Identifying biomarkers of spatial memory with direct brain recordings in the Treasure Hunt task

Miller, J.[1], Watrous, A.[1], Novich, C.[1], Lee, S.A.[1], Sperling, M.[2], Sharan, A.[2], Worrell, G.[3], Berry, B.[3], Lega, B.[4], Jobst, B.[5], Davis, K.[6], Sheth, S.[7], Das, S.[6], Stein, J.[6], Gorniak, R.[2], Rizzuto, D.[8], Jacobs, J.[1]

[1]Columbia University, [2]Thomas Jefferson University Hospital, [3]Mayo Clinic, [4]University of Texas, Southwestern, [5]Dartmouth University, [6]Hospital of the University of Pennsylvania, [7]Columbia University Medical Center, [8]University of Pennsylvania

Introduction

- Treasure Hunt: a novel 3D adaptation of a Morris water maze, designed to investigate memory for object locations in a rich virtual environment.
- Key features: 1) Rapid acquisition of data, 2) Well defined encoding periods, 3) Multiple measures of performance, 4) Fun to play.
- Main finding: Human intracranial recordings reveal low frequency power increases related to good spatial memory at frequencies lower than traditional rodent theta.

Task Design

Trial: Subjects navigate a 3D beach opening treasure chests that may contain objects. After four chests, subjects are probed with the objects and must indicate the original locations. Gain points based on accuracy.

Session: 40 trials, 100 objects

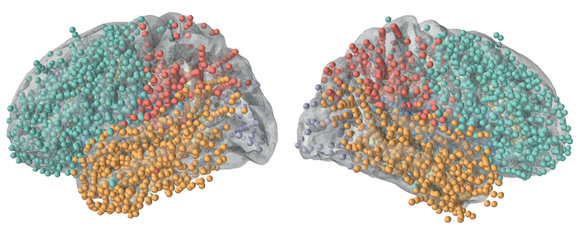
Navigate/Encode

Rate confidence

Place Target

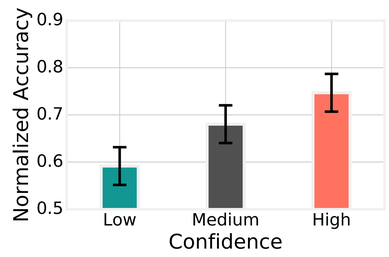
Feedback

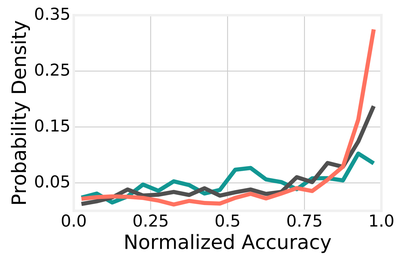
- **43 patients**
- **90 sessions**
- **5060 bipolar electrodes**



Behavioral results

Normalized accuracy: distance between response location and true object location, ranked by all possible response locations. Chance = 0.5.

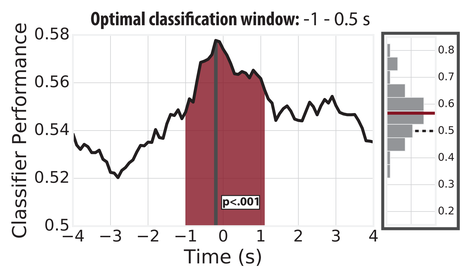




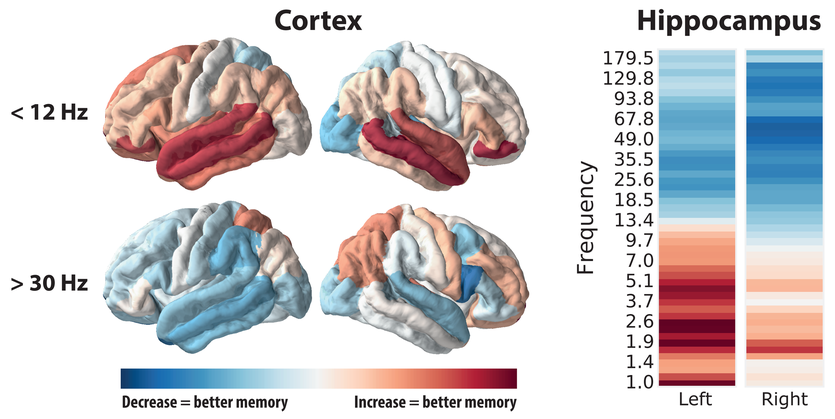
Multivariate decoding of spatial memory

Classification method: L2 regularized logistic regression trained on memory encoding. Features: oscillatory power at 8 (right) or 50 (below) log-spaced frequencies between 1 and 200 Hz.

Successful recall: better than median response and not low confidence.



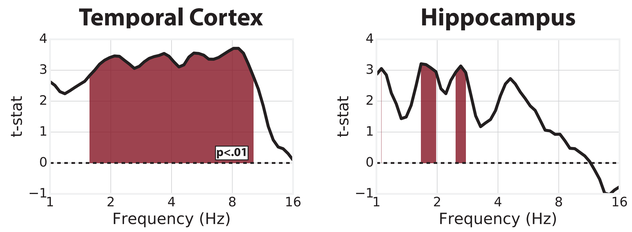
Neural signature of good spatial memory

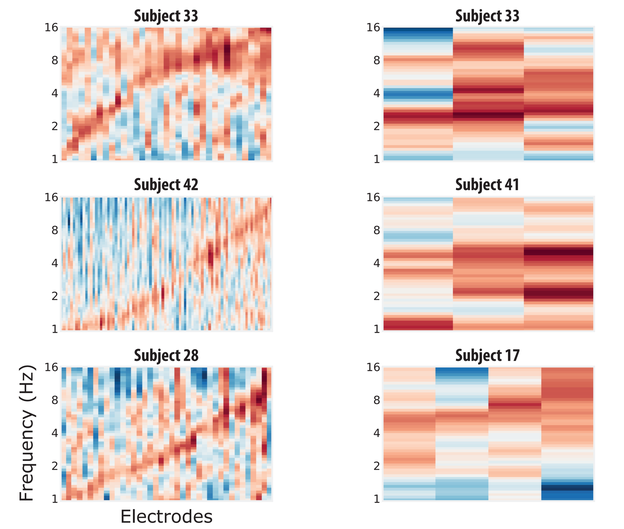


Low frequency increases and high frequency decreases in both cortex and hippocampus.

Theta power predicts memory

Increased low frequency power in temporal cortex and hippocampus is associated with better spatial memory. The precise frequency of this effect often varies from electrode to electrode, especially in TC.





Summary

- Reliable decoding of good spatial memory for object locations in a novel 3D task.
- Prominent increases in low frequency oscillatory power are linked to successful spatial learning.

Reprints/questions: jonathan.miller@columbia.edu

This work was supported by the DARPA Restoring Active Memory (RAM) program (Cooperative Agreement N66001-14-2-4032). The views, opinions, and/or findings contained in this material are those of the authors and should not be interpreted as representing the official views or policies of the Department of Defense or the U.S. Government.