

Establishing Directionality of Episodic Memory Flow

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Episodic memory is a fundamental component of human cognition that depends on complex communication between neural networks. This type of memory requires remembering personal events and their contexts. It relies on multiple brain regions such as the frontal cortex, the parietal cortex, and the hippocampus (Battaglia, Benchenane, Sirota, Pennartz, & Wiener, 2011; Nyhus & Curran, 2010). More specifically, past studies have shown that this kind of memory retrieval involves increased activity in the the left inferior parietal cortex (IPC) and the right dorsolateral prefrontal cortex (dlPFC) (Anderson et al., 2010; Das & Menon, 2021; Nyhus & Badre, 2015). This study seeks to further investigate the neural mechanisms that make up episodic memory retrieval by considering the role of theta oscillation in coordinating the activity of these networks.

Theta oscillations are a brain wave pattern that naturally occur at a frequency of 4-8Hz. While research suggests a link between these waveforms and memory retrieval activity, the direction of information flow between brain regions is still unclear (Nyhus & Curran, 2010). By measuring theta oscillations this study attempts to assess the directional flow of information throughout these networks, which we hypothesize flows from the right IPC to the left dlPFC. Cognitive disorders like anxiety, depression, schizophrenia, and autism are all linked to disrupted theta oscillations. Therefore, this study has potential to inform the development of diagnostic tools and treatments for these illnesses.

This project employs a combination of techniques including electroencephalogram (EEG) to measure neural activity with millisecond precision and Granger causality analysis to determine the directional flow of information (Bressler & Seth, 2011; Friston, Moran, & Seth, 2013; Seth, Barrett, & Barnett, 2015). For this study, participants were asked to perform a source recognition task, during encoding, they were asked to study a list of words and either create a mental image of the scene described by the word or rate the pleasantness of the word. Later, during retrieval, participants were shown new words as well as the previously learned words and asked whether they remember any words and if they do, which activity the word was from (the pleasantness activity or the mental image activity).

Data was collected using a 64 channel EEG system which was processed to remove any artifacts before being analyzed with Granger causality analysis. EEG directly collects signals originating from the brain through electrodes placed onto the subject's scalp. Granger causality analysis will determine if information flows from the left IPC to the right DLPFC during post-retrieval monitoring. Granger causality analysis is a type of statistical analysis that uses prediction models to determine a time-lagged causal relationship between data sets. Granger analysis assumes that causes precede and predict their effects, while this computational technique does not establish a 100% causal relationship, it indicates directionality between the data sets.

Through June and July of 2025 the study focused on data collection and the beginning phases of data processing. EEG data was collected from 14 participants as they performed the post-retrieval episodic memory tasks. We used this data to amend and supplement data previously collected for this study. 3D headscans for each participant were also collected to aid in the localization of electrode placement. This additional location information of the electrodes on the scalp will be used during analysis to help streamline the localization of the neural activity being measured.

This research addresses a significant gap in the understanding of neural processes that facilitate episodic memory retrieval. By investigating the flow of information, the results could inform our understanding of the network dynamics involved in memory retrieval and show how these oscillations contribute to the interactions. Understanding this directionality can assist in the development of diagnostic tools and treatments for cognitive impairments impacted by theta oscillations.

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