The Use of Neurofeedback with Real-Time Functional MRI to Suppress Physiological Noise.

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INTRODUCTION: Neurofeedback refers to experiments and therapeutic techniques that present subjects with real-time information about their own measured signal, such as brain activity measured with functional magnetic resonance imaging (fMRI). The most extended form of neurofeedback is ECG-Neurofeedback, which has been reported to be successful for clinical applications [1,2]. However, one important limitation of ECG-Neurofeedback is low spatial resolution. Real-time fMRI (rtfMRI) was introduced more than a decade ago [3] but, recent rapid advances in MRI signal reception and detection hardware (multi-channel detectors, better RF coils, faster imaging) as well as computer technologies (increases in image reconstruction speed) resulted in wider implementation of the real-time fMRI [4]. The neurofeedback techniques based on rtfMRI offer excellent spatial resolution and the ability to feedback activity from specific brain structures. Using rtfMRI-Neurofeedback, experimenters have already proven that subjects can self-regulate: pain perception [5], activation on areas such as the hand motor area [6], or the amygdala [7].

In the present study, we employed rtfMRI neurofeedback to investigate whether healthy subjects can learn to self-regulate the variability of the fMRI response in areas affected by high levels of physiological noise [8]. In particular, subjects were asked to attempt to reduce the standard deviation (SDEV) of the fMRI signal in the ventricles and in the posterior sinus. We hypothesized that learning to self-control the variability of the fMRI signal in these extra-cortical areas would be accompanied by increased fMRI time series temporal signal to noise ratio (TSNR=mean voxel time course signal/time course standard deviation [8]) in both white (WM) and gray (GM) matter compartments.

MATERIAL and METHODS: MRI Imaging: Six subjects (3 males/3 females) were scanned in a 3T General Electric HDx MRI Scanner equipped with home made rtfMRI system. Sixteen-element receive-only aluminum array (Nova Medical Inc) and Gradient Echo single shot EPI were used. Physiological noise localizer parameters (EPI, TR/TE=400/27ms, FA=35°, FOV/slice=240/44mm, matrix=64x64, #Slices=7, #Volumes=400). All other functional runs (EPI, TR/TE=2000/30ms, FA=90°, FOV/slice=240/44mm, matrix=64x64, #Slices=20, #Volumes=140, first 4 volumes were not used in data analysis to ensure fMRI signal steady state). Neurofeedback Display: Figure 1A shows ROIs used. Two dynamic bars (Figure 1B) left bar sinus ROI, right time course successful for clinical applications [1,2]. However, one important impo technologies (increases in spatial resolution) was introduced more than a decade ago [3] but, recent rapid advances in technologies (increases in image reconstruction speed) resulted in wider implementation of the real-time fMRI [4]. The neurofeedback techniques based on rtfMRI offer excellent spatial resolution and the ability to feedback activity from specific brain structures. Using rtfMRI-Neurofeedback, experimenters have already proven that subjects can self-regulate: pain perception [5], activation on areas such as the hand motor area [6], or the amygdala [7].

In the present study, we employed rtfMRI neurofeedback to investigate whether healthy subjects can learn to self-regulate the variability of the fMRI response in areas affected by high levels of physiological noise [8]. In particular, subjects were asked to attempt to reduce the standard deviation (SDEV) of the fMRI signal in the ventricles and in the posterior sinus. We hypothesized that learning to self-control the variability of the fMRI signal in these extra-cortical areas would be accompanied by increased fMRI time series temporal signal to noise ratio (TSNR=mean voxel time course signal/time course standard deviation [8]) in both white (WM) and gray (GM) matter compartments.

RESULTS and CONCLUSIONS: All except one (subject S BJ2) subjects were able to self-regulate the variability of the fMRI signal in the selected ROIs. We observed a substantial variability across subjects in the amount of control achieved. Five subjects showed significant reduction (p=0.013) of SDEV in the ventricles, and four subjects (p=0.002) in the posterior sinus (mean+/−sd=(−30.8+/−12.5)% and (−37.0+/−16.7)%, respectively). For the five subjects who were able to decrease variability in any of the ROIs, the TSNR associated with after-training runs is significantly higher than for pre-training runs in both white (p=0.028) and gray matter (p=0.029) compartments (Figure 2A and 2B, respectively). Mean TSNR percentage increases from five subjects (mean+/−sd) for GM and WM were: (35+/−24)%, (23+/−16)%, respectively. These results show: (1) that subjects can actively reduce SDEV of the fMRI signal in the ventricles and the posterior sinus using fMRI neurofeedback; and (2) such SDEV decrease is accompanied by a significant increase of fMRI TSNR in both white and gray matter compartments.