Synchronous and asynchronous theta activity mark human episodic memory encoding

John Burke[1], Kareem Zaghloul[4], Joshua Jacobs[3], Michael J. Kahana[2]

University of Pennsylvania School of Medicine[1] and Department of Psychology[2], School of Biomedical Engineering, Science & Health Systems, Drexel University[3] Surgical Neurology Branch, NINDS, National Institutes of Health[4]

Computational Memory Lab
University of Pennsylvania

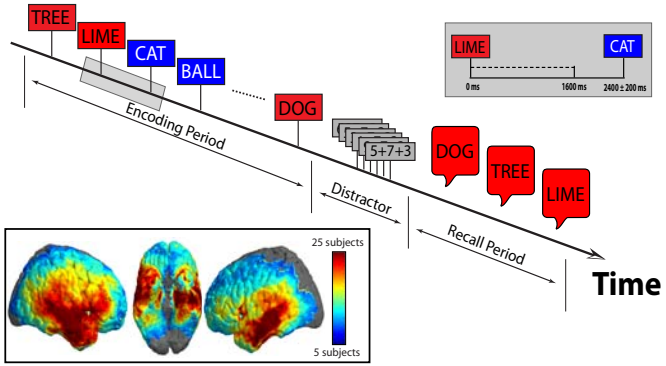
Motivation

Theta activity during memory encoding has been hypothesized to represent oscillations that synchronize to mediate memory formation[1].

Do the data support this hypothesis?

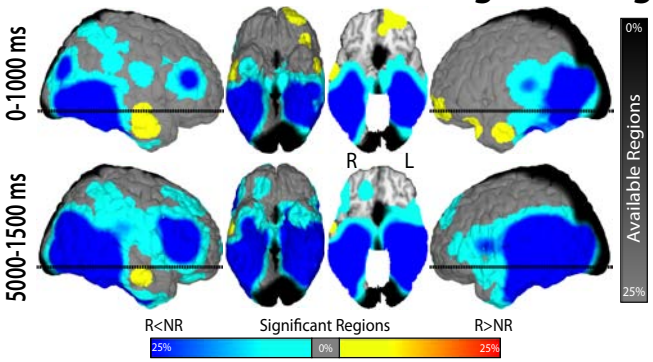
A confounding and unexplained empirical observation is that theta power has been shown to overwhelmingly decrease during memory encoding[2].

Methods: ECoG and Free Recall

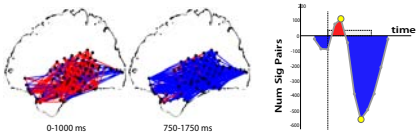


We collected electrocorticographic (ECoG) data from 68 left-language dominant neurosurgical patients during a free recall task.

Theta Power Decreases During Encoding

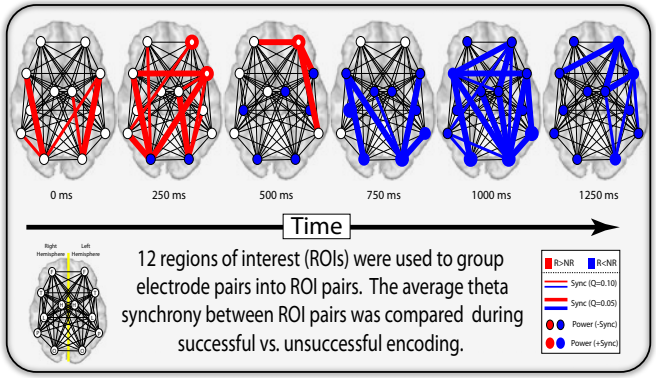


Calculating Theta Synchrony



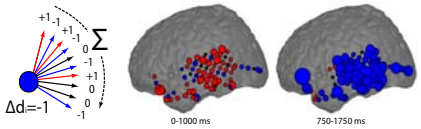
We calculated the phase-locking value[3] (PLV) between all electrode pairs during encoding.

Theta Synchrony during Encoding



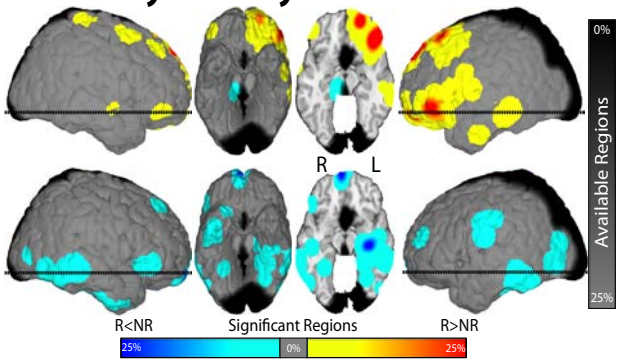
12 regions of interest (ROIs) were used to group electrode pairs into ROI pairs. The average theta synchrony between ROI pairs was compared during successful vs. unsuccessful encoding.

Localizing Synchrony: Graph Theory

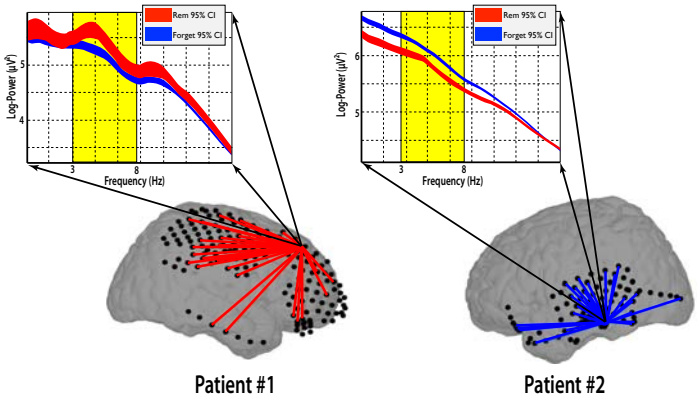


To more precisely localize changes in synchrony, we used a graph theoretic approach.

Theta Synchrony Localizes to L. PFC

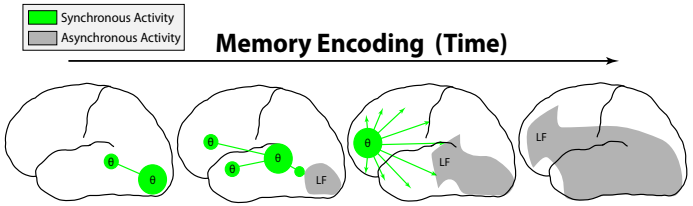


Two Patterns of Theta Explain Results



Successful memory encoding causes two changes in the theta band.
(1) asynchronous, broadband decreases in low-frequency (LF) power
(2) synchronous, narrowband theta (θ) oscillations

Theta Activity During Memory Encoding



Theta oscillations synchronize to mediate memory formation.

However, asynchronous theta activity also robustly co-varies with memory formation. Together, synchronous and asynchronous theta occur in a coordinated spatio-temporal pattern during encoding.

References

1. J. Fell and N. Axmacher. *Nat Rev Neurosci.* (2011) **12**(2):105-118.
2. P. Sederberg et al. *Cerebral Cortex. (2007)* **17**(5):1190-1196.
3. J. P. Lachaux et al. *Hum. Brain Mapping (1999)* **8**(4):194-208.

Correspondence:
John F. Burke (john.fred.burke@gmail.com)