Personalized Neurofeedback: a systematic comparison of self- and externally-paced training in healthy adults

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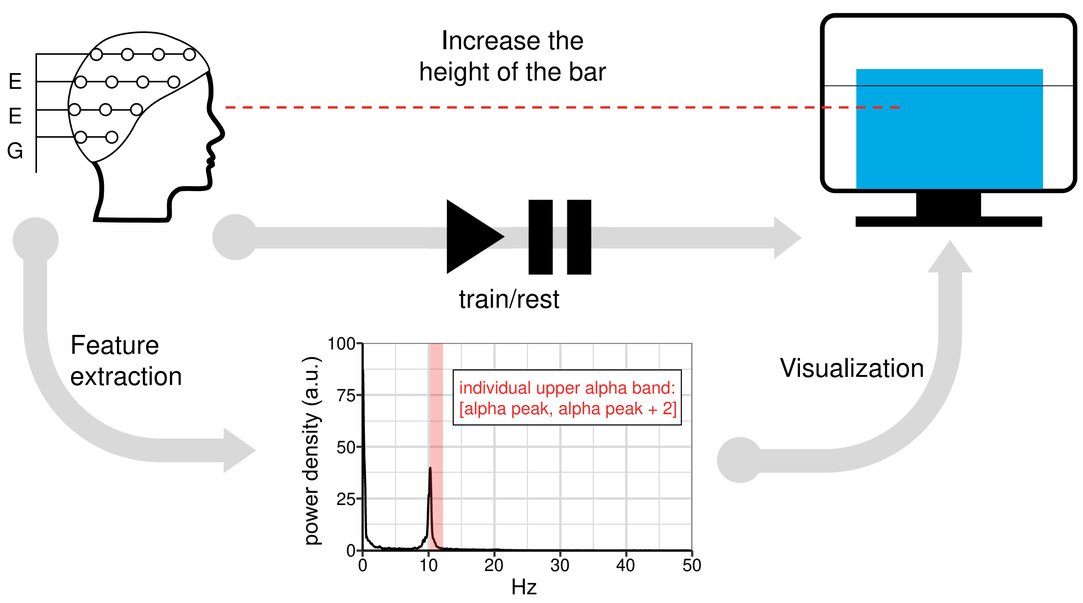
Introduction

Neurofeedback (NF) refers to the iterative process in which individuals effectively learn to regulate their brain activity. Previous studies have demonstrated its efficacy in improving cognitive performance [1]. However, standardized neurofeedback protocols have revealed large inter-individual variations in learning rates [2]. To account for these variations, personalized training protocols are required. One approach is allowing participants to train on their own pace. Recent studies suggests that participants profit from self-paced training [3]. In this study, we investigated the effect of pacing in the context of neurofeedback on cognitive performance.

Neurofeedback procedure



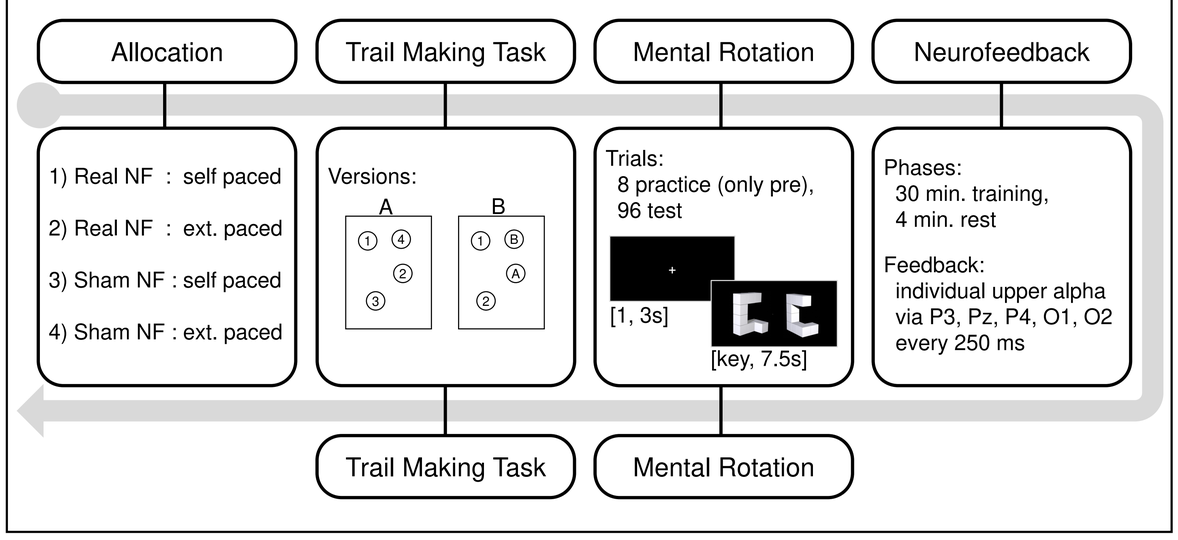
Hypotheses:

1. Brain activity increase: real > sham neurofeedback
2. Neural correlates: real > sham neurofeedback
3. Cognitive performance increase: self-paced > external-pacing

Methods

The study followed a randomized, double-blind and sham controlled design to investigate the effect of neurofeedback (real, sham), pacing (self, external) and their interaction. We allocated 64 students on a 2:1 basis to either real or sham neurofeedback and subsequently on a 1:1 basis to either self- or external-pacing.

Study procedure



For electrophysiological data acquisition we used a BrainAmp DC amplifier (Brain Products) with a 32 channel easycap (10/20 system). We kept the impedance of all electrodes below 20 kΩ throughout the experiment.

Outcome measures:

- Brain activity: individual upper alpha frequency power
- Cognitive performance: completion time for the trail making task [4], accuracy and response time in the mental rotation task [5]

Results

- Brain activity increased in the real NF condition nearly twice as much as during sham NF (Fig. 1)
- The more participants increased their brain activity during real NF, the more they improved their cognitive performance (Fig. 2)
- Cognitive performance increases were larger in the self- than in the externally-paced training (Fig. 3)

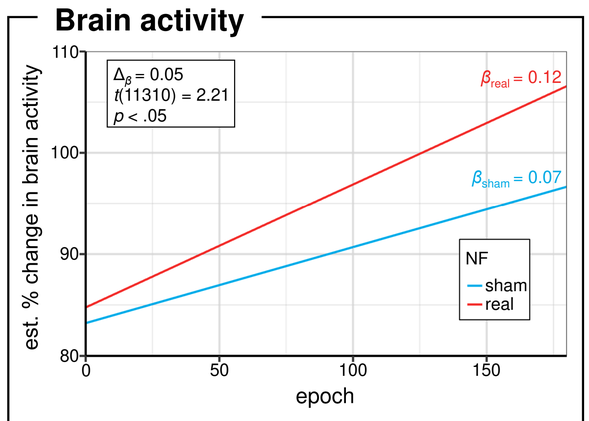


Fig. 1. Estimated percentage change in individual upper alpha power compared to baseline power between neurofeedback (NF) conditions. Parameters were estimated in an AR(1) linear mixed model including NF condition, epoch and their interaction as fixed effects and participant as a random intercept.

Neural correlates

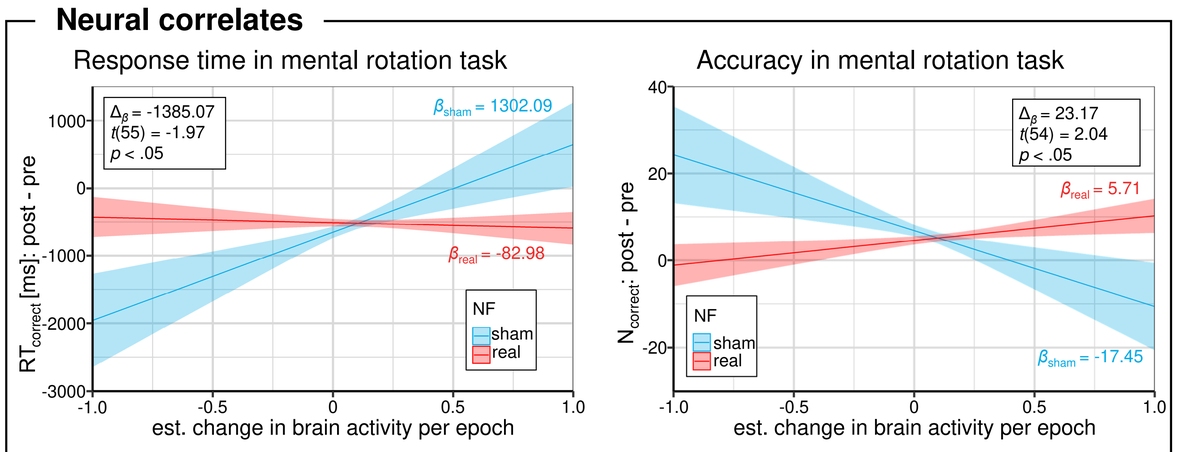


Fig. 2. Ribbons indicate ± 1 standard error of regression coefficients. To evaluate neural correlates, we estimated linear models including the increase in individual upper alpha power, neurofeedback (NF) conditions and their interaction as predictors.

Cognitive Performance

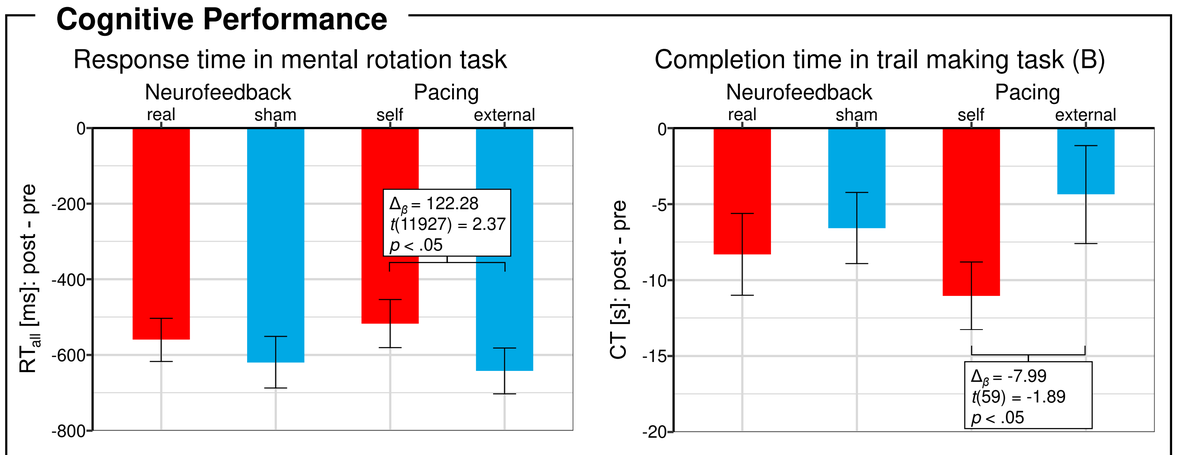


Fig. 3. Error bars indicate ± 1 standard error of the mean. To test our hypotheses, we estimated linear mixed models including neurofeedback, pacing, time point and their interaction as fixed effects and participant as a random intercept.

Discussion

- Previous studies classified participants by their ability to increase brain activity either as responder or as non-responder. Here we expanded this binary approach by demonstrating the linear relationship between increases in brain activity and increases in cognitive performance.
- Varying effects of self-paced training on performance in a mental rotation task and trail making task are in line with previous research. Several studies have demonstrated greater increases in self-paced tasks [3].
- Future studies should investigate if an individually validated selection of the target frequency band increases model fits and the effects on cognitive performance.

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Fonds National de la Recherche Luxembourg

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