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What brain patterns should we reinforce during BCI training procedures targeting motor imagery abilities?

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Introduction: Motor imagery (MI) can be defined as a *"dynamic state during which one simulates an action mentally without any body movement"* [1]. The aim of MI is to optimise learning (e.g., in athletic training) or re-learning (e.g., in motor rehabilitation after stroke) by mastering the technique of new motor skills, but also through attentional focus [2] thanks to brain plasticity mechanisms. Indeed, similarities exist between MI and motor execution with regards to the solicitation of certain brain networks and regions, including premotor, parietal, and somatosensory regions [3]. Current BCI protocols targeting MI consist in positively reinforcing the maximum modulation of sensorimotor rhythms (SMRs) from baseline levels. This suggests that we consider that the growing expertise in the MI task will be associated with a higher desynchronisation of neurons in the sensorimotor cortices [4]. Yet, experiments investigating the neural efficiency hypothesis have shown that experts happen to have a reduced modulation of neural activity in comparison to novices [5], which can be attributed to a more efficient resource distribution. This efficiency would take form of reinforced temporal and spatial stability during MI tasks [6,7]. Thus, our questions are as follows: **Q1.** Does expertise modify the brain patterns associated with a MI task? **Q2.** If so, are those modifications elicited exclusively during MI of mastered movements? Or do these modifications reflect the acquisition of a generic skill (whatever the imagined movement)? **Q3.** Is maximising the percentage of desynchronisation a relevant objective? If not, what metrics of performance should be used in order to optimise the training of users/patients to self-regulate their brain activity?

In order to investigate those different questions, we will recruit athletes who can be considered as an expert population in MI because of their frequent mental training use (to prevent overtraining or during rehabilitation but also as warm-up routines and rehearsal technique).

Material and Methods: We will recruit 48 participants who will be divided into three groups: "basketball experts" (*G1exp*), "dance experts" (*G2exp*) and "novices" (*G3*) [16 participants per group, 8 men, 8 women]. All participants will perform 20 MI trials lasting 10s each for all four of the following movements: a simple reaching action (*T1* – for which all participants are experts), a complex novel drawing task (*T2* – for which none are expert), a basketball free throw (*T3* – expertise of *G1exp* only) and a short pre-defined dancing choreography (*T4* – expertise of *G2exp* only). EEG activity will be recorded during trials. This paradigm will enable us to compare MI-related brain patterns between experts and novices (*G1exp/G2exp* vs. *G3*) **(Q1)**. It will also enable us to assess the extent to which the potential modifications of brain patterns due to expertise are specific to expert movements or generic (for *G1exp* and *G2exp*: *T3* vs. *T4*; for all, control: *T1* vs. *T2*) **(Q2)**. From those results, we will investigate which performance metrics seem the most relevant to use in MI-based BCI/NF paradigms **(Q3)**.

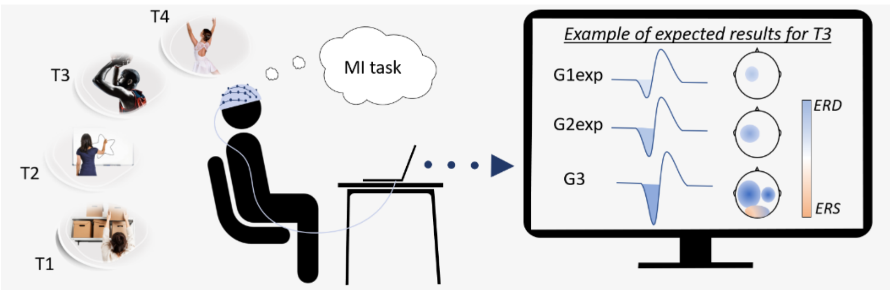

Figure 1. *Experimental procedure that we plan on using*

Discussion: This study will enable us to acquire new knowledge regarding the neural efficiency hypothesis. If our results comfort this hypothesis, it will be important to identify, implement and evaluate new metrics of performance to guide BCI/NF users during their training (i.e., instead of ERD%). Following the neural efficiency hypothesis, we expect experts to show brain patterns that are more spatially and temporally stable than those of novices [6,7]. In other terms, in experts, we expect the modulations of brain activity during MI to be circumscribed to sensorimotor cortices (provided that they perform kinaesthetic MI) and to be highly stable across trials in terms of location and frequency. In addition, we hypothesise that those modulations will represent a general skill. In other terms, we expect the same patterns to be elicited for experts when doing MI of a mastered technique from their discipline, but also when doing MI of a novel movement of similar nature (in our case a different physical activity). Indeed, we believe that a transfer of neural efficiency exists. However, this phenomenon might only happen to a certain extent and not be identifiable for MI of a complex novel task or of a simple everyday life action. To our knowledge, this last hypothesis hasn't been tested in the current literature and will therefore require an exploratory approach.

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