Hippocampal theta-gamma phase amplitude coupling distinguishes between narrative generation and recall

Diogo Santos-Pata, Ruoxi Luo, Jiayu Cheng, Sze Chai Kwok ✉
Division of Natural and Applied Sciences, Data Science Research Center, Duke Kunshan University, Duke Institute for Brain Sciences, Kunshan, Jiangsu, 215316, China

Summary

Theta-gamma phase amplitude coupling in the hippocampus is associated with recall of memory but little is known about its role in narrative generation based on semantic cues. The distinction between the generation and recall is also not entirely clear. Local field potentials (LFPs) were recorded from the hippocampus of 6 adult drug-resistant epilepsy patients with implanted depth electrodes as they performed a task that required them to both generate a narrative and recall their self-generated narratives based on pairs of visual items. We performed an event related phase amplitude coupling (er-PAC) analysis and contrasted between the two conditions. We observed a significantly stronger PAC effect for narrative recall than narrative generation at the 30-70Hz band around 1.0-1.5 s before speech onset, but also conversely a stronger PAC effect for narrative generation than recall at the 50-60 Hz band around 1.5 s after speech onset. Additionally, a significant difference was observed 0.5 to 1.0 seconds after stimulus onset, with a stronger PAC for recall than for narrative generation. The present findings provide physiological evidence that the human hippocampus codes differentially for narrative generation and memory recall in terms of theta-gamma phase amplitude coupling, offering insights into the mechanisms underlying semantic and episodic memory systems in the hippocampus.

Method

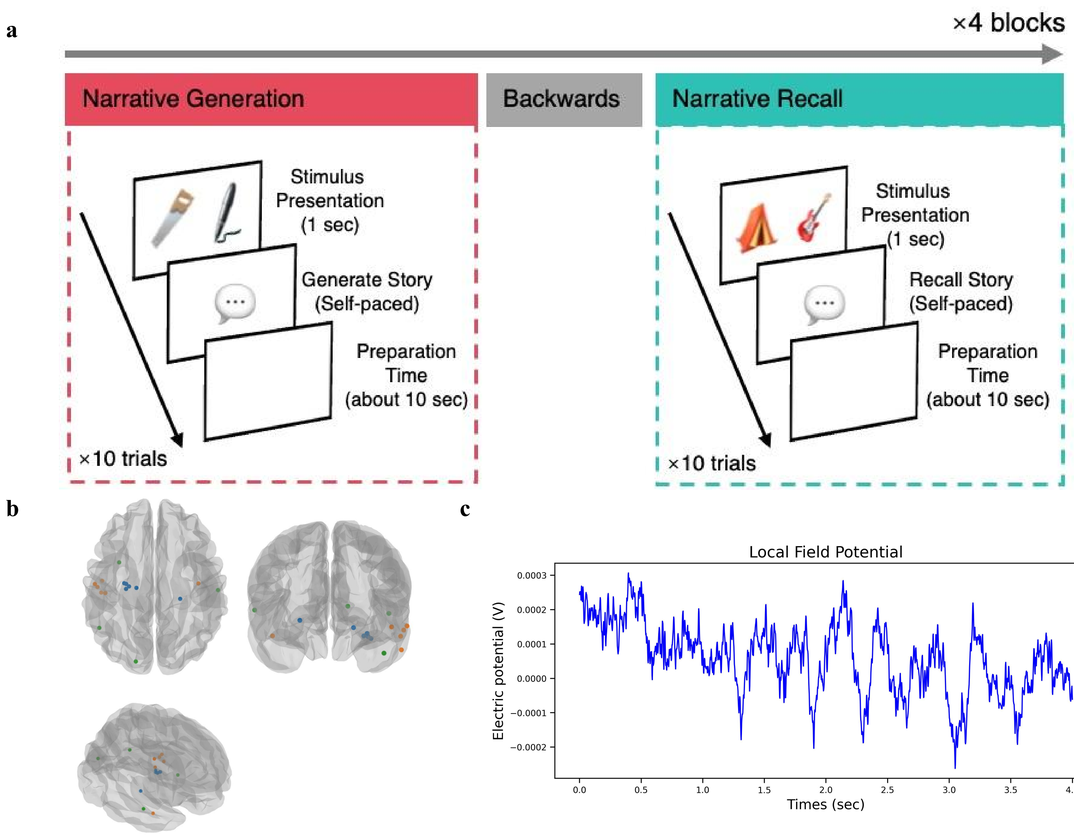

Fig1: Experimental design and data collection
1a. Experimental design. The experimental session consisted of 4 blocks for narrative generation test and 4 blocks for narrative recall. Each block consisted of 10 trials. For each trial, a pair of visual stimuli were presented on screen for 1 s.
1b. Location of intracranial electrodes. Hippocampus (blue); temporal cortex (orange; not used in this study); control sites (green; not used in this study).
1c. Local field potential (LFP) recording from stimulus to speech onset in one trial. Sampling rate = 512 Hz. LFP is corrected by the recording from adjacent white matter.

Result

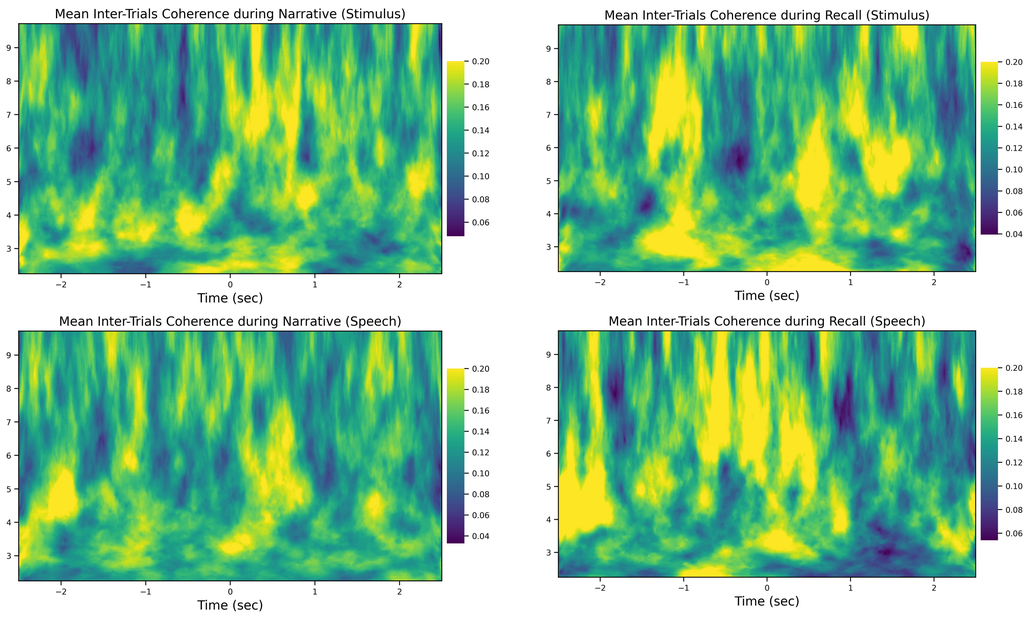

Fig 2: Inter-trial coherence around stimulus and speech onset
Mean inter-trial coherence during task of different frequency. We observed a modulation of theta wave (4-8 Hz) around stimulus onset and speech onset. The inter-trial coherence is stronger in recall than narrative generation.

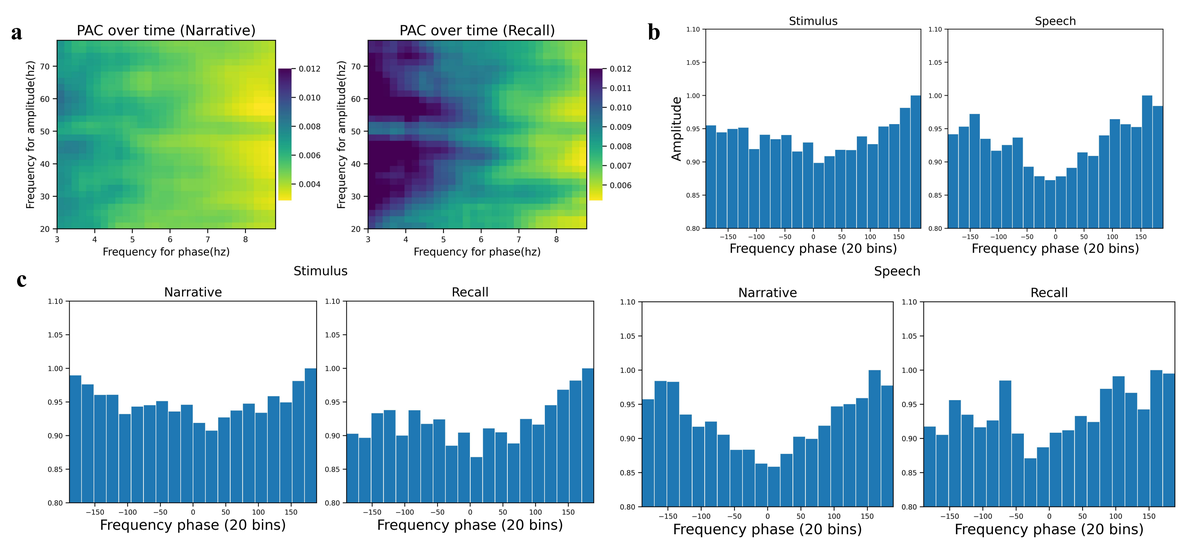

Fig 3: Theta-gamma phase amplitude coupling
3a. Mean phase-amplitude coupling over time from stimulus onset to speech onset. Mean PAC was stronger in recall task.
3b. Distribution of gamma amplitude on theta phase around stimulus and speech onset. There is a modulation between theta phase and gamma amplitude, as bin amplitudes deviated from a uniform distribution.
3c. Distribution of gamma amplitude on theta phase in narrative generation and recall.

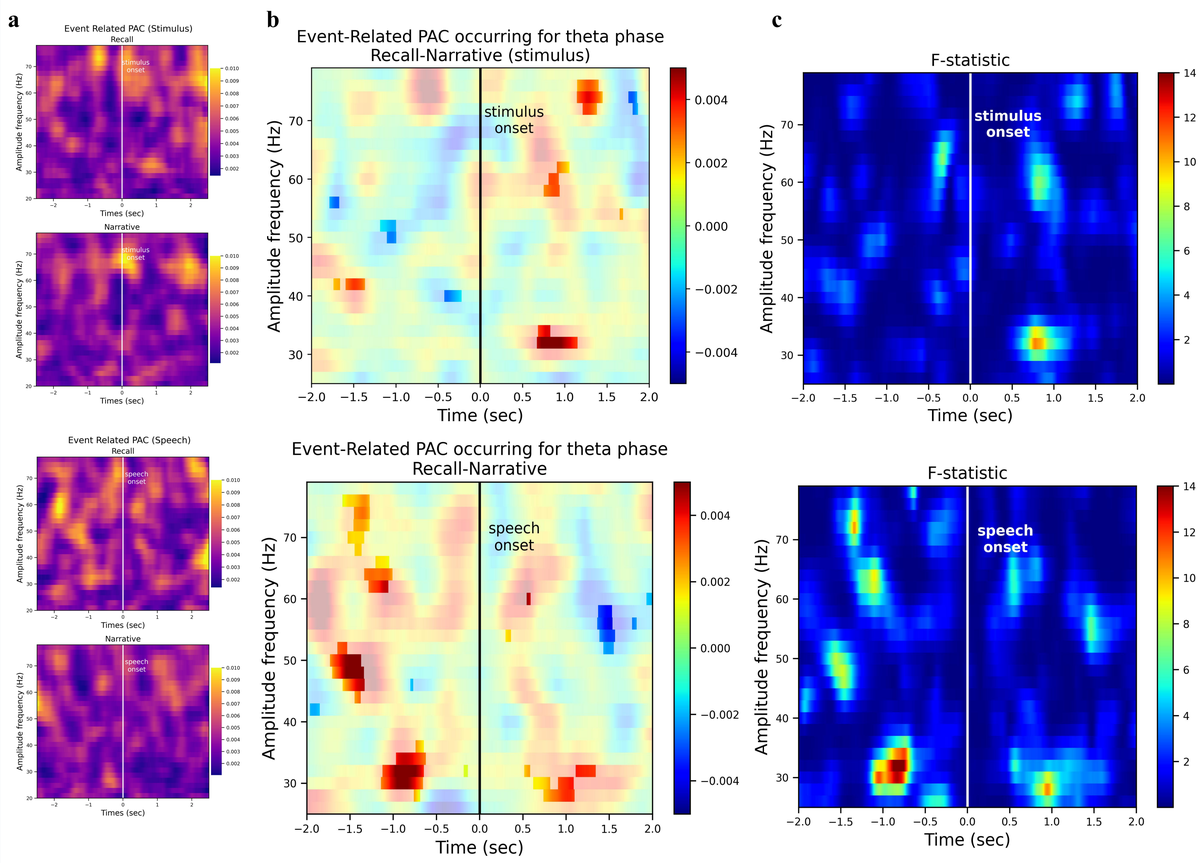

Fig 4: Event related TG-PAC during narrative generation and recall
4a. Mean event related phase amplitude coupling (ERPAC) around 2.5 s before and after stimulus and speech onset. In both conditions, PAC is stronger in recall trials. ERPAC is computed over trials and shows the coupling along the timeline.
4b. A comparison of narrative generation and recall. The value with a p-value <= 0.05, are presented in darker colors. A stronger PAC effect was observed for narrative generation in the 50-60 Hz band around 1.5 s after speech onset and 0.5 to 1.0 seconds after stimulus onset (top). A significantly stronger PAC effect was observed for narrative recall in 30-70 Hz band around 1.0-1.5 s before speech onset (bottom).
4c. F-statistic of the distinction. The threshold for the F-value is 4.96, and the frequency with an F-value greater than the threshold is considered significant.

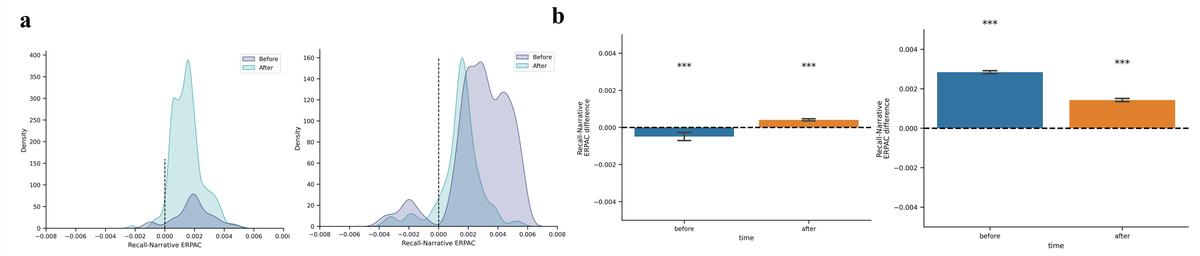

Fig 5: Density and significant value of ERPAC difference before and after speech/stimulus onset
5a. Density of significant ERPAC difference between narrative generation and recall. Stimulus (left); speech (right). Narrative recall obtains a higher density after stimulus than before stimulus onset (left) and a higher density before speech onset than after speech onset (right).
5b. Significant value of ERPAC difference between narrative generation and recall. Stimulus (left); speech (right). Error bar: 95% confidence

Highlights

- **Theta-gamma phase amplitude coupling increases both in narrative generation and recall**
- **Distinct theta-gamma code between narrative generation and recall**
- **After stimulus onset and before speech onset narrative recall showed a stronger PAC effect**
- **Phase amplitude coupling participate in the coding of recall**

szechai.kwok@duke.edu
www.kwoklab.org
@Kwokszechai