Time series analysis of the EEG signals for Epilepsy seizure forecast

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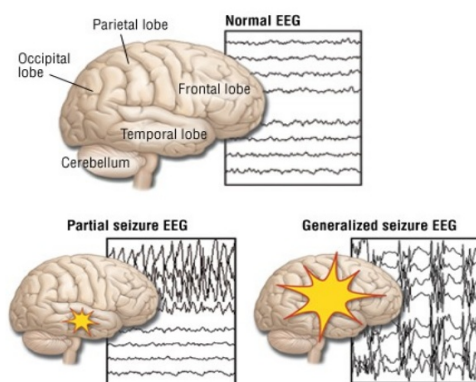* Corresponding author: David Quesada* (E-mail: dquesada@stu.edu)

Graphical Abstract

Fig. 1: The intensity and brain area affected subdivides Epileptic seizures. EEG is able to record the evolution of it.

Abstract.

Epilepsy is a Central Nervous Disorder that is affecting millions of people with a different degree of severity. This project is aimed at studying the feasibility to use the software R for statistical analysis of EEG signals in order to perform statistical forecast of epileptic seizures by constructing functional networks based on the cross-correlation of time series from different electrodes. Such functional associations are a result of an emergent neuronal activity of a large amount of neurons, thus, they will be guidance to physicians. A further understanding of the causes will require a combination of biomedical modeling and sensing with fMRI and EEG combined.

1. Introduction

Epilepsy is a Central Nervous Disorder that is affecting millions of people with a different degree of severity. Epilepsy is the 4th most common neurological problem in the USA, followed by migraines, strokes and Alzheimer disease. The average incidence of this condition each year in the USA is estimated at 48 incidents for every 100,000 people [1]. Young children and older adults are the groups with the highest rates. In addition, the prevalence of this condition is estimated at 2.2 million people or 7.1 for every 1000 people in the USA. Depending on the level the patient is at the moment, seizures can be controlled either with medications or with surgical procedures. However, during surgical procedures many complications might show up, mainly due to the lack of knowledge of functional neuronal networks operating behind epileptic seizures [2]. Therefore, a reliable methodology capable to predict in advance the beginning of seizures would have a tremendous impact on the quality of life of these patients and might prevent further complications with the management of this condition. In this end, EEG provides a reliable method to detect the seizures with very good temporal resolution [3,4] (see Fig. 1).

This project is aimed at learning about available epileptic databases, the format of the data, the RStudio package eegkit to do EEG signal processing, and principles of network science. It is rather a review project rather than a computational one and constitutes an entry-level mathematics-oriented project for Biology majors.

2. Methodology

One of the challenges new applied biomedical-oriented star-ups face is the cost of technology oriented software. In the Biomedical fields, MATLAB has a long tradition of being use. Despite of that "gained seniority", there are new possibilities that are based on community open source projects. R software and its Integrated Development Environment (IDE) RStudio are potential alternative to MATLAB. Within R, the package **eegkit**

[5] allows the processing of EEG signals. Thus the first objective of this project was to get introduced and familiar with such package.

The second objective was to access available epileptic EEG databases in order to apply eegkit to the existing datasets. In that regards, the following sources were used: European Database on Epilepsy – Epilepsiae [6], Free accessible database of 23 patients with MRI and EEG information for both phases, pre and post-operatory from Warsaw Memorial Child Hospital [7], and EEG and ERP data available for public download [8]. One common trouble encountered with accessing to data was the standardization of the output format for EEG and its further translation into a readable by R binary. At this point, it is worth to mention that MATLAB toolbox eeglab [9] is more versatile and easy to use, thus the further use of R will be determined by the ability to create a more easy-to-use interface competing with eeglab.

Third objective was to create within R the cross-correlation matrix between different time series obtained from different electrodes. Once the matrix is created, a criterion for a strong connectivity is set. For instance, Pearson correlation above 0.6 thresholds is considered a strong correlation between different electrodes. Connectivity above 0.6 thresholds is also segmented in order to see the strongest links and how far electrodes and consequently patches of neurons are connected.
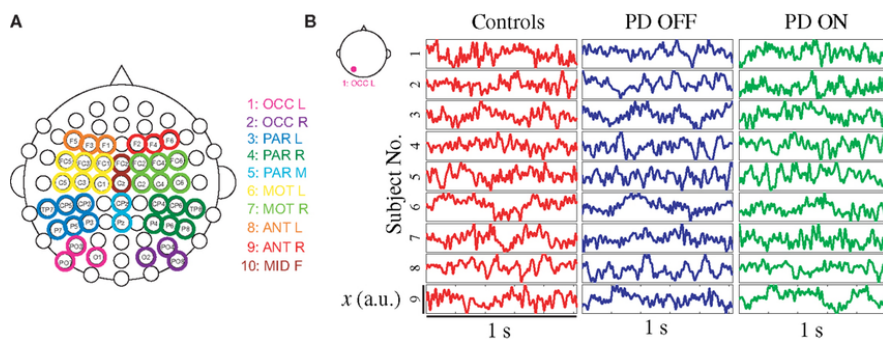
3. Results

Fig. 2: (A) Positions of the electrodes and its planar representation within eegkit, (B) time series from specific patient before and after were stimulated.

Working with the scheme of 64 electrodes, they can be represented and selected at out convenience within eegkit (see Fig. 2 A). Likewise, time series from specific patient and from a specific electrode can be selected and plotted (see Fig. 2 B). The mining of the data from within eegkit still need to be worked out better. It was one of the most difficult moments with the package. Another important trouble encountered with eegkit was the exporting of graphs. In many cases screenshots were needed because a regular export procedure did not work. The cross-correlation analysis was not performed because of the above-mentioned troubles with eegkit and lack of standardization of the datasets. Nevertheless, the familiarity with the desired goal is exemplified in Fig. 3.
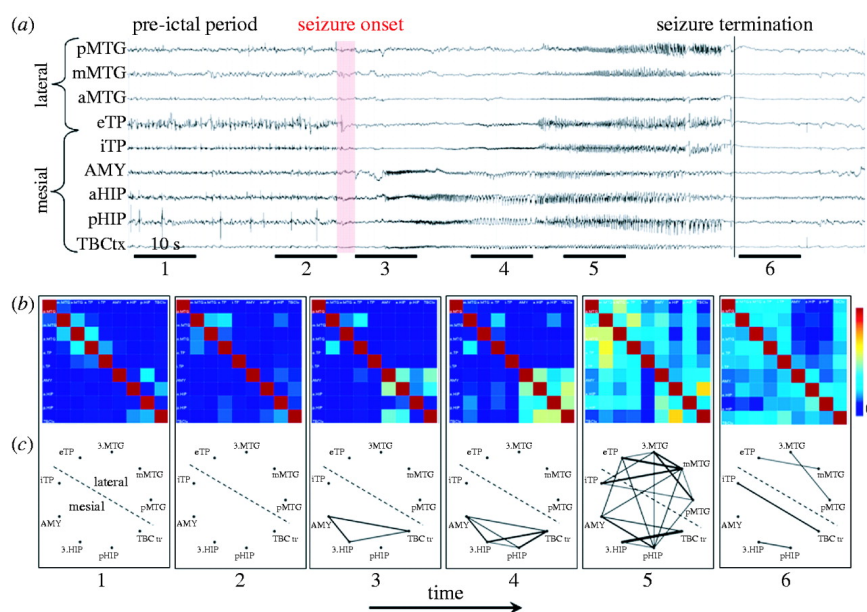
Fig. 3: Schematic representation of the obtention of electrode-correlated network from EEG time [1]

4. Conclusions

Access to medical records it is a difficult task for several reasons: availability, reliability, and the standardization of the output formats.

Despite of the implementation of the application "eegkit" is not at the stage that datasets might be uploaded easily and the obtained graphs exported to other applications. Therefore, the full analysis expected to be done from the very beginning it could not be accomplished in most. Even though, it might be seen initially as a negative moment, it opens new opportunities for further developments and collaborations.

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