

Why BCI researchers should focus on attempted, not imagined movement

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Introduction: For the past decades, developments on non-invasive motor-based Brain-Computer Interfaces (BCIs) have mainly relied on one major assumption: that motor imagery in healthy users is a good model of the strategy a motor-impaired individual would be using for BCI control. Consequently, motor imagery (MI) has been adopted as a meaningful task for both healthy and impaired users. However, the brain response is difficult to detect in some subjects and therefore high accuracy cannot always be achieved. We argue that for more reliable and efficient communication and control, patients should use movement attempt (MA) instead. Moreover, not imagined but movement execution (ME) can be shown to be a better model in healthy users of this end user strategy of attempted movement.

There is considerable evidence that the neural response of MI differs significantly from both ME and movement attempt (MA) in paralysed individuals. Indeed, the ERD produced during MI is generally weaker than for ME. This difference is not surprising, as MI differs from ME in a number of ways; (1) MI requires an active process of inhibiting movement execution, and (2) MI has no proprioceptive feedback about action execution. Whilst the lack of feedback is similar to the situation in paralysed individuals the inhibitory process is a potential difference. Thus it is unclear whether paralysed individuals should use MI or MA to control a movement-based BCI. Further one cannot simply assume that imagined movement in healthy individuals is an effective substitute for attempted movement in paralysed individuals.

Material, Methods and Results: To investigate this question we re-analysed two existing EEG datasets from our lab which compared ME, MA and MI within subjects. In the first study [1] ten tetraplegic patients performed attempted and imagined fingertapping with both hands—allowing us to investigate the effect of output inhibition in paralyzed individuals. In the second [2] dataset 4 healthy individuals performed ME, MI and MA, where a neuromuscular blocking agent was used to prevent prevent muscle activity in the MA condition. This experiment allowed us to again investigate the effect of output inhibition in MI and also the similarity of ME and MA in healthy individuals. A summary of the main results of these analyse is presented in Figure 1.

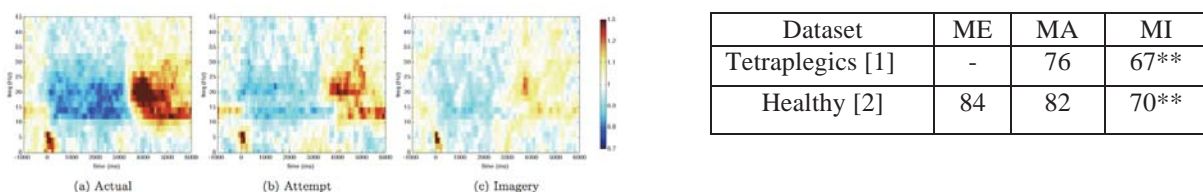


Figure 1. Left: Grand Average time-frequency responses for Executed (a), Attempted but blocked (b) and imagined (c) finger tapping in healthy participants. Right: Average percentage correct classification for the two studies, **indicates significantly ($p < .05$) reduced performance.

Discussion: Our results clearly show that for both paralyzed and healthy individuals MI results in significantly lower BCI performance. Further, the results in healthy individuals indicate that ME generates more similar responses to MA, in terms of both classification rates and spectral components than MI.

Significance: Considering the combined evidence presented here, we conclude that (1) Instructions to BCI end users should focus on attempted, not imagined, movement strategies and (2) Executed movements form a more realistic model of BCI end user strategies. Therefore BCI testing and validation with healthy users should be based on motor execution rather than motor imagery.

References

- [1] Y. Blokland, L. Spyrou, D. Thijssen, T. Eijsvogels, W. Colier, M. Floor-Westerdijk, R. Vlek, J. Bruhn, and J. Farquhar. Combined eeg-fnirs decoding of motor attempt and imagery for brain switch control: An offline study in patients with tetraplegia. *IEEE Transactions on Neural Systems and Rehabilitation Engineering*, 22:222–229, 2014.
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