Estimation of Neural Code from the Electroencephalogram (EEG)

Rendicontazione

Informazioni relative al progetto

ESNECO

ID dell'accordo di sovvenzione: 893825

Sito web del progetto

DOI
10.3030/893825

Progetto concluso il 9 Gennaio 2022

Data della firma CE
28 Marzo 2020

Data di avvio
16 Ottobre 2020

Data di completamento
15 Ottobre 2022

Finanziato da
EXCELLENT SCIENCE - Marie Skłodowska-Curie Actions

Costo totale
€ 171 473,28

Contributo UE
€ 171 473,28

Coordinato da
FONDAZIONE ISTITUTO ITALIANO DI TECNOLOGIA
Italy

Periodic Reporting for period 1 - ESNECO (Estimation of Neural Code from the Electroencephalogram (EEG))

Periodo di rendicontazione: 2020-10-16 al 2022-10-15

Sintesi del contesto e degli obiettivi generali del progetto

The action "Estimation of Neural Code from the Electroencephalogram (EEG)" was focused on answering the question: Where does the electroencephalogram (EEG) come from? Electroencephalography is one of the most important non-invasive brain imaging techniques in

neuroscience and in the clinic; it has been widely applied to diagnose numerous brain diseases. What we know about how to use the EEG for clinical diagnose is largely based on a machine-learning perspective that employs features of the EEG signal to detect and classify the neural disease. However, the underlying brain mechanisms that produce those EEG features are largely unknown. Few labs have been interested in linking neurophysiology to the EEG. The EEG could be a much more powerful and insightful brain measurement tool if only we could understand the neural mechanisms that produce it. It is remarkable to think that EEG has been a dominant tool in studying healthy and diseased brain function, and for diagnosing medical conditions, for a century, and we still do not have answers to this fundamental question.

The goal of this Marie Skłodowska Curie Action (MSCA) has been to develop rigorous mathematical tools to disambiguate the EEG and robustly interpret it in terms of specific neural features (e.g. excitation-inhibition ratio). Such features are key elements in determining the neural microcircuit configuration and have been documented to contribute to important brain disorders such as schizophrenia and autism spectrum disorders. These brain disorders result, at least in part, from anomalous changes in the functional organization and dynamics of neural circuits. However, we still do not know how to identify these atypical changes of neural dynamics in terms of the EEG signal. Ensuring healthy lives and promoting the well-being at all ages is a priority at European and global levels. Understanding the origins of EEG may increase the usability of EEG to diagnose brain disorders and predict treatment outcome success.

Lavoro eseguito dall'inizio del progetto fino alla fine del periodo coperto dalla relazione e principali risultati finora ottenuti

Work was conducted via 6 work packages (WPs), of which, 5 were completed (WP1, WP2, WP4, WP5 and WP6). WP1 sought to build feed-forward models that could approximate the EEG signal from networks of simplified neuron models. Our feed-forward models were shown to predict well the EEG signal across different configurations of the cortical network. It yielded a journal publication in PLOS Computational Biology. Results of WP1 were also presented in the Neuromatch Conference 3.0. WP2 involved developing algorithms for inferring changes in parameters of the neural circuit caused by changes in the EEG signal. The Fellow delivered a journal article in Brain Informatics that shows results for WP2. There is another forthcoming journal article that includes more detailed findings of WP2. In WP4, we successfully validated our inference methods on empirical data from mice. In particular, the mathematical methods developed in WP2 were validated with data that combined electrophysiological recordings in mice with chemogenetic perturbations to manipulate neural activity. The Fellow exceeded goals by validating the inference models on magnetoencephalogram (MEG) data of human subjects (data provided by another project). Results of WP4 will be included in the forthcoming journal article. In WP5, the Fellow published in high quality, open-access international journals and international conferences, uploaded the source code to public open-source repositories, as well as delivered different public engagement activities to popularize and communicate findings of the action (such as the European Researchers' Night 2021 or the IIT international talks). In WP6, for researcher training, the Fellow attended different training workshops, conferences, lab meetings, journal clubs and seminars of different international labs in different

countries. In WP6, the Fellow participated in the research and financial management of the action and developed the Career Development Plan (CPD).

Progressi oltre lo stato dell'arte e potenziale impatto previsto (incluso l'impatto socioeconomico e le implicazioni sociali più ampie del progetto fino ad ora)

This MSCA has pushed forward the frontiers of neural code estimation from EEG measures in numerous ways. Interpreting experimental EEGs in terms of neural processes ultimately requires being able to compute realistic EEGs from simple and tractable neural network models, and then comparing the predictions of such models with data. This MSCA allowed the Fellow to contribute to the first goal by developing simple yet robust and accurate mathematical expressions (termed proxies) to compute EEGs from networks of simplified neuron models. Our proxies have closed the gap between neural network theory and empirical EEG data, which has opened the possibility of interpreting experimentally measured EEGs in terms of neural models of brain function. The Fellow has also greatly contributed to the second goal by developing and validating inference approaches that can predict changes in key neural parameters (such the excitation-inhibition ratio) from EEG data.

The Fellow's findings are generating important new knowledge about contributions of different neural phenomena to EEGs and are helping quantify how neural parameters change with manipulations of neural circuits or in brain disorders. For example, the models developed by the Fellow have been used to first show that some specific spectral features of EEGs can be an index for underlying change in the synaptic excitation-inhibition ratio and that excitation-inhibition imbalance affects autistic males and females differently. Being able to detect imbalances in neural parameters using standard brain imaging could be useful for clinical diagnose. Future studies will be able to use biomarkers based on the computational tools developed in this MSCA to monitor responses to drug treatments that aim to adjust the balance between neural parameters.

Lab team Picture

Ultimo aggiornamento: 29 Aprile 2022

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