prefrontal Cortex
3. Parietal Lobe

Research Question: What interactions occur during the Memory Replay?

Problem Statement

- How do oscillations in different frequency bands change with respect to the Sharp-Wave-Ripple for each brain area?
- What is the causal relationship between brain areas during memory consolidation?

Main Goals:

- Describe changes in the spectral power over time for each brain area with respect to the SWR during different memory-related tasks.
- Determine the predictive power of one brain region's activity over another one's based on their spectral power during the occurrence of the SWR.

Methods to analyze spectral activity and spectral causality of neural signals.

The following methods can determine the change of spectral power and prediction power between neural signals of different brain areas.

1) Multitaper Spectral Analysis

Time-Frequency representation of signals. Useful for localizing changes in frequency over time. Described by Olhede and Walden (2012) [1]

$$\Psi(\omega) = U(\omega)\alpha_{\beta,\gamma}\,\omega^{\beta}e^{-\omega^{\gamma}}$$

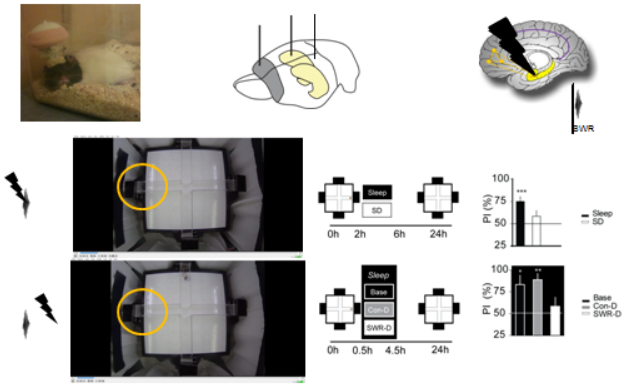
2) Spectral Granger causality

Statistical hypothesis test for determining whether one time series is useful in forecasting another one.

$$I(\phi) = -ln(1 - \frac{(\sum_{jj} - \frac{\sum_{ij}^2}{\sum_{ii}}) \mid H_{ij}(\phi)^2 \mid}{S_{ii}(\phi)})$$

Experimental Method

Plus-Maze task and Sharp-wave-ripple disruption

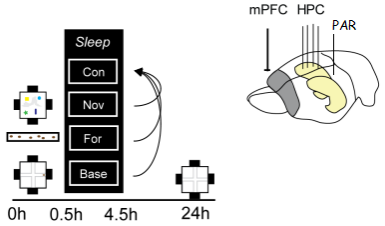


Experimental Method

Sessions:

1. Novelty experience.
2. Foraging for chocolate.
3. Baseline (No learning).
4. PlusMaze task.

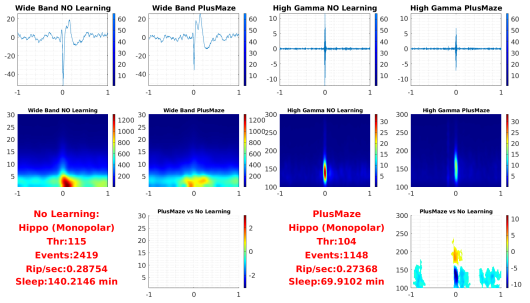
4 hours of Electrocortical (ECoG) recordings during different behavioural sessions.



Results: Baseline (No learning) vs PlusMaze (Learning)

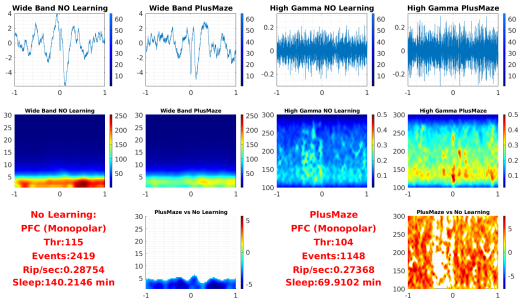
Statistical Analysis: Cluster-based permutation test on time-frequency data

- Hippocampus



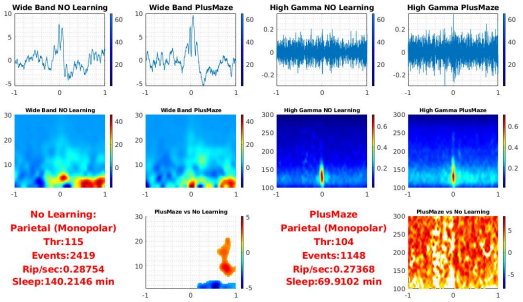
Results: Baseline (No learning) vs PlusMaze (Learning)

- Prefrontal Cortex



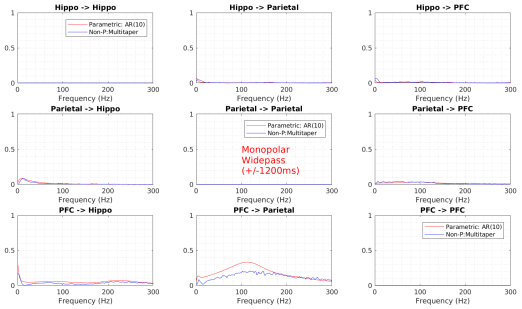
Results: Baseline (No learning) vs PlusMaze (Learning)

- Parietal lobe



Results

Spectral Granger Causality:



Summary of Results

A cluster-based permutation test revealed a significant increase of spindle range activity in PAR compared to the baseline during the learning task.

General decrease of delta activity for PAR and PFC during the learning session when compared to the baseline. Furthermore,there was a considerable increase of high gamma activity of PAR and PFC.

The Granger Causality test provides evidence that PFC activity precedes PAR activity.

Next steps to follow

- Correct baseline preprocessing in order to generalize results among tasks and rats.
- Optimize computation of results and increase the number of ripples being used.
- Rerun test on the Novelty and Foraging tasks.
- Describe Effect of SWR disruption.
- Perform statistical analysis on Granger Causality results.
- Compute Granger Causality time-frequency analysis.
- Test and improve robustness of spectral coherence connectivity between signals.

References

[1]:Genzel L, et al. "The Ying and Yang of Memory Consolidation: Hippocampal and Neocortical", PLOS Biology, 2017.

[2]: Ylinen A. et al, "Sharp Wave-Associated High frequency Oscillation (200 Hz) in Intact Hippocampus: Network and Intracellular Mechanisms, Journal of Neuroscience, 1995.

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