Functional connectivity predicts MI-based BCI learning (oral presentation)

Marie-Constance Corsi, Mario Chavez, Denis Schwartz, Nathalie George, Laurent Hugueville, Ari E. Kahn, Sophie Dupont, Danielle Bassett, Fabrizio de Vico Fallani

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M.-C. Corsi[1,2*], M. Chavez[3], D. Schwartz[4], N. George[4], L. Hugueville[4], Ari E. Kahn[5], S. Dupont[2], D.S. Bassett[5-8], F. De Vico Fallani[1,2]

[1]Inria Paris, Aramis project-team, F-75013, Paris, France; [2]Institut du Cerveau et de la Moelle Epinière, ICM, Inserm, U 1127, CNRS, UMR 7225, Sorbonne Université, F-75013, Paris, France; [3]CNRS, UMR 7225, F-75013, Paris, France; [4]Institut du Cerveau et de la Moelle Epinière, ICM, Inserm U 1127, CNRS UMR 7225, Sorbonne Université, Ecole Normale Supérieure, ENS, Centre MEG-EEG, F-75013, Paris, France; [5]Department of Bioengineering, School of Engineering and Applied Science, University of Pennsylvania, Philadelphia, PA 19104, USA; [6]Department of Neurology, Perelman School of Medicine, University of Pennsylvania, Philadelphia, PA 19104, USA; [7]Department of Physics and Astronomy, College of Arts and Sciences, University of Pennsylvania, Philadelphia, PA 19104, USA; [8]Department of Electrical and Systems Engineering, School of Engineering and Applied Science, University of Pennsylvania, Philadelphia, PA 19104, USA

*E-mail: marie.constance.corsi@gmail.com

Introduction: Despite its clinical application [1], [2], voluntarily modulating brain activity appears to be a learned skill that affects the usability of brain-computer interfaces (BCIs) and neurofeedback systems. Indeed, it is often associated with a strong inter-subject variability and with the difficulty for a substantive portion of the population to self-regulate their brain activity [3]. To address these issues, several approaches based on the search for better neural decoders [4], but also for psychological and/or neurophysiological factors [5], [6] have been considered. If studies revealed the involvement of a larger brain network, beyond the BCI-targeted areas [7], [8], the evolution of the functional connectivity over BCI sessions has poorly been studied. We hypothesized that the training would be accompanied with a decrease of functional integration in areas related to learning process, and that the properties of such network would provide information to predict the amount of learning.

Material, Methods & Results: We performed experiments on a group of twenty naive healthy subjects during a BCI training consisting of 4 sessions over 2 weeks in which electroencephalographic signals were recorded. The task consisted in controlling the vertical position of a moving cursor through the α and/or β modulation to reach a target displayed on a screen. To hit the up-target, the subjects imagined a right-hand grasping and to hit the down-target, they remained at rest. After removing physiological artifacts by performing an Independent Components Analysis, cortical activity was obtained by obtaining the individual head model with the Boundary Element Model and by estimating the sources with the weighted Minimum Norm Estimate. To perform the connectivity analysis, we computed the imaginary coherence between each pair of ROIs [9]. To study the regional connectivity, we then computed the relative node strength N by summing the values of the associated row of the connectivity matrix.
We observed a significant improvement of the BCI scores over sessions (one-way anova, $p << 10^{-3}$) proving that a training effect was obtained. Over the sessions, we found a progressive decrease of task-related connectivity in both α and β ranges across sessions involving mainly fronto-occipital and parieto-occipital interactions. At the regional level, connectivity changes revealed a significant across-session declines spatially distributed involving bilaterally visual areas and associative regions in both α and β ranges.
Better BCI performance was associated with the decrease of relative node strength in areas involved in visual attention task (occipital pole), in both mental rotation and working memory (orbital part of the inferior frontal gyrus), in decision making and memory consolidation (fronto-marginal gyrus). We observed a significant and positive correlation between the regional connectivity and the learning rate, defined here as the relative difference of BCI scores between consecutive sessions ($p < 0.035$). It indicated that the potential to improve performance is higher when the functional disconnection of these regions has not yet started. Notably in the α_2 band, significant predictions were obtained in areas involved during the visual information processing (middle occipital gyrus) and during motor imagery and working memory (precuneus).

Discussion & Significance: In this study, we identified functional connectivity changes during BCI training. They were characterized by a progressive functional disconnection over sessions. These network features appeared to be significant predictors of BCI learning rate. If conducting studies on longer BCI training to assess the evolution of these patterns is necessary, our results could pave the way to an individualized BCI training based on the study of the properties of the functional brain network organization.

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