Identification of brain markers of mental imagery after stroke for the design of rehabilitative brain-machine interfaces.

Descriptif

Context. Stroke is one of the leading causes of disability in the world and has a significant impact on both patients and society. It affects approximately 150,000 people per year in France. Motor deficits are the most common consequence of stroke. It is estimated that only one third of patients will regain their previous condition, one third will be dependent, while the rest will have more or less disabling after-effects. A certain degree of recovery is generally observed in the first months, and a significant proportion of patients recover 70% of their maximum strength, but a certain number do not follow this rule. Identifying biomarkers of functional recovery is one of the challenges of research in the field. Moreover, these are an important element to improve the use of brain-computer interfaces (BCIs). BCIs have emerged in the last decades as innovative tools for functional recovery after stroke and for autonomy support. Their applications are also very promising in the case of brain stem or spinal cord damage, in Charcot's disease or in the case of severe neuromuscular damage by allowing the translation of brain activity into commands for the control of real or virtual objects. However, their use suffers from an inefficiency phenomenon that limits their control for 30% of patients.

Objective. The goal of this project is to identify new biomarkers derived from EEG data to improve the detection of neurophysiological signatures related to mental imagery tasks in stroke patients, so as to improve the effect of BCI-based rehabilitation in the long term.

Methodology. To do so, we'll analyze existing longitudinal neuroimaging datasets from stroke patients available the ARAMIS team of the Institut du Cerveau (ICM), and will plan new experiments involving BCI neurofeedback applications. Based on the current research of the two PIs, different analytical tools will be developed and validated to quantify the impact of the communication between brain areas, or functional connectivity, on the identification of a brain recovery profile and on the improvement of BCI training programs. Indeed, in the case of stroke, studies have shown that functional recovery is accompanied by a reorganization of brain connectivity networks. To date, few studies have focused on using this reorganization to identify such biomarkers.

Relevance. This project, multidisciplinary by nature, combining engineering approaches with clinical neuroscience, is highly relevant to the IUIS and to the Initiative Humanites Biomedicales.

Encadrement

2 PI, with complementary characteristics, will ensure the PhD supervision: F De Vico Fallani (computational modeling, BCIs), P Bartolomeo (clinical neuroscience, mental imagery). Both PIs are already collaborating and their teams are located in the same institute (ICM), which facilitates interaction and cosupervision.

Recent publications in relation to the proposed research project :

1 - Cattai, T., Colonnese, S., Corsi, M.-C., Bassett, D. S., Scarano, G., & De Vico Fallani, F (2021). Phase/amplitude synchronization of brain signals during motor imagery BCI tasks. IEEE

Transactions on Neural Systems and Rehabilitation Engineering. https://doi:10.1109/TNSRE.2021.3088637

2 - Gonzalez-Astudillo, J, Cattai, T., Bassignana, G., Corsi, M.-C., & De Vico Fallani, F. Network-based brain computer interfaces: principles and applications. (2020) Journal of Neural Engineering https://doi:10.1088/1741-2552/abc760

3 - Corsi, M.-C., Chavez, M., Schwartz, D., George, N., Hugueville, L., Kahn, A., Dupont, S., Bassett, D. S., & De Vico Fallani, F., (2020) Functional disconnection of associative cortical areas predicts performance during BCI training. NeuroImage https://doi.org/10.1016/j.neuroimage.2019.116500

4 - Kaufmann BC, Cazzoli D, Bartolomeo P, et al. Auditory spatial cueing reduces neglect after right-hemispheric stroke: A proof of concept study [published online ahead of print, 2022 Jan 19]. *Cortex*. 2022;148:152-167. doi:10.1016/j.cortex.2021.12.009

5 - Toba MN, Pagliari C, Rabuffetti M, et al. Quantitative Assessment of Motor Neglect. *Stroke*. 2021;52(5):1618-1627. doi:10.1161/STROKEAHA.120.031949

6- Liu J, Spagna A, Bartolomeo P. Hemispheric asymmetries in visual mental imagery. *Brain Struct Funct*. 2022;227(2):697-708. doi:10.1007/s00429-021-02277-w

Calendrier

PhD training: 36 months

- November 2022 to May 2023 (6 months): Analysis of longitudinal neuroimaging datasets from stroke patient. EEG, fIRM and tractography processing. Functional connectivity analysis. Identification and selection of neurophysiological biormarkers.
- June 2023 to October 2023 (6 months): Design of BCI program and writing clinical study protocol for long-term rehabilitation. Writing the ethics committee form. Handholding real-time processing of brain signals software (OpenViBE) and rTMS training.
- November 2024: Start of patient inclusion
- November 2024 to May 2025 (18 months): Clinical evaluation, data acquisition and analysis, outcomes evaluation.
- June 2025 to October 2025(6 months): Writing and publication of scientific papers. Communication of scientific results.

Profil

The ideal applicant for this position holds a Master of Science (M2 Recherche) with a background in neurology (e.g., clinician) with an interest in data analysis (e.g., experimental data analysis, imaging data processing, applied mathematics).

The project offers the best training potential for applicants who already have experience analysing experimental data (e.g. electrophysiology or brain imaging data), and have a solid programming background in Python and R. However, more than a formal background, drive is crucial for success in science, and it is expected that the applicant will also develop some of these skills only after joining the group. The Ph.D. fellow will be trained in the acquisition and

analysis of EEG, functional MRI and tractography data and will be introduced to the design of BCIs. Clinical neurophysiology needs more quantitative scientists, as well as data science needs more clinician. We also see it as part of our mission to educate the next generation of neuroscience practionners and professors in computational approaches.

Finally, to fully enjoy this project, the ideal applicant is also likely to have a specific interest in reeducation therapy and/or clinical applications in neurology.