Perfusion changes associated with real-time fMRI neurofeedback training targeting motor cortex

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Purpose: Neurofeedback based on real-time functional magnetic resonance imaging (rt-fMRI) trains subjects to regulate localized brain activity. [1] The ability of subjects to learn to volitionally control localized brain activity within motor cortex may have clinical implications for motor rehabilitation. Current studies have investigated brain activities as measured by changes in blood oxygen level dependent (BOLD) signal, which is determined by various coupling factors such as local cerebral blood flow (CBF) and oxygen consumption rate by surrounding tissues. To further understand the underlying mechanism of neuofeedback associated BOLD signal changes, this preliminary study focused on voxel-wise comparison of CBF changes within the whole brain before and after neurofeedback training targeting motor cortex.

Methods: The study was approved by the local ethical committee and written informed consent was obtained from all the participants. Six healthy right-handed volunteers (aged 25.3±1.4 years) were recruited with no previous experience in fMRI neurofeedback. Similar to the experimental design by deCharms and his colleagues, [2] neurofeedback scans were conducted continuously on five days using a 3T MR750 scanner (GE Healthcare, Milwaukee, WI) with an 8-channel phase array head coil. Two runs were performed each day and each run consisted of five rest/increase cycles. Each cycle consisted of a 30-s rest block, followed by a 60-s increase block, during which the participants were instructed to increase the activation of the left motor cortex using the finger tapping imagery task for the dominant right hand, followed by a 60-s decrease block (Fig. 1). Real-time analysis was performed using the Turbo BrainVoyager (Brain Innovation BV, Maastricht, The Netherlands) and a visual representation of BOLD signal changes within the motor cortex fed back to the subject in the scanner in real time. Whole brain perfusion images were acquired before and after neurofeedback training on separate days using the pulsed continuous arterial spin labeling (pCASL) technique (TR/TE 1350/5 ms, flip angle 155°, labeling duration 1.5 s, post label delay 1.5 s, matrix =128x128, FOV 24 cm, thickness/gap 4/0 mm). Quantitative CBF maps were calculated with the vender provided Functool. Voxel-based analysis was performed using SPM8, followed by the paired T test to reveal pre- to post-training perfusion changes. The AlphaSim program implemented in AFNI was used for multiple comparison correction ($p<0.05$).

Results: Fig. 1 shows a representative BOLD signal pattern to demonstrate the self-regulation of the brain activity within the motor cortex to match the experimental design. Pre- to post-training comparison revealed significantly increased CBF in the left motor and somatosensory cortex, superior temporal gyrus, insula and the visual cortex but significantly decreased CBF in the right anterior dorsolateral prefrontal cortex (DLPFC) (Fig. 2).
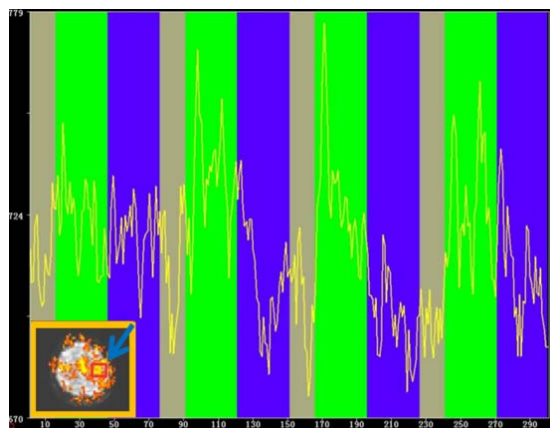

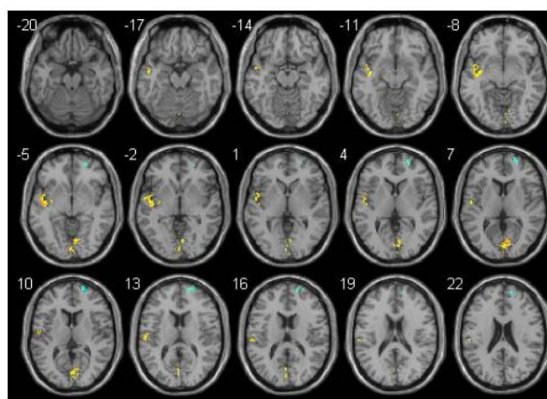Fig. 1. Representative BOLD signal pattern within motor cortex during the neurofeedback scan

Fig. 2. Comparison of CBF changes before and after neurofeedback training (Yellow: increase; Blue: decrease; corrected $p<0.05$)

Discussion and Conclusion: In this preliminary study, we found increased CBF in the left motor and somatosensory cortex as well as the visual cortex but decreased CBF in the right anterior DLPFC associated with the training using the right-hand motor imagery task, which might provide interesting insight into the mechanism of neurofeedback training. More subjects are required for further study.

References:

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