Interactions Among Brain Areas During Memory Retrieval

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This summer, in collaboration with Professor Erika Nyhus, I’ve immersed myself in analyzing neural data and worked towards mapping interactions between brain regions. This project aims to quantify the direction and magnitude of neural connections in an effort to reveal the causal relationships between brain regions as memories are retrieved. Such connections take the form of ‘brain waves,’ or voltage oscillations resulting from the synchronized firing of neurons as information is sent and received. In particular, this study looks at oscillations with frequencies of 4-8 Hz, referred to as theta activity, which numerous studies have implicated as integral to the brain’s memory functioning (Nyhus & Curran, 2010). We rely on data from electroencephalogram (EEG) recordings to chart the changing voltage signals emitted by the brain.

In this study, subjects were presented with words one at a time on a screen. At each new word, subjects were asked to encode the word either by mentally pronouncing it backwards to themselves (a ‘Read’ task) or by picturing an associated place (a ‘Place’ task). Thirty minutes later, while fitted with the EEG sensors, subjects were again presented with a series of words and asked to identify either the source of the word (‘Read’ or ‘Place’) or else deem it entirely new. In a previous analysis of this data, Professor Nyhus found theta effects in the right frontal and left parietal areas. Theta power was consistently greater for old vs. new words, corresponding to the trials in which memory was engaged. This summer’s analysis aims to expand upon these findings by investigating the causal relationships between these same regions in order to further understand the nature of their interactions.

Our technique depends upon calculating the Granger Prediction, an analysis tool which describes the degree of causality between two sources over time. The Granger Prediction (also termed Granger Causality) has long been used in economics but only recently been applied in the neurosciences. By implementing autoregressive model fitting, it tests the efficacy of using one source activity to predict another’s. The Granger Prediction changes in proportion to this degree of directed influence, growing as source A becomes a better predictor of source B. When computed at successive time points, we can begin to describe the causal relationship between these sources – for example, in the brain as a subject recalls a memory.

So far, I’ve spent my time this summer manipulating the data into the proper format for connectivity analysis. An EEG recording has to first be sorted, segmented, and cleaned of noise. I’ve then gone on to analyze the data in the time and frequency domains, and to localize these sources of theta activity to anatomical regions of the brain. I’ve learned to design 3D brain models and grown fluent in Matlab code; each step takes us a little closer to our goal. This week marks the exciting occasion of my first attempt at the Granger Prediction, as we begin to compute connectivity measures between localized sources. Our analysis will continue on into the fall.

(a) This 3D head model provides a template by which to normalize each subject’s brain activity
(b) Sources of theta activity are mapped to slices of an MRI

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