Knight Laboratory — Fall 2017— Honors Thesis Proposal

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1. Framework

Background There is little known about the neural intricacies and ambiguities of human communication. The article by Stolk, et al. "Cerebral coherence between communicators marks the emergence of meaning" attempts to explore this area of study, proposing that the right temporal region of the brain is the site of pair-specific cerebral coherence representing shared communicative history.

Two important technical terms to define before delving into the specifics of the experimental paradigm, include HGB (high gamma band) activity and HGB brain activity coherence. HGB activity corresponds to the neuronal activity that occurs in the range of 60 to 140 Hz, though this range is subject to some debate. Activity at a particular frequency indicates that clusters of neurons are firing that particular number of times per second. However, this activity is defined by magnitude and is generally not considered oscillatory since these pulses are rarely in phase. As for HGB brain coherence, this measure can be described as the degree to which two brains produce the same frequency content at roughly the same time, not to be confused with lower neuronal frequency waves (delta, theta, alpha, etc.) oscillating at the same frequency in phase.

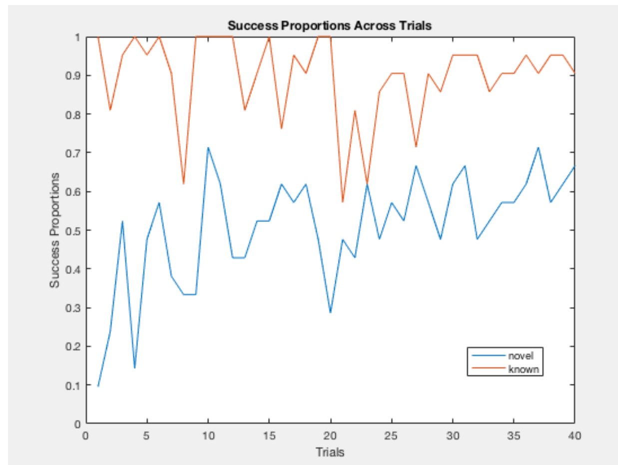
Research Questions and Objectives Some research questions we aim to address include,

- Is EEG (electroencephalography) able to capture the nuances of HGB brain activity in a dual EEG (subject pair) task?
- Which methods of data analysis yield the most fruitful results when considering EEG data, and even more specifically, when researchers are interested in non-attentional neural information?
- Given that the previous two questions are answered sufficiently, how exactly does the emergence of a pair-specific shared communicative history during the simultaneous exposure to new experience manifest in the brain?

The task used in the dual EEG experiment is almost identical to that described in the Stolk, et al. paper, however, the experimental conditions differ greatly. I have omitted details of task and experimental conditions in this proposal in order to focus on analysis specifics. We are interested in replicating the findings of the Stolk et al. paper using EEG, since the task specific brain activity has previously only been recorded using fMRI, a brain imaging technique with higher spatial resolution than EEG. We are looking to understand the range of effects EEG is able to capture, and if so, how to successfully extract these effects through a series of preprocessing and analysis steps. In the case that we are unable to find the predicted high levels of HGB brain coherence in subject pairs during novel trials, we will focus on other frequency bands of interest that are more commonly discussed in EEG experiments, such as the alpha band (8 to 12 Hz).

We have already recorded the EEG signals of 21 pairs of participants performing the communicative task, and have finished pre-processing and cleaning of the resulting data. Now, we are in the process of completing a diverse set of analyses, some of which are described below. Although each of the analyses we plan to conduct has been explained, validated, and/or replicated in previous papers, none have yet been tested in this particular paradigm, where we are interested not in stimulus-locked attentional shifts, but rather the gradual neural patterns induced by the conceptual nature of the task and development of shared communicative history.

Implications This study, if conclusive, may have a serious impact on the future study of HGB brain coherence, especially in EEG experiments. In the most optimistic scenario, we will have successfully implemented a specific and well-tailored analysis pipeline that is capable of extracting non-attentional brain activity from large quantities of EEG data. This tool may later be implemented in experiments attempting to shed further light on the purpose and function of HGB brain activity.



If we are able to, in some capacity, replicate the findings of the paper by Stolk, et al. we can further support the argument that the cerebral dynamics corresponding to the growth of shared communicative history through exposure to novel tasks, synchronizes across participants' right temporal lobes. In addition, this study would also provide evidence for the more abstract notion that successful communication relies on mutually adjusted knowledge separate from communicative behaviors. In the data we have collected, we have, in fact, already observed a noticeable difference in the behavioral nature of known and novel trials. The figure just right of this section illustrates this point. The proportions of known trial (trials of the task that have already been seen by the pair) success remain relatively high across all known trials, however, there is a gradual increase in the proportions of success across the novel trials; this is an expected trend if we assume that interpersonal communicative alignment is being adjusted during each novel trial and this quality dictates the precision of the pair specific communication.

2. Tools and Methodologies

The mechanisms underlying the brain imaging technique, EEG, will be explained in the actual thesis paper. For the sake of including a majority of the thesis plan, I have omitted these details. The EEG FieldTrip toolkit, a brain imaging software package developed by the Donders Institute for Brain, Cognition and Behavior, has been an integral part of the post-experimental processing. This toolkit allowed for relatively straight-forward preprocessing and cleaning of the data, as well as providing a host of built-in functions that allow for readable and easily modularized analysis scripts.

3. Analyses

Similarity Matrices This analysis technique, pioneered most recently by Haxby and Kriegeskorte, abstracts away from brain imaging modalities and captures the similarity (or dissimilarity) between underlying brain activity patterns corresponding to specific experimental stimuli (in our case, different stimuli are simply different trials). We performed a series of analyses with similarity matrices; the purpose of and conclusions drawn from the similarity analyses will be carefully documented in the thesis.

Matrix Correlations Using the pre-calculated similarity matrices, we examined the correlations between subject pair off-diagonal arrays extracted from both the baseline segments of the trials and of the actual trials. Baseline segments refer to the short period of time (somewhere between one to two seconds) before the beginning of each short trial; it is a segment of time during which the participant is not engaged in any task. The off-diagonal correlation measure represents the degree of correlation between similarity arrays containing the similarity measure between trials temporally adjacent to each other.

Searchlight Approach This analysis technique is almost exactly like that of the similarity matrix comparisons except that in this analysis each similarity matrix is calculated using signals gathered from a group of seven or fewer neighbouring channels (electrodes) instead of all 64. These groupings are dictated by the fieldtrip neighbors.mat, and allow for a spatially resolved representation of the similarity analysis results.

Source Analysis Source analysis is a common and well-accepted analysis technique within the realm of brain imaging, especially considering studies involving EEG data. Source analysis, in brief, attempts to locate 'sources' of brain activity by working backwards, taking the 2D electrode signal mappings and imposing these signals onto a 3D brain template. This brain template consists of a large number of voxels (depends on voxel resolution), each of which could be a 'source' of neuronal activity. Source analysis uses laws of probability to predict which of the myriad of voxels are most likely to have produced the brain activity pattern that the EEG image has captured. As one may expect, this is an extremely computationally heavy analysis, and consequently, we will perform all other analyses before attempting this one.

4. Tentative Thesis Timeline

September	Evaluation of Searchlight Approach
October	Searchlight Approach Wrap-up and Hyper-alignment Implementation
November	Hyper-alignment Evaluation and Wrap-up
December	Source Analysis Implementation
January	Analysis Wrap-up
February	Thesis Outline and Writeup
March	Draft and Thesis Revision
April	Thesis Finalized
May	Thesis Review

5. Acknowledgements

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