Intermittent Compared to Continuous Real-time fMRI Neurofeedback Boosts Control of Amygdala Activity

Anja Dietrich1, Lydia Hellrung2, Maurice Hollmann1, Burkhard Pfeifer3, Elisabeth Roggenhofer1, Christian Kalberlah4, Arno Willringer1,4, Annette Horstmann1-3

1Max Planck Institute for Human Cognitive and Brain Sciences, Leipzig; 2Department of System Neuroscience, TU Dresden; 3Leipzig University Medical Center, SB 10525; 4Leipzig University Medical Center, IB7 Adiposity Diseases; 5Clinic of Cognitive Neurology, University Hospital Leipzig; 6Mind & Brain Institute, Berlin School of Mind and Brain, Humboldt-University Berlin.

adietrich@cbmp.de hellerung@cbmp.de

Introduction

Real-time fMRI (rtfMRI) neurofeedback (NF) allows participants to dynamically self-regulate activation in several brain regions through the evaluation and adaptation of motor strategies [e.g., 1, 2, 3]. However, there are several technical challenges in the field of rtfMRI [4]. One outstanding issue is the timing of NF presentation to guarantee optimal performance.

In many studies NF was presented continuously [e.g., 1, 2, 5]. Although this kind of NF provides participants with a maximum of information, it might distract from the experimental task. Alternatively, no continuous NF delivery (delayed feedback) might have the advantage of a more naturalistic interaction. Nonetheless, ongoing research would need to be improved to self-regulate brain activity at least under some conditions [9].

Here, we compared self-regulation performance of amygdala activity via positive mood between participants receiving continuous or intermittent NF. In addition, we explored whether amygdala regulation could be trained without any NF. Our results showed that intermittent neurofeedback boosts learning to control amygdala activity.

Methods

1 RI-fMRI and NF setup

MR data acquisition:
- EPI sequence on Siemens 3T VERIO: TR = 2 s, TE = 25 ms, matrix size=64 x 64 voxel, bandwidth = 1953 Hz, flip angle = 90°, voxel size 3 x 3 x 2.6 mm3, AC/PC aligned.

Online data analysis/Explorer:
- Feedback signal averaged/BOLD signal of ROI (CON: mean of 3 volumes, INT: mean of preceding block).

2 Training Sessions

Experimental paradigm:
- Task: generate a positive mood by positive memories or creation of original positive feelings.
- Sessions: Practice, 3 x Training Transfer (same task, no NF).
- Continuous NF (CON, n=16): Feedback update after each trial.
- Intermittent NF (INT, n=18): Feedback update after each block (Happy, Count).
- No feedback group (NFG, n=8): NF thermometer visible, but inactive, no feedback presentation.

Success of training:
Self-regulated amygdala activation progressively increased across the experiment in the feedback groups (linear trend; CON: F(1), 14=0.324, p=0.509; INT: F(1),16=2.7.14, p=0.045), but not the control group. Therefore, we considered the group without NF presentation (NFG) not to learn self-regulation of the amygdala. Due to the linear trend, both NF groups, on the other hand, are assumed to have learned amygdala regulation by the help of NF.

Comparison of time courses:
The averaged time courses over all subjects from the different groups show that participants who received intermittent feedback could follow the feedback instructions most precise (correlation coefficients for INT: r = 0.45, p < 0.001; CON: r = 0.13, p < 0.03; NFG: r = 0.21, p < 0.12).

Discussion

This study showed that NF was necessary to learn self-regulation amygdala activity. Moreover, although both NF groups learned to regulate amygdala activation, the group receiving intermittent NF outperformed the continuous NF group.

As continuous feedback is updated after each acquired volume, it provides participants with a maximum of information. Johnson et al. (2012) also mentioned that continuous feedback may induce greater interest or engagement in the task and ensures high attention. Nevertheless, there might be some constraints inhibiting participants’ learning.

Participants have to associate feedback to mental events that are often complex and difficult to interpret (character of the hemodynamic response) while simultaneously evaluating the feedback and still engaging in the experimental paradigm. In the end, this might distract from the task.

Although in intermittent paradigms the NF signal is averaged over longer periods, a reduction of the aforementioned distracting factors probably outweighs this disadvantage. That’s why we recommend usage of intermittent NF over continuous NF for paradigms where subjects know about the strategy to be used. As rtfMRI experiments are per se rather exhausting, less distracting NF probably helps to improve performance in future NF tasks.

Results

Fig. 4: Linear trend analysis of the 4 experimental runs. Depicted are the individual values of the 3 training runs as well as the transfer run of each group (CON: continuous feedback; INT: intermittent feedback; NFG: no NF).

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Comparison of different kinds of neurofeedback (CON vs. INT): Repeated measures ANOVA revealed a significant main effect of run (F(2),9=10.427, p=0.003) and group (F(1),9=5.202, p=0.01). Due to the group effect, we assume the NF groups to differ their performance over the course of the whole experiment. More specifically, participants receiving intermittent NF outperformed those receiving continuous NF.

References


Fig. 5: Averaged time courses for groups. Depicted are the averaged timelocous for the groups 3rd training run.

Fig. 6: fMRI BOLD signal change (Happyness.Count) of the left amygdala (mean ±sd). Depicted are the 3 training groups as well as the transfer run of the two NF groups (CON: continuous feedback, INT: intermittent feedback).