

Targeting emotion regulation with fNIRS neurofeedback training - a feasibility study in healthy participants

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Introduction

Emotion regulation is a fundamental component of mental health, and deficits in regulatory control are associated with a range of affective disorders. Functional near-infrared spectroscopy (fNIRS) neurofeedback (NFB) offers a non-invasive approach to enhance emotion regulation by enabling individuals to modulate activity in prefrontal control networks. Positive mental imagery (PMI) has been shown to engage regions involved in cognitive and emotional control, including the left dorsolateral prefrontal cortex (DLPFC) and pre-supplementary motor area (pre-SMA). While previous studies suggest that NFB can facilitate self-regulation of brain activity, evidence for learning effects across multiple sessions and transfer of these skills to feedback-independent contexts remains limited. The present study investigated the feasibility and efficacy of a multi-session PMI-based fNIRS NFB protocol targeting the left DLPFC and pre-SMA in healthy participants.

Methods

Twenty-three healthy participants completed three PMI-based fNIRS NFB sessions scheduled one week apart. Each session comprised individualized localizer runs to determine optimal target channels, followed by three NFB runs delivering real-time visual feedback derived from (deoxygenated hemoglobin) HbR signal changes. A final transfer localizer without feedback was conducted to evaluate generalization of regulation effects. Hemodynamic responses were modelled using an autoregressive iteratively reweighted least squares general linear model. Exploratory behavioural assessments included standardized measures of emotion regulation and mood, as well as subjective ratings of perceived controllability. We hypothesized that PMI with NFB would elicit stronger activation than without, show regulation success across sessions, and improve localizer performance pre- to post-experiment. The protocol was preregistered on The Open Science Framework (DOI: [129 10.17605/OSF.IO/Y476X](https://doi.org/10.17605/OSF.IO/Y476X)), and all data (<https://osf.io/6ub9j>) and code (<https://osf.io/zyx64>, https://github.com/mariannageo/fNIRS_PMI) are openly available.

Results

Contrary to our preregistered hypotheses, left dorsolateral prefrontal cortex and pre-supplementary motor area activation was higher (i.e., more negative HbR) during localizer runs without feedback than during NFB ($p < 0.01$, $\eta^2 = 0.41$). Across sessions, no significant learning effects or transfer to post-training localizers were observed, with Bayesian analyses favouring the null hypothesis. Subjective controllability in Session 2 correlated negatively with HbR beta values ($\rho = -0.55$, $p < .01$), indicating alignment between perceived and neural regulation success. By Session 3, about 38 % of participants reached at least 60% of their individualized threshold, and 28.5% achieved the full threshold. Mood analyses showed decreased depression alongside reduced vigor and increased fatigue, while trait emotion regulation remained unchanged. Additionally, exploratory subgroup

analyses showed that 65% of participants exhibited consistently negative beta values (expected activation pattern), during both the localizer and NFB conditions.

Conclusions

PMI-based fNIRS NFB targeting the left DLPFC and pre-SMA is technically feasible and produces measurable neural and subjective effects. However, real-time feedback did not increase regulation-related activation or yield consistent learning and transfer. These results are thus at odds with our prior expectations. Nevertheless, further data analysis revealed that participants show robust self-regulation success that also corresponded to their subjective experience. The subgroup analyses indicate partial conceptual feasibility, as participants achieved reliable self-regulation (responders). Overall, data suggest that cognitive demands associated with feedback and limited training exposure may limit efficacy. Implications for future studies are discussed and include the need for refining task design, extending training duration, and identifying responder characteristics a priori to enhance NFB learning performance and yield more robust behavioural outcomes.