

Modulating Brain Activity via Multi-echo fMRI Neurofeedback

M. Chiew^{1,2}, A. Y. Kuo^{2,3}, and S. J. Graham^{1,2}

¹Rotman Research Institute, Toronto, ON, Canada, ²Medical Biophysics, University of Toronto, Toronto, ON, Canada, ³Sunnybrook Health Sciences Centre, Toronto, ON, Canada

Introduction

Functional magnetic resonance imaging (fMRI) is emerging as a modality that can support real time neurofeedback (NF), which is a therapeutic and neuro-rehabilitative research tool that enables individuals to modulate their brain activity through neurophysiological cues derived from real-time fMRI data. Possible applications include remediation of pain, mood disorders, and improvement of stroke recovery [1]. To date, fMRI NF experiments have relied on echo planar and spiral imaging acquisitions. Here, we continue developing a novel pulse sequence designed for this application [2], through a simple validation demonstration of NF involving the primary sensorimotor cortex (SMC).

Experiment

A prototype multi-echo (ME) fMRI sequence was implemented to acquire a 256-echo T2* decay curve per repetition time (TR=1s), for 32 coarse voxels (5x20x20 mm³) along a linear column. The sequence utilized very selective suppression (VSS) pulses for spatial saturation [2] and “flyback” readout gradients for ME sampling [2]. Prescription occurred across both left and right SMCs based on a T1-weighted structural image and a functional localizer (spiral in/out) with bilateral hand clenching. Raw data was received roughly 375ms after acquisition and processed through an optimized ME weighting scheme [3] according to expected theoretical BOLD contrast. All experiments were run at 1.5 T on a GE Signa MRI system (16 channel HDX, GE Healthcare, Milwaukee, USA) using the quadrature birdcage head coil.

The feedback experiment was a block design in which participants were to activate repeatedly a specific target SMC (either right or left) that was not divulged to them. Rather, they were asked to modulate their brain activity by performing a clenching task with their right or left hand based on the feedback signal. Clenching blocks were interspersed with rest blocks with no motor activity. All blocks were 20 s in duration, and each experiment consisted of 5 independently analyzed epochs (rest plus clench block). Feedback was presented visually on a display screen during rest blocks as a colour bar with positive feedback (correct brain activity) shown in green and negative feedback (incorrect brain activity) shown in red. Four healthy right handed adults (3 male, mean age 33.5 years, range 25 - 41) were studied with approval from the Research Ethics Board at Sunnybrook Hospital.

$$L = \left[\frac{C_L}{R_L} - \frac{C_R}{R_R} \right] * P$$

Equation 1 – Laterality feedback metric calculation

Equation 1 shows the calculation of the laterality index (L) feedback signal displayed to participants, where C and R denote the mean amplitudes during the clench and rest blocks respectively, and the subscripts denote left or right. P takes on the values +1 when target SMC is left, and -1 when the target is right. On receiving feedback, the participant judged how to modulate their brain activity by the appropriate left or right motor behaviour.

Results

For 18 repeated experiments across the 4 participants, there was a 100% success rate in matching the target brain activity, and in 16/18 scans the feedback was robust enough for the matching to occur after only one epoch. Figure 1 shows a representative experiment.

Discussion

The results demonstrate this novel pulse sequence is suitable for performing NF experiments. In the future, the sequence can be used to address important issues such as the minimum time interval over which brain activity and behaviour can be modified using fMRI NF, and the potential role of NF in neuro-rehabilitation.

References

1. deCharms RC., *Nat Rev Neurosci.* **9**, 720-729 (2008)
2. Kuo, AY et al., *ISMRM*, Toronto (2008)
3. Posse S et al., *Magn Reson Med.* **42**, 87-97 (1999)
4. Caria A et al., *NeuroImage* **35**, 1238-1246 (2007)

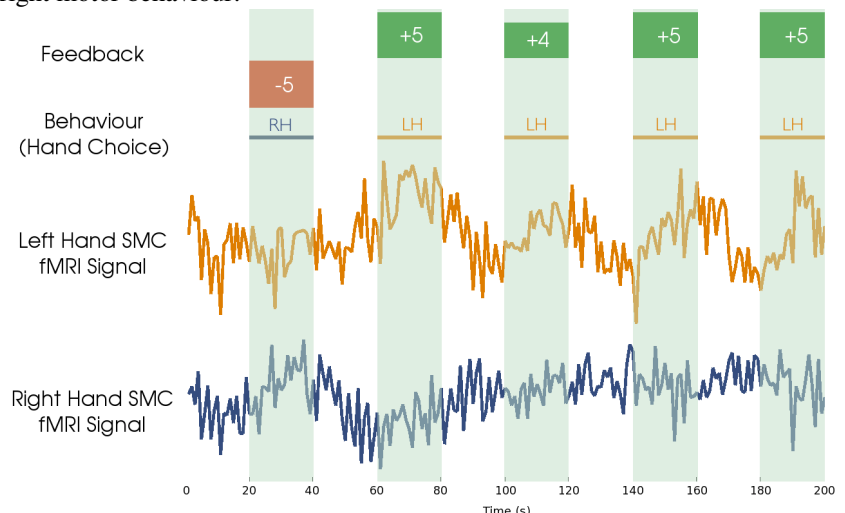


Figure 1 – Summary of Experiment #2 from participant #2. The target SMC for this experiment was Left Hand.