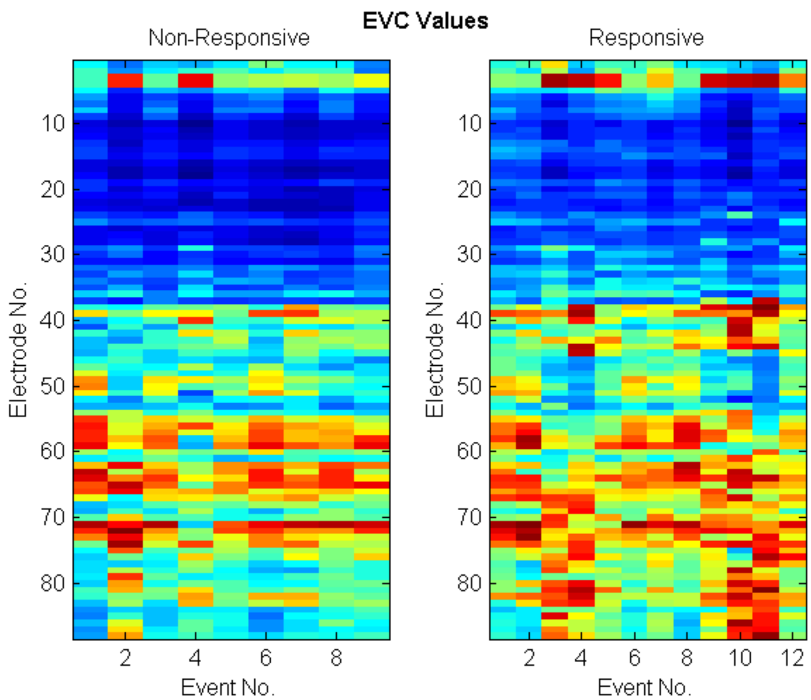
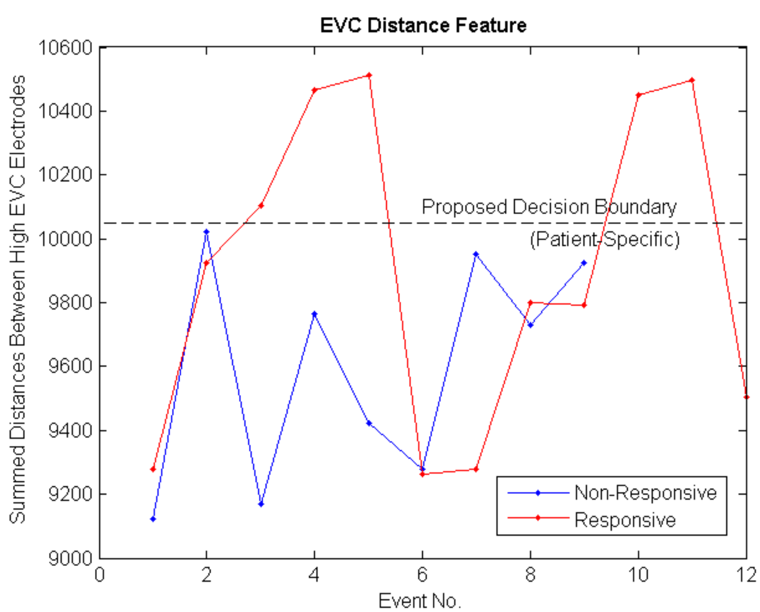
# EN.580.694: Statistical Connectomics
# Final Project Report

Michele Lohr · May 14, 2015

## Characterizing epileptic brain network response to mental effort



**Opportunity** Epilepsy is considered a network phenomenon characterized by "hypersynchronous" atypical activity during seizure, at both the single neuron level and higher neural populations [1][2]. Evidence of seizure cessation in epileptic patients through mental effort exercises (e.g., spelling or mathematical problem solving) has been observed [3], but it is not fully understood how this stimulus works and how to characterize when it will work.

**Challenge** A number of tools can be applied to understand epileptic networks, e.g. neuroimaging (MRI, fMRI), and electromagnetic recordings (ECoG, MEG) [4]. ECoG data are localized, instantaneous, gridded measurements of brain electrographic activity and useful for monitoring drug-resistant epileptic (DRE) patients prior to resection surgery [5]. However, the complexity of the brain electrical activity and the high-dimensionality of the ECoG time series data are challenging from a network modeling perspective.

**Action** We proposed to test a new network connectivity feature derivable from ECoG data that can be used to characterize a patient's response to mental effort stimulus following abnormal brain activity, e.g. after-discharges (ADs). A patient is deemed responsive if the ADs terminate and non-responsive if the ADs continue following a math question. The first step was to determine if there is evidence of a connectivity feature that can be used to develop a future classifier or predictor. We implemented a variant of an approach [5][6] leveraging connectivity features (centralities) that have shown promise in correctly locating seizure foci based on ECoG data over time, but adapted the approach to our problem and included spatial information on the electrodes as well. Specifically, we first reduced our 88 channel ECoG datasets to 88-element eigenvector centrality vectors (EVC), each representing a 4-s time window prior to an AD event. Next, a feature was calculated as the summation of the spatial distances between each of the highest (19) EVC nodes or electrodes and all other electrodes. The data provided with this project are EVCs corresponding to each 4-s ECoG dataset collected on DRE patients with known outcome to mental effort stimulus. The hypothesis is that mental effort is effective due to its global effects on brain network connectivity, and the more global the effect, the more effective the seizure or AD mitigation.

**Resolution** Shown in the figure above left are 9 EVCs calculated prior to the corresponding 9 AD events in which the patient was non-responsive to a mental stimulus exercise following the event. Above right are 11 EVCs calculated prior to the corresponding 11 AD events in which the patient was responsive to mental effort stimulus. The final feature of summed distances at the bottom illustrates that larger distances, and thus more global connectivity of the brain network, is often evident in patients prior to effective seizure mitigation via mental effort exercises, as hypothesized.

**Future Work** Moving forward, the significance of the proposed decision boundary in the second figure can be tested by calculating the above feature for a large number of cases with randomly permuted electrode location labels, i.e., classification performance on the null distribution. Additional features will be investigated, along with other graph classification techniques, e.g., using signal-subgraphs [7], that may allow for a more intuitive approach for handling the data dimensionality and learning aspect of the problem.

# References


[1] Yaffe R, Borger P, Megevand P, Groppe D, Kramer M, Chu C, Santaniello S, Meisel C, Mehta A, and Sarma S 2015 Physiology of functional and effective networks in epilepsy *Clinical Neurophysiology*

[2] Netoff T, Clewley R, Arno S, Keck T, and White J 2004 Epilepsy in small-world networks *Neurobiology of Disease*

[3] Lesser R, Lee H, Webber W, Prince B, Crone N, and Miglioretti D 2008 Short-term variations in response distribution to cortical stimulation *Brain*

[4] Holmes M and Tucker D 2013 Identifying the epileptic network *Frontiers in Neurology*

[5] Yaffe R, Burns S, Gale J, Park H, Bulacio J, Gonzalez-Martinez J, and Sarma S 2012 Brain state evolution during seizure and under anesthesia: a network-based analysis of stereotaxic EEG activity in drug-resistant epilepsy patients *34th Annual International Conference of the IEE EMBS*, San Diego, CA, 28 August - 1 September 2012.

[6] Burns S, Santaniello S, Yaffe R, Jouny C, Crone N, Bergey G, Anderson W, and Sarma S 2014 Network dynamics of the brain and influence of the epileptic siezure onset zone *PNAS*

[7] Vogelstein J, Gray W, Vogelstein R, and Priebe C 2013 Graph classification using signal-subgraphs: applications in statistical connectomics *IEEE Transactions on Pattern Analysis and Machine Intelligence* 7 (35)