Harnessing Network Competition to Identify Connectivity-Based Predictors of Seizures in Drug-Resistant Epilepsy

Justo Montoya-Gálvez[1,2], Alessandro Principe[2], Rubén Moreno-Bote[1]

[1]Theoretical and Computational Neuroscience (TCN) - Center for Brain and Cognition
Universitat Pompeu Fabra – Barcelona

[2]Epilepsy group - Hospital del Mar Barcelona
Universitat Pompeu Fabra – Barcelona

Epilepsy is one of the most prevalent neurological conditions worldwide, with 30% of its patients presenting drug resistant epilepsy (DRE) and not responding to treatment. Seizure prediction devices could help tailor targeted therapy, but they require highly accurate, customizable methods.

Here, we propose a framework for understanding the epileptic brain as an assembly of subnetworks with at least two kinds of modules: the Epileptogenic Network (EN) and the Healthy Network(s) (HN). We hypothesize that seizure generation, or epileptogenesis, arises from a competitive dynamic between these subnetworks. The EN seeks to impose its pathological activity, while the HN, or parts thereof, strive to maintain the activity underlying cognitive functions. This interplay is facilitated by functional connectivity changes within and between the subnetworks. Specifically, during seizure generation, the EN is believed to increase intraconnectivity while becoming detached from HN control. Conversely, the HN aims to reassert control over the EN, promoting non-pathological activity.

In this study, we analyze intracranial EEG data from drug-resistant epilepsy patients, treating it as network activity. Spectral graph theory is then applied to connectivity matrices of both healthy and epileptogenic states to investigate differences and assess their potential as seizure prediction markers. Our findings reveal differences between epileptogenic and healthy states in terms of stability and timescales. Importantly, these differences enable the accurate detection of epileptogenic states, achieving accuracy exceeding 80%, recall surpassing 90%, and precision exceeding 95%. These insights, in conjunction with an ongoing competition-based algorithm, hold promise for the development of a robust seizure prediction protocol.