

# BRAIN CONTROL PERFORMANCE USING SINGLE- AND DUAL-ROI'S IN REAL-TIME fMRI WITH NEUROFEEDBACK

Jason G Parker<sup>1,2</sup>, Jonathan Sackett<sup>3</sup>, Phani Kidambi<sup>2</sup>, Lacey Sickinger<sup>1</sup>, and Cemil Kirbas<sup>1,4</sup>

<sup>1</sup>Innovation Center, Kettering Health Network, Kettering, OH - Ohio, United States, <sup>2</sup>Biomedical, Industrial, and Human Factors Engineering, Wright State University, Dayton, OH - Ohio, United States, <sup>3</sup>Siemens Medical Solutions USA, Malvern, PA, United States, <sup>4</sup>Psychiatry, Wright State University, Dayton, OH - Ohio, United States

**Purpose** Neurofeedback based on real-time image reconstruction and contrast quantification of fMRI volumes allows information on brain activity to be communicated to participants during acquisition at a rate equal to 1/TR (1,2). Typically these methods monitor a single region-of-interest (ROI) in the reconstructed volumes and display the signal modulation of that area using a visual presentation system that the participant can see. By enabling patients to modulate areas of the brain which are abnormally active, fMRI with neurofeedback has been shown to hold potential in treating a variety of disorders including tinnitus (3), severe pain (4), and depression (5). Despite these encouraging results, the extent by which humans can control brain function remains poorly understood. The purpose of this work was to determine if humans receiving neurofeedback on two brain regions simultaneously were less effective at learning brain control than those receiving feedback on a single region.

**Materials and Methods** *Subjects* Ten healthy right handed subjects (5 male, 5 female) were randomly assigned to two groups, with Group 1 undergoing single-ROI neurofeedback and Group 2 undergoing dual-ROI neurofeedback. *Equipment* A 1.5 Tesla MR scanner (Siemens MAGNETOM Avanto, Siemens, Erlangen, Germany) with an 8-channel birdcage head coil was used for all acquisitions. A video projection system (BrainLogics MRI Digital Projection System, Psychology Software Tools Inc., Sharpsburg, PA) was used for delivery of visual information to a mirror affixed to the top of the head coil. *Experimental Procedure* The experimental procedure required two separate visits on consecutive days, each of which used an identical neuroimaging procedure made up of four acquisitions. The first acquisition was a standard motor fMRI using a GRE sequence with a 64x64 element matrix, 24 slices, 4.5mm x 4.5mm x 5mm voxel size, 1mm slice gap, TR/TE = 2000/10ms, and flip angle = 90°. The motor task was an alternating finger tapping movement of the right hand, administered according to a boxcar paradigm made up of 24s rest and 24s task periods. In the second acquisition, a 3D anatomical MPRAGE sequence was then acquired with a 512x512 element matrix, 120 slices, 1mm x 1mm x 1mm voxel size, TR/TE = 500/15ms, and flip angle = 15°. Activation maps were calculated during the 3D anatomical acquisition using a custom software program that included motion correction (translational components only), spatial smoothing with a Gaussian convolution (FWHM = 6mm), and a temporal convolution (weights = {0.25,0.5,1,0,0.5,0.25}). The block design model was convolved with a pre-defined hemodynamic response function (HRF) and the General Linear Model was used to generate activation and deactivation maps. For ROI analysis, activation maps were thresholded to 50% of the maximum parameter estimate and deactivation maps were thresholded to 50% of the minimum (negative) parameter estimate. An ROI was drawn using a custom graphical user interface around the activation cluster in the left primary motor cortex (M1) of each subject. For subjects in Group 1, a second ROI was drawn around the entire frontal lobe and used for sham feedback. For subjects in Group 2, an ROI was drawn around the most pronounced deactivation cluster in the right sensorimotor cortex or subcortical regions. The third acquisition was a practice session which used a sequence identical to the fMRI acquisition but presented the subjects with real-time information on the selected ROI's as shown in Figure 1. The top graph represented the activation cluster (M1) and the bottom graph represented the sham (Group 1) or deactivation cluster (Group 2). This practice session lasted 96s (48 volumes) and allowed the subjects to familiarize with the neurofeedback procedure and hemodynamic response mechanisms by physically moving their fingers during the task periods. The fourth acquisition was identical to the third but lasted 6m24s (192 volumes) and required that the subjects did not move. Group 1 subjects were instructed to modulate the top graph only, raising it during task conditions and lowering it during rest conditions. Group 2 subjects were instructed to modulate both graphs by simultaneously raising the top graph and lowering the bottom graph during task conditions, and lowering the top graph and raising the bottom graph during rest conditions. *Data Analysis* The 192 volumes from the fourth acquisition were processed for each subject by applying the same preprocessing steps used in fMRI processing. The mean percentage change from baseline was calculated in the M1 ROI using a predefined HRF convolved with the boxcar paradigm for weighting. A two-group unpaired t-test was used to evaluate differences between the two groups at each visit as well as between visits.

**Results** The group results in terms of mean % signal change are shown in Table I. No significant differences in mean % signal change were found between Group 1 and Group 2 at either Visit 1 or Visit 2. Group 1 also did not change significantly between Visit 1 and Visit 2. Group 2 did decrease in performance between Visit 1 and Visit 2 ( $p = 0.07$ ), but again this effect was not considered significant. Results from a single subject in Group 2 are shown in Figure 2. The measured data are shown in blue and the boxcar design convolved with the HRF is shown in red. This subject demonstrated good control over M1 and deactivation mechanisms in the right sensorimotor cortex, with parameter estimates (after converting to t-statistics) of 13.5 and -12.1, respectively.

**Conclusion** No significant differences in brain control were found between single- and dual-ROI feedback methods. This finding may indicate humans can learn to control multiple brain regions at once without significant decreases in performance.

## Figures and References

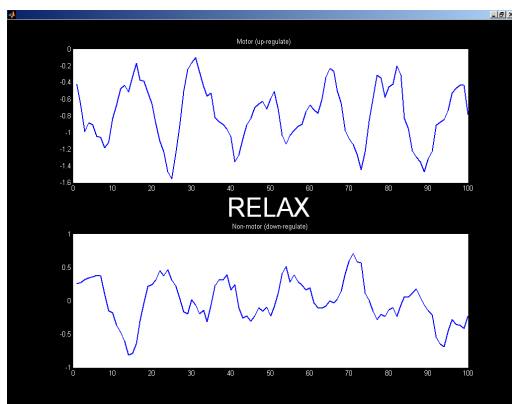


Figure 1 – Example visual display for Acquisitions 3 and 4.

Table I – Mean % change for the two groups at each visit

	Visit 1	Visit 2	p-value
Group 1	0.24 ± 0.17	0.25 ± 0.21	0.45
Group 2	0.31 ± 0.2	0.16 ± 0.09	0.07
p-value	0.34	0.26	

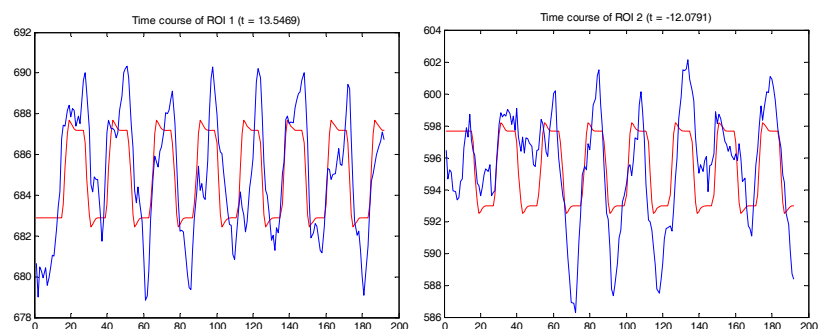


Figure 2 – Brain control over M1 (left) and sensorimotor (right) regions for a single subject. Measured data are shown in blue and the expected HRF is shown in red.

1. LaConte, S.M. NeuroImage, 56:440-454. 2010.
2. Hamilton, J.P., Glover, G.H., Hsu, J.J., et al. Human Brain Mapping, 32:22-31. 2011.
3. Haller, S., Birbaumer, N., Veit, R. Eur. Radiol. 20: 696-703. 2010.
4. deCharms, R. C. et al. Proc. Natl Acad. Sci. USA 102, 18626-18631. 2005.
5. Johnston, S., Linden, D.E.J., Healy, D., Goebel, R., Habes, I., Boehm, S.G. Cogn Affect Behav Neurosci, 11:44-51. 2011.