Spatial Abilities Play a Major Role in BCI Performance

C. Jeunet[1,2,*], F. Lotte[2], M. Hachet[2], S. Subramanian[3] & B. N'Kaoua[1]

[1]University of Bordeaux, France; [2]Inria Bordeaux Sud-Ouest, France; [3]University of Sussex, UK.

*200 Avenue de la Vieille Tour, 33 400 Talence, France. E-mail: camille.jeunet@inria.fr

Introduction: Despite their promising potential impact for many applications, Mental-Imagery based BCIs (MI-BCIs) remain barely used outside laboratories. One reason is that 15% to 30% of naïve users seem unable to control them [1] and only a few reach high control abilities. Although different predictors of BCI performance (i.e., command classification accuracy) have been investigated to explain this huge inter-user variability [2, 3], no strong predictive model has yet been determined. This could be due to (a) the often small samples used (N=5 or 6) and (b) the fact that these predictors have been mostly determined based on one-session experiments. Yet there is no evidence that performance obtained at the first session is predictive of users' MI-BCI control ability.

Material, Methods and Results: In [4], we investigated the impact of the user's personality and cognitive profile on MI-BCI performance based on a 6-session experiment. Averaging performances over these sessions reduced the intra-subject variability (e.g., due to fatigue or external factors), and thus led to a better estimation of participants' MI-BCI control ability. Each session comprised 5 runs during which the participants (N=18) had to learn to perform 3 MI tasks: left-hand motor imagery, mental rotation and mental calculation. The results stressed the impact of mental rotation scores (measured using questionnaires), and which reflect Spatial Abilities (SA), on mean MI-BCI performance [r=0.696, p<0.05] (see Fig. 1[A]). SA are the mental capacities which enable the construction, transformation and interpretation of mental images. In a more recent study (to be published), we trained 20 participants to control a 2-class MI-BCI by performing motor-imagery of their left- and right-hands, within 1 session of 5 runs. Results confirmed the role of SA: mental rotation scores were correlated with peak MI-BCI performance [r=0.464, p<0.05]. This suggests that SA are a generic predictor of MI-BCI performances.
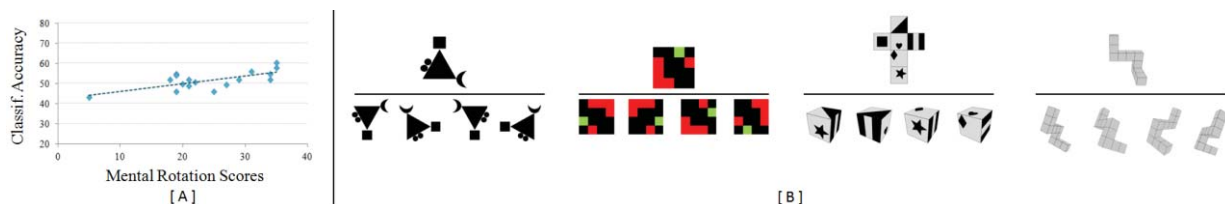

Figure 1.   *[A] Diagram representing the mean classification accuracy for the different subjects as a function of their mental rotation score; [B] One item per exercise included in the Spatial Ability training:the shape on top is the target, and the participant must identify the two shapes that are identical to the target among the four below.*

Spatial Ability Training: The strong correlation between SA and MI-BCI performance raised a new research question: Is there a causal effect between SA and MI-BCI performance? In other words: Would an improvement of users' SA result in an increase of their MI-BCI control abilities? We implemented an SA training protocol (see Fig. 1[B]) including different exercise types and difficulties. In the coming weeks, we will test this protocol efficiency in terms of MI-BCI performance improvement by comparing it to a standard MI-BCI training approach. We will also investigate the neurophysiological correlates of the SA training (notably the implication of the motor cortex) to improve the understanding of the relationship between SA and MI-BCI performance.

Perspectives for Stroke Rehabilitation: If a causal link between SA and MI-BCI performance is confirmed, this would be a promising way to improve MI-BCI performance and thus MI-BCI-based applications such as stroke rehabilitation [5]. Also, current MI-BCI based stroke rehabilitation procedures [5] require the execution of MI tasks which can induce (or increase) a depressed state in patients by reminding them of the loss of movement in their limb. Since SA training and mental rotation tasks activate the motor cortex [6], they might also be used as a more transparent way to indirectly induce synaptic plasticity in the motor cortex during rehabilitation.

Significance: Through SA, we propose a new approach for MI-BCI training that could offer promising perspectives for MI-BCI and stroke rehabilitation. We are currently evaluating and validating this approach.

References
[1] Allison B, Neuper C. *Could Anyone Use a BCI?* Springer London, 2010.
[2] Kleih S, Kübler A. Psychological Factors Influencing Brain-Computer Interface (BCI) Performance. *Proc. SMC 2015 -in press-.*
[3] Ahn M, Jun SC. Performance Variation in Motor Imagery Brain-Computer Interface: A Brief Review. *J. Neuroscience Methods,* 2015.
[4] Jeunet C, N'Kaoua B, Subramanian S, Hachet M, Lotte F. Predicting Mental-Imagery-Based BCI Performance from Personality, Cognitive Profile and Neurophysiological Patterns. *Accepted, PloS One.*
[5] Ang KK, Guan C. Brain-Computer Interface for Neurorehabilitation of Upper Limb After Stroke. *Proceedings of the IEEE,* 2015.
[6] C. Windischberger, C. Lamm, H. Bauer, E. Moser, "Human Motor cortex activity during mental rotation", *NeuroImage*, 2003.