THETA OSCILLATIONS INCREASE AT CRITICAL JUNCTURES OF OVERLAPPING MAZES

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BACKGROUND

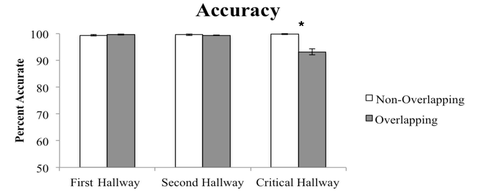
•Theta oscillations are present during human spatial navigation and episodic memory encoding and retrieval.[1-4] Animal research has shown that theta oscillations are indicative of interactions between the hippocampus and prefrontal cortex during cognitive tasks.[5-7]

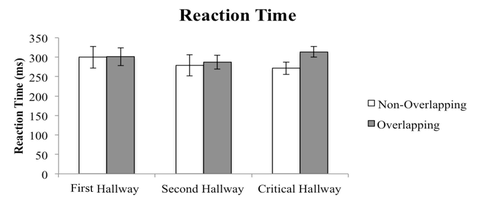
•Previous research in our laboratory using fMRI has shown that navigation of mazes with overlapping landmarks evokes activity in regions within the medial temporal lobe and the prefrontal cortex.[8,9]

•Hasselmo and Stern (2014) proposed that upon seeing the first hallway (Cue) the entire spatiotemporal trajectory of a maze can be retrieved based on the coordination of place and time cells by theta phase coding.

•We used EEG recording **to examine theta activity while participants navigated through overlapping and nonoverlapping virtual mazes**. Based on previous fMRI work and computational modeling, **we hypothesized that theta activity would occur at time points where both memory retrieval and prospective coding are necessary for the disambiguation of overlapping trajectories.**

BEHAVIORAL RESULTS





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[1]Ekstrom et al. (2005) *Hippocampus*, 15(7): 881-889.
[2]Rutishauser et al. (2010) *Nature*, 464(7290): 903.
[3]Watrous et al. (2011) *Nature neuroscience*, 16(3):349.
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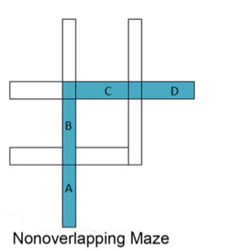
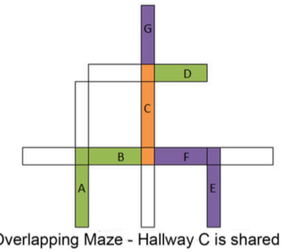
[5]Jones and Wilson (2005) PLoS Biology, 3:e402.
[6]Benchenane et al. (2010) *Neuron*, 66, 921-936.
[7]Fujisawa and Buzsaki (2011) *Neuron*, 72, 153-165.
[8]Brown et al. (2010) *The Journal of Neuroscience*, 30(21): 9414-7422.
[9]Brown and Stern (2013) *Cerebral Cortex*, 24(7): 1906-1022.

TASK DESIGN



Nonoverlapping Maze



Overlapping Maze - Hallway C is shared

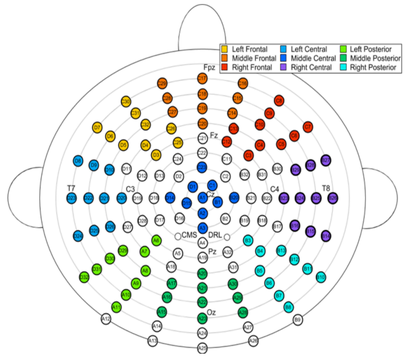
Example hallway

•Subjects navigated through virtual mazes displayed on a computer screen. 6 mazes shared the third (Critical) hallway (overlapping condition). 6 additional mazes were nonoverlapping.

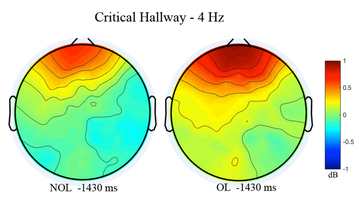
•17 healthy adults, aged 18-27 years, underwent training on the task. A day later, subjects performed the task during EEG recording.

•EEG Parameters: 128 scalp electrodes, six exogenous electrodes recorded using a Biosemi Active Two system. Electrodes were grouped into nine clusters

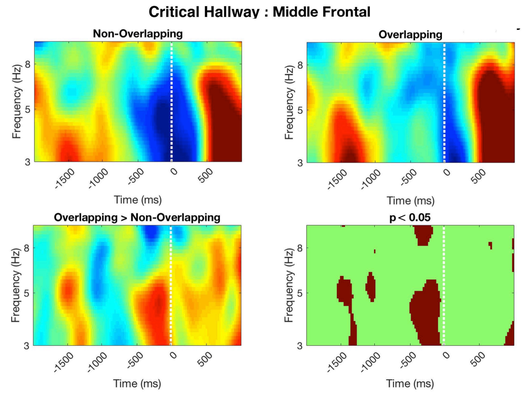
•Analysis focused on comparison of two time points: The First Hallway (Contextual Cue) and Overlapping Hallway (Critical).



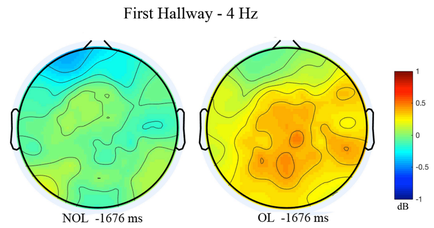
RESULTS : CRITICAL HALLWAY

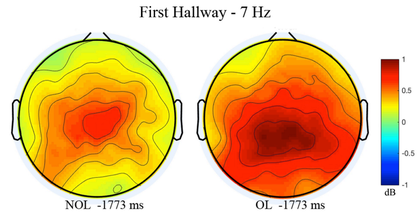


• Theta activity significantly increased at the beginning of and at the intersection of the third hallway in all the frontal clusters and in the middle and right central clusters in the overlapping condition compared to the non-overlapping condition.



RESULTS : FIRST HALLWAY



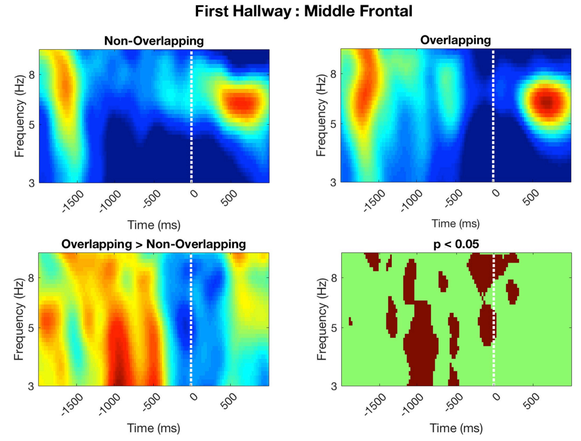


•An increase in theta oscillatory power was observed in at the beginning of the first hallway (Cue) in the overlapping condition (OL) compared to the nonoverlapping condition (NOL).

•Increases in theta oscillatory power were greater and extended across a wider range of frequencies in overlapping mazes in the first hallway.

•These results are consistent with the idea that theta is related to prospectively thinking ahead about how to successfully navigate through the maze.

•The increase in theta occurred at timepoints in the maze where fMRI data has demonstrated activity in the hippocampus and PHC (Brown et al., 2010, 2013).



SUMMARY & CONCLUSIONS

•Theta activity increased in the first hallway of the maze which served as a cue and provided the context that enabled the participant to think through the upcoming sequence of turns.

•The first hallway (cue) showed increased theta activity in overlapping mazes at both upper and lower theta frequencies suggesting both a motion and memory component to oscillatory activity in sequence disambiguation.

•Theta activity in both the first (cue) and critical (overlapping) hallways is consistent with fMRI results showing increased activation in medial temporal lobe and prefrontal cortex at these time points in the maze task (Brown et al 2010; 2013).

•Only the overlapping condition shows increased theta activity at the time that the participant is making a response in the critical hallway. This is the timepoint that requires the disambiguation of the two overlapping trajectories and overcome interference from the paired maze that shares the hallway.

•In conclusion, the data presented in this human EEG study adds an additional component to our understanding of how the brain disambiguates overlapping navigational trajectories. The data presented here demonstrates an increase in theta activity at time points that coincide with time points where we saw increased CA3/DG activity in our fMRI study (Brown, Hasselmo, and Stern, 2014), and additionally supports model predictions using a variant of this task (Hasselmo and Stern, 2014) in which theta is involved in both prospective and retrospective processes.