

Development of Simulator Training to Reduce Head Motion Artifact in fMRI

S. Ranieri^{1,2}, S. Boe³, F. Tam¹, L. Gordon⁴, T. Dawson¹, J. Ween⁵, W. McIlroy⁶, and S. J. Graham^{1,7}

¹Rotman Research Institute, Baycrest Centre for Geriatric Care, Toronto, ON, Canada, ²Institute of Biomaterials and Biomedical Engineering, University of Toronto, Toronto, ON, Canada, ³Toronto Rehabilitation Institute, Toronto, ON, Canada, ⁴Faculty of Health Sciences, Queen's University, Kingston, ON, Canada, ⁵Kunitz-Lunenfeld Applied Research Unit, Brain Health Complex, Toronto, ON, Canada, ⁶Department of Kinesiology, Faculty of Applied Health Sciences, University of Waterloo, Waterloo, ON, Canada, ⁷Department of Medical Biophysics, University of Toronto, Toronto, ON, Canada

Purpose

There has been a longstanding need to develop techniques that improve data quality in functional magnetic resonance imaging (fMRI) by suppressing motion artifact. Head motion exceeding a few millimetres remains problematic and high interest participants including the elderly, patients with neurological disorders, and especially stroke patients often exceed this threshold, leading to unacceptable artifact levels and fMRI data that must be discarded. Here, a new technique is described that attempts to reduce participant head motion through feedback training in an fMRI simulator, prior to scanning.

Methods

An MRI simulator (Psychology Software Tools Inc.) coupled with a 3D tracking system (miniBird, Ascension Technologies Corp.) was used for the training procedure. Participants underwent training using a pressure bulb interface programmed in Labview (National Instruments Inc.) that required unilateral hand gripping to control an on-screen animation involving a cursor and a vertical target. The goal was to grip and raise the cursor into the target and hold for 4 s. Tasks were performed in an event-related design spanning 130 s with 4 s events and 8 s rest periods, while motion data were collected from a sensor fixed to the participant's forehead. Motion data from the first two runs (right and left hand) were analyzed to determine whether the participant was likely to benefit from training. Maximum vector motion was evaluated, and vector motion data were correlated with event-related task timing as a square wave convolved with a canonical hemodynamic response function (Cohen, 1997). This latter calculation quantified the severity of task correlated motion with respect to BOLD fMRI artifact. The threshold used for training eligibility was movement > 1 mm during a run and task correlation coefficient $r > 0.30$ ($p < 0.05$). Participants performing below these thresholds were judged capable of remaining sufficiently still in fMRI studies.

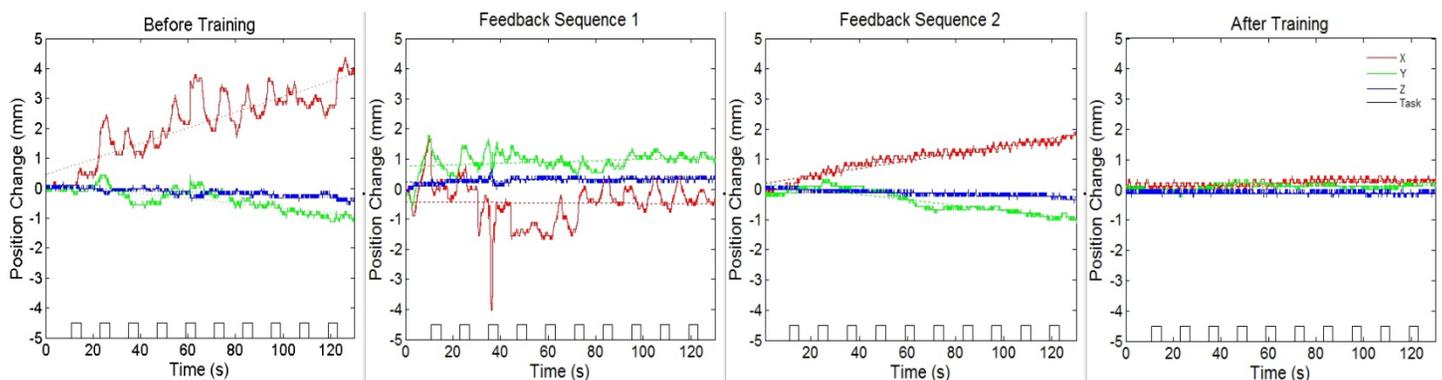
Eligible participants were trained over four additional 130 s runs. In addition to before and after training runs, the two middle runs provided head motion visual feedback from the tracking system (streaming line graph of X (inferior-superior), Y (right-left) and Z (anterior-posterior) displacement versus time, Fig. 1). Training runs were performed using the stroke participant's weakest hand. Event timing was queued by tapping the participant's unaffected leg and the participant was instructed to squeeze the bulb with pressure similar to the previous runs, because visual stimuli for the gripping task were not shown during motion feedback. The participants were told to keep their head as still as possible during each of the four runs. After simulator training, the participants underwent multislice axial oblique echo planar fMRI using a research dedicated 3T system (TIM Trio, Siemens Medical Solutions Inc., vb15 software) with a 12-channel head coil.

Results

Three stroke participants (ages 39 – 72, with mild to moderate hemiparesis) were evaluated using the described training protocol. Each initially presented with excessive head motion and showed substantially decreased head motion after training (representative data from one participant shown in Fig. 1). Participants had most difficulty limiting nodding motion in the X direction, which typically leads to through-plane motion in fMRI. Some of the motion was clearly task-correlated, characteristic of muscle co-contraction that occurs in stroke pathology. Improvement was measured by the total vector motion of each participant (1-3) before and after training: (1) 11.25 +/- 0.13 mm before, 0.83 +/- 0.13 mm after; (2) 1.63 +/- 0.13 mm before, 0.67 +/- 0.13 mm after; (3) 4.47 +/- 0.13 mm before, 0.51 +/- 0.13 mm after. Similar effects were observed for the correlation coefficient results for the test waveform and collected data ($p < 0.05$): (1) 0.37 before, 0.27 after; (2) 0.30 before, 0.24 after; (3) 0.43 before, 0.15 after.

These data show significant improvement in head motion for stroke participants after simulator training, such that motion was reduced below 1 mm and $r < 0.3$. The data supports the use and further development of simulator training as a method to suppress head motion directly. In the future of this ongoing study, participant head motion in subsequent fMRI scans will be evaluated using AFNI (Cox, 1996) as well as external monitoring with infrared camera tracking (Tam, 2009). Future minor refinements to the training protocol will include auditory queues in place of tapping to reduce timing error and the potential for startle responses, and providing a target area representing +/- 1 mm of motion to the streaming motion feedback data to provide improved training context to the participant.

Figure 1 – Motion data from participant (3) displayed as X, Y, and Z displacement versus time. Task timing is shown as blocks along the time axis.



¹M.S. Cohen, *NeuroImage*, 6: 93-103, 1997. ²R.W. Cox, *Comput Biomed Res*, 29(3): 162-173, 1996. ³Tam et al, *Proc Intl Soc Magn Reson Med*, 17:1197, 2009.