Functional Connectivity and Neural Oscillations in Episodic Memory

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Whenever you are explicitly thinking about events in your past and the context in which they are derived, you are engaging your episodic memory. Given the complexity of these memories and the sensory activity associated with them, the brain must enlist a large network of areas to process and retrieve those memories. Through numerous studies on this memory system, cognitive neuroscientists suggest a strong involvement of the frontal cortex, parietal cortex, and hippocampus regions during episodic memory, particularly during the retrieval of memories (Nyhus and Curran, 2010). While understanding which areas of the brain "light-up" during specific cognitive tasks provides valuable insight, the ability to decipher how such brain areas interact and talk to each other provides a much more complete picture. Neural oscillations, or the electric waveforms resulting from many neurons firing simultaneously, serve as a key mechanism for regional interaction in the brain (reviewed in Fries, 2005). All this synchronous neural firing establishes well-defined neural networks that enable complex cognitive performance. Often, we associate distinct neural oscillation frequencies with states of consciousness, i.e. beta waves (14-30 Hz) during awake, normal levels of alertness, but in the context of episodic memory, we focus on theta (4-8 Hz) oscillations due to their presence in that frontal-parietal brain network during episodic memory tasks. My independent study this year attempted to bridge the gap in knowledge about theta oscillations' involvement in episodic memory processes and strive to reveal the directionality of information flow among the previously specified brain areas. This research holds robust clinical repercussions as well, given that many neuronal disorders, such as anxiety disorders, autism, depression, and schizophrenia involve disruption of neural oscillations and memory impairment (Basar and Guntekin, 2008; Uhlhaas and Singer, 2006).

To identify the transient oscillatory activity during episodic memory retrieval we used raw electroencephalography (EEG) data from previous Nyhus lab's studies that presented memory tasks requiring identification of an item and its source, or the context in which the item was presented. EEG is a widely used neuroimaging technique that enables the recording of electrical activity on the scalp of a person's head, thereby creating a direct measurement of the activity of neurons firing synchronously across brain networks. After various levels of preprocessing, during which noise from the surrounding environment is removed from the signal, we applied a mathematical model called Granger causality to analyze the directional flow of information at theta frequency. Based on past research, we predicted that information necessary for episodic memory will flow from the left inferior *parietal cortex* to the right dorsal lateral *prefrontal cortex* parts of the brain at theta frequency.

In order to begin pursuing the objectives of this project, I completed a nine-week course in Matlab, the computer program we primarily used to process our EEG data and implement the Granger causality analysis. Matlab carries a few software tools specific to EEG, such as EEGLab, that enable us to process our data and perform Granger causality analysis. In order to acquire a more practical understanding of EEGLab's application and to accelerate the progress of our project, I used the funding from the Grua-O'Connell Grant to attend a teaching workshop at UC San Diego in November specific to EEGLab. With the training I received at the workshop, I was able to perform preprocessing on our raw data and begin to apply Granger causality to the data using a plugin called SIFT in the EEGLab. While we successfully preprocessed the data, we are not confident in the granger results and output from the SIFT plugin, and we are in the process of communicating with the experts from the teaching workshop. In the meantime, we've been modifying previously developed Matlab scripts that use FieldTrip, another toolbox that can be used to perform Granger Causality analysis, to fit the goals of our study. However, our preliminary findings did not align with our hypothesis that information flow in the theta frequency moves in the left IPC to right DLPFC direction. Although we cannot disregard these preliminary results, they must be taken with a grain of salt, and we are performing further analysis by expanding the analyzed frequency range and by trying a different granger technique, i.e. the EEGLab SIFT toolbox.

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