Self-regulation of Amygdala Activation with Real-Time fMRI Neurofeedback

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INTRODUCTION: Real-time functional magnetic resonance imaging (rtfMRI), in which fMRI data processing and display keep up with hardware acquisition [1], has made it possible to provide real-time neurofeedback, allowing a person to view and regulate the fMRI signal from his/her own brain [2]. Here we explore the feasibility of rtfMRI neurofeedback training of BOLD responses of the amygdala in healthy human subjects. The amygdala plays a crucial role in emotional processing and is involved in a broad spectrum of emotions from happiness to fear [3]. Major psychiatric disorders, such as schizophrenia, depression, and bipolar disorder, are accompanied by significant changes in amygdala activity [4]. For this reason, the application of rtfMRI neurofeedback to regulate amygdala activation may have important therapeutic value in psychiatry.

METHODS: The experiments were performed on General Electric Discovery MR750 3T MRI scanner with the standard 8-channel head coil array. Gradient echo EPI sequence with FOV/slice=240/2.9mm, TR/TE=2000/30ms, SENSE=2, flip=90°, 34 axial slices, was employed for fMRI. T1-weighted MPRAE sequence was used for anatomical reference and to define ROIs. Neurofeedback was implemented using a custom real-time fMRI system [5] utilizing AFNI real-time features and a custom GUI software. The study included 21 male participants who underwent comprehensive screening and qualified as healthy controls. For each subject, three spherical ROIs (7 mm radius in Talairach space) were centered, respectively, at the left and right amygdala (Fig. 1), and the horizontal segment of intraparietal sulcus (HIPS) region. An average fMRI signal from the target ROI was presented as a red bar (Fig. 1), which was updated every 2 s. Eleven subjects took part in experiments with real rtfMRI neurofeedback (target ROI: left amygdala). For the other 10 subjects, sham neurofeedback was used (target ROI: HIPS region). The experiment included six 9 min runs. Each run (except the Rest) consisted of 40 s long blocks with Rest, Happy, and Count conditions (Fig. 1). For the Happy condition, the subject inside the scanner was asked to feel happy by evoking happy memories so as to raise the level of the red bar displayed on the screen. The target level (blue bar) was raised from run to run. For the Count condition, the subject was asked to count back starting from 100 by subtracting a given number. No neurofeedback was provided (no bars displayed) during the Rest and Count conditions, and during the entire Transfer run.

RESULTS: The fMRI activation levels during each Happy condition were measured in real time relative to the baseline obtained by averaging fMRI signal for the preceding Rest block. At the post-processing stage, the baseline was obtained by linear interpolation of fMRI signals measured during the Rest blocks before and after a given Happy block (Fig. 1). Fig. 2 shows the activation levels for Happy conditions averaged for each run and across all subjects. Steady increase in the left amygdala activation during the Happy condition (with respect to the Rest condition) across all runs with real neurofeedback is observed. The results for the right amygdala (not shown) exhibit a similar trend, but the training effect is less pronounced.

CONCLUSION: Our results demonstrate that healthy subjects can learn to self-regulate their amygdala activation by performing emotional tasks with rtfMRI neurofeedback. This effect was predominantly observed in the left amygdala, compatible with evidence that the response to happy face stimuli presented below the level of conscious awareness is associated with amygdala activation that is lateralized [6]. This proof-of-principle study suggests possible applications of rtfMRI neurofeedback training in treatment of patients with neuropsychiatric disorders.