

Alpha-based neurofeedback to enhance visuospatial attention: protocol, feasibility, and preliminary findings

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Introduction:

Covert attention is an important ability that enables one to focus on an object, person, or place without moving the eyes. The alpha increase on the side of attended visual field (ipsilateral) and decrease on the ignored visual field (contralateral) greatly participate in the success of this mechanism. Alpha lateralization index (α LI) promotes the top-down processing of stimuli, their voluntary selection according to their salience and task relevance. The resulting acute focus increases the efficiency of these stimuli.

Yet, after right cerebral hemisphere damage (following a stroke, or traumatic brain injury), 30 to 50% of survivors show spatial neglect syndrome. Visuospatial attention deficits, particularly hemispatial neglect, represent a critical target for functional recovery after stroke. They are characterized by left side attention failure including bumping into objects, not moving, dressing, or eating, with high risks for safety (injury, traffic ignorance, threat) and reduced independence. Alpha abnormalities are a surface expression of connectivity breakdown, notably the white matter tracts integrity in fronto-parietal pathways. Often, right hemisphere lesion is accompanied by a pathological α increase (contralateral to the attended visual field) while it decreases in healthy population, leading to left-space processing deficit (Kerkhoff et al. 2021, Lasaponara et al. 2019).

Neurofeedback (NFB) offers a compelling perspective as a non-invasive intervention, enabling individuals to progressively modulate their own brain activity with potential for generalized cognitive rehabilitation. Alpha-based NFB is hypothesized to shift the attentional resources toward the contra lesional hemifield, re-establish the α LI unbalance (diminish right or increase left alpha power), and therefore reduce the neglect symptoms.

Alpha-based NFB validation with a healthy population is the first step, that accomplished in the present study. Implementing NFB, and even more so combining it with fMRI, raises substantial experimental and technical challenges, particularly concerning real-time artifact correction to ensure signal fidelity. This project aims to characterize the behavioural benefits of alpha-based

NFB training and to identify the neural correlates of successful regulation, with the long-term goal of refining future NFB protocols for clinical rehabilitation.

Methods:

Eleven healthy older adults (6 males, 32.5 y.o $\pm$ 1.1, Oldfield laterality: 94.4 $\pm$ 11, QCM anxiety: 1.9 $\pm$ 0.8, MAIA: 3.15 $\pm$ 1.2, challenge: 4.5 $\pm$ 1, interest: 4.55 $\pm$ 0.7) participated to our experimental design consisting of four EEG neurofeedback sessions ($\approx$ 30 min each) during which they learned to modulate their occipito-parietal alpha activity by applying lateralized covert attention shifts. During the regulation runs the participants are asked to orient their covert attention to the left while looking at the cross. Their goal is to make the wheels turn clockwise and as fast as possible (actual feedback of the real-time α LI). Pre-post assessments include a Posner and Visual search paradigms to quantify attentional performance and evaluate the effect of alpha-based NFB on different aspects of visuospatial attention.

Results:

The results support the feasibility of the protocol. We observe voluntary modulation of alpha oscillations during training, behavioural indications of attentional enhancement and successful validation of EEG correction pipelines inside the MRI environment during the neurofeedback. We observed an intra-session increase of α LI (speed of the wheel) in session 1. Other sessions do not show significant increase but stabilization. However, the intra session average performance increased from session 1 to session 3 and stabilized in the scanner (session 4). This metric is associated with the behavior showing that this nfb related increase is beneficial for visuospatial attention. More specifically the increase of alpha power on the left seems to correlate with the accuracy increase of the left stimuli at the Posner. Moreover, N2pc and PCC increased after the neurofeedback training.

Conclusion:

We showed that EEG-based Neurofeedback increased α lateralization throughout the 3 training sessions and was maintained in the MRI. Visuo-spatial attention has been enhanced pre-post NFB. NFB induced α LI increase promoted the lateralization of the attentional modalities as measured by Posner and visual search tasks. These findings encourage further neurobehavioral and neuroimaging analyses, paving the way toward optimized NFB-based rehabilitation strategies for hemispatial neglect.