DOI: 10.3217/978-3-85125-962-9-172

Network features for motor imagery-based brain-computer interfaces

J. Gonzalez-Astudillo[1]*, F. De Vico Fallani[1]

[1]Sorbonne Université, Paris Brain Institute - ICM, CNRS, Inria, Inserm, AP-HP, Hôpital de la Pitié Salpêtrière, F-75013, Paris, France

*Hôpital Pitié, 47 Bd de l'Hôpital, 75013, Paris, France. E-mail: julianagonzalezastudillo@gmail.com

Introduction: It is well known that the motor cortex is principally involved in controlling the contralateral side of the body. Most of the motor-based Brain-Computer Interface (BCI) paradigms rely on this spatial layout to decode motor imagery (MI) from brain signals [1]. Furthermore, recent neuroimaging studies demonstrated that also functional connectivity (FC) reveals this lateralization during motor-related tasks [2].

Material, Methods and Results: In this work, we explored the dual contribution of brain network topology and space in modeling MI states through functional lateralization [3]. Specifically, we introduced new network metrics to quantify *integration* (ω) and *segregation* (σ) (Fig. 1-A). These properties respectively account for the contribution of within- and across-hemispheric connections for pairs of homotopic nodes *i* and *j*.

To assess our approach, we used six open-access datasets of healthy participants [4]. This data contains EEG signals measured during MI experiments focusing on left and right hand grasping motions. We estimated spectral coherence-based networks. Then we computed the network lateralization metrics for each electrode. To statistically evaluate the power of these properties in differentiating between MI tasks, we performed a 5000 permutation t-test. We resumed the obtained results in Fig. 1-B.

Discussion: This analysis enabled us to identify the most discriminant electrodes. Both metrics engage a subset of nodes mostly located in the M1 cortex, but also the PMA, SMA and S1 areas which are crucial in the planification and execution of a movement. We observe that ω shows higher values over the motor cortex, while σ also involves frontal areas, usually associated with attention and motor planning.

Significance: In the BCI classification scenario, these network properties not only can improve the overall accuracy, but they also have the advantage of being neurophysiologically interpretable, compared to state-of-the-art approaches, like CSP and Riemannian methods, that are instead blind to the underlying mechanisms. These results show the neurophysiological plausibility of our proposed network approach. Moreover, they prove to be highly relevant features for decoding a MI mental task.

Acknowledgements: This research has received funding from the program "Investissements d'avenir" ANR-10-IAIHU-06 (Agence Nationale de la Recherche-10-IA Institut Hospitalo-Universitaire-6). FD acknowledges support from the "Agence Nationale de la Recherche" through contract number ANR-15-NEUC-0006-02.

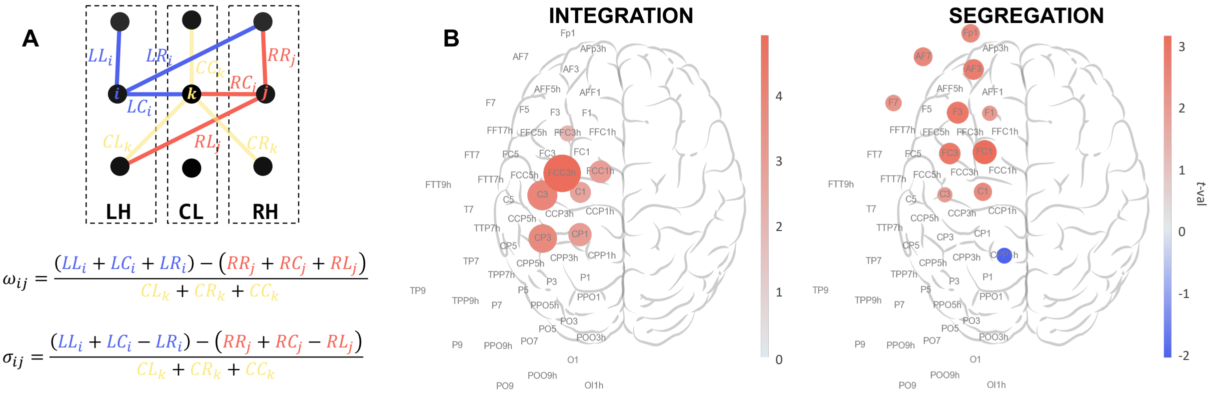

Figure 1. A- *. Integration (ω) and segregation (σ). Each term represents the strength of a node in the homotopic pair i and j. More precisely, the capital letters respectively denote the locations of node i and the nodes it establishes connections with (e.g., LR_i means that node i belongs to the left hemisphere and we consider the connections that link it to the right hemisphere nodes). Note that for the particular case of brain signals recorded with an EEG system, the electrodes placed in the midline sagittal plane (C_k) do not strictly belong to a hemisphere, then we consider them to normalize the metrics values. LH: left hemisphere, RH: right hemisphere and CL: central line.* ***B-*** *Group-averaged node-t-values between right and left MI mental states. By definition, lateralization metrics are anti-symmetric with respect to the hemispheres. For the sake of simplicity, only the left hemisphere is shown in here.*

References:

[1] G. Pfurtscheller, and FH. Lopes Da Silva, Event−related EEG/MEG synchronization and desynchronization: basic principles, Clin Neurophysiol 110, 1842-1857 (1999).
[2] T. Cattai, S. Colonnese, MC. Corsi, DS. Bassett, G. Scarano, and F. De Vico Fallani, Phase/amplitude synchronization of brain signals during motor imagery BCI tasks, IEEE Transactions on Neural Systems and Rehabilitation Engineering 29, 1168-1177 (2021).
[3] SJ. Gotts, HJ. Jo, GL. Wallace, ZS. Saad, RW. Cox, and A. Martin, Two distinct forms of functional lateralization in the human brain, PNAS 36, E3435-E3444 (2013).
[4] V. Jayaram, and A. Barachant, MOABB: trustworthy algorithm benchmarking for BCIs, J. Neural Eng. 15, 066011 (2018).

Published by Verlag der Technischen Universität Graz