Hippocampal Theta During Memory Guided Virtual Navigation in Human Intracranial EEG

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Introduction

The hippocampus and surrounding medial temporal lobe (MTL) are implicated in mammalian spatial and episodic memory function

The hippocampal LFP is dominated by 4-8Hz theta oscillations during volitional movement in rodents, and these are particularly prominent during the initiation of movement [Vanderwolf 1969]

Theta rhythm co-ordinates the firing of principal neurons in the hippocampus and may contribute to spatial coding [O'Keefe and Recce 1993]

However, the relationship between Type-I movement related theta and human spatial memory is unclear

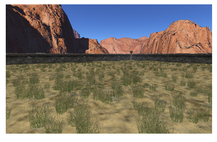
We examined intracranial EEG recordings from MTL depth electrodes in four pre-surgical epilepsy patients performing a self-paced virtual reality navigation and spatial memory task

Task Design and Analysis

During encoding, participants were asked to navigate towards and encode the location of four objects, five times each, that were presented sequentially and pseudo-randomly in consistent locations [Doeller et al. 2008]

During subsequent retrieval trials, participants were cued with an image of one object, and asked to navigate to the previously encoded location of that object


x 20


x 20

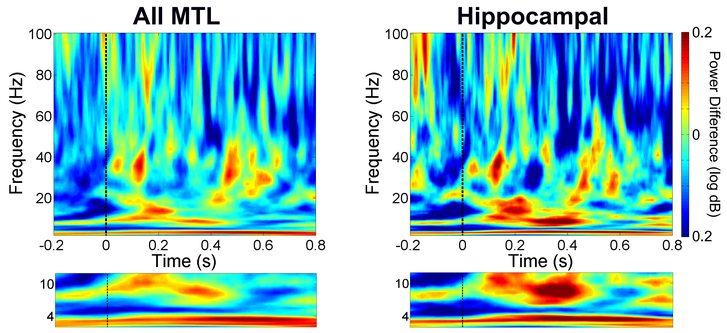
The following epochs were then extracted:
[-0.2 : 0.8s] after the onset of at least 1.3s continous translational movement
(29 ± 20 during encoding / 57 ± 24 during retrieval)

[-0.2 : 0.8s] after the onset of at least 0.8s continuous pure rotation
(26 ± 17 during encoding / 67 ± 30 during retrieval)

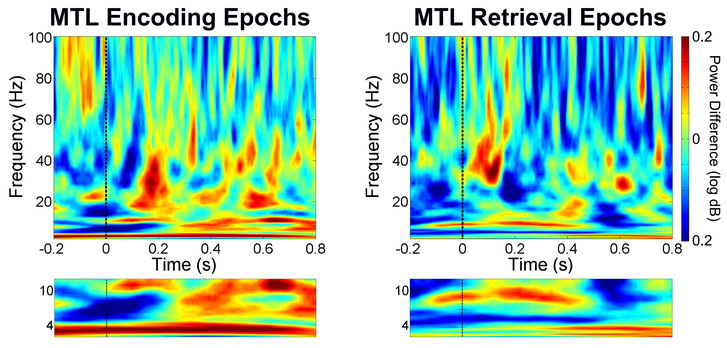
[0.25 : 1.25s] after the onset of a stationary period lasting at least 1.5s, jittered by ±100ms (15 ± 11 during encoding / 83 ± 29 during retrieval)

Spectrograms were generated from mean normalised EEG using a five-cycle Morlet wavelet transform and log-normalised before averaging across epochs and subjects

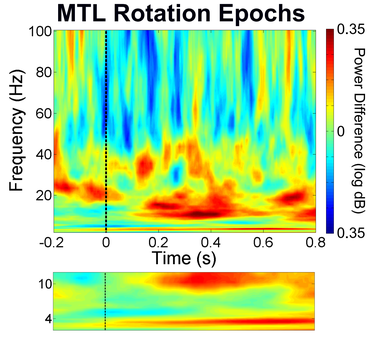
Theta at Movement Onset



Increase in theta power during movement onset compared to stationary epochs - in accordance with previous MEG results [Kaplan et al. 2012]



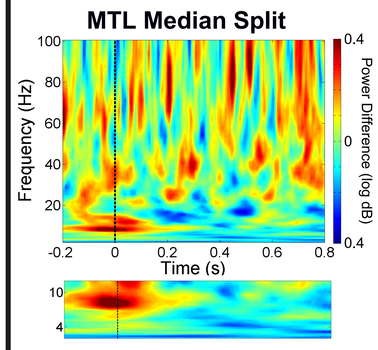
Theta power increase is particularly prominent during retrieval, while 2-4Hz delta power is more prominent during encoding [see also Kahana et al. 1999]



Theta power increase is specific to translational movement - it is not manifest at the onset of pure rotation

Delta power is present during both translational and rotational movement

Theta Power and Performance



Theta power at movement onset during retrieval epochs is greater during high performance trials, consistent with MEG results [Kaplan et al. 2012]

Trials are median split by average distance error for each object

No correlation between 2-4Hz delta power and performance

Patient Information

All patients are right handed
Two male and two female
Two left and two right hemisphere implants
Mean age of 31 ± 9.6 years
Two patients with three amygdala, three hippocampal and six lateral contacts
Two patients with three amygdala, six hippocampal and nine lateral contacts
All patients performed within the range of a population of healthy young adults

Conclusions

Theta power is increased during the initiation of translational movement, particularly when that movement is driven by spatial memory retrieval

Delta power is increased during all translational and rotational movement, often appearing several hundred milliseconds prior to movement onset

Theta - but not delta - power at movement onset correlates with spatial memory performance

It is unclear which of these prominent oscillations is most similar to Type I rodent theta [see Jacobs and Kahana 2010]

Replicating results across species provides a firmer basis for understanding electrophysiological data and computational models of human memory in the light of well established neuronal mechanisms identified in rodents

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Jacobs J, Kahana MJ (2010) Direct brain recordings fuel advances in cognitive electrophysiology. Trends in Cognitive Science 14(4): 162-171
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