Effect of Hand Feedback Visualization on Head Motion During fMRI of Neuropsychological Testing

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Introduction: Neuropsychological tests (NP) - behavioral tasks that very commonly involve handwriting and drawing - are widely used in the clinic to detect abnormal brain function. Functional magnetic resonance imaging (fMRI) may be useful in increasing the specificity of such tests [1]. However, performing complex pen-and-paper tests during fMRI involves engineering challenges. Previously, we developed an fMRI-compatible, computerized tablet system to address this issue [2]. However, the tablet did not include visual feedback of hand position (VFHP), a human factors component that may be important for fMRI of certain patient populations. Because the user is lying in the magnet bore, they cannot view their hand during this process and must rely on their sense of proprioception, associated with muscle movements. Visual feedback of hand position while performing complex hand movements is extremely desirable, reducing learning requirements and improving motor performance, especially in patients with neurological impairment [3,4]. A real-time system was thus developed to provide VFHP and integrated with the tablet in an augmented reality display. Attempting to visualize the hand position in the absence of VFHP during performing such complex motor movements may induce subject's head motion, potentially resulting in false activations. The purpose of the present work is to assess the influence of VFHP on head motion and the associated brain activity involving a set of handwriting tasks in young healthy adults. It is hypothesized that using the tablet with VFHP to perform the handwriting tasks leads to less head motion and reduced false activations in healthy young adults, compared to using the tablet without visual feedback of hand position (without VFHP).

Method: An fMRI-compatible video camera (MRC Instruments) was mounted on the tablet to record color video of hand position during handwriting task performance. A widely used skin color detection algorithm was used to extract (segment) the hand and stylus from the tablet background colors in each video frame [5]. The segmented hand and stylus were then superimposed in real time with computerized NP test presentation and stylus responses, on a computer screen at 30 Hz frame rate (33 ms maximum time lag). The tablet computer was programmed to administer the handwriting tasks following an approach similar to that of Werner et al [6]. The tasks involved a) copying a grocery list; b) copying phone numbers, and c) copying a paragraph. These tasks are shown to be sensitive to motor impairment in patients with early probable Alzheimer's Disease (AD). For each task, a rest interval of 10 s was included between each trial, consisting of a white screen with a central black fixation cross. Each task was repeated four times. Eight young healthy right-handed adults performed fMRI of handwriting tasks in a 3T GE MR750 system with 8 channel head coil, and spiral in-out k-space acquisition. Four subjects performed handwriting with VFHP, and another four performed handwriting without VFHP. For each run, six degree of freedom motion parameters were extracted using rigid body motion registration. Temporal standard deviation (tSD) of motion parameters were calculated for each subject in Matlab (MathWork Inc.). Difference in tSD of motion parameter values for the "with VFHP" and "without VFHP" conditions across the groups were then assessed statistically using two-sample t-test. In addition, a conventional general linear (GLM) model using a set of low-frequency polynomials and motion parameters as regressors of the design matrix were performed on the fMRI data of each subject before motion correction. The resulting brain maps were compared between the two groups by random-effect group analysis. Group brain activation maps for the contrast between "with VFHP" and "without VFHP" conditions were obtained using "Analysis of Functional Neuroimaging" (AFNI) freeware [7] using false discovery rate (FDR) < 0.05.

Results: The two-sample t-test results showed statistically significant ($p<0.05$) reduction in the tSD of motion parameters for the "with VFHP" compared to "without VFHP", with dominant effect in the pitch direction (i.e. nodding motion). The fMRI results for the two groups of individuals with and without VFHP are shown in Fig.1. The color overlay depicts voxels that are significantly correlated ($p<0.05$) with the motion parameters during performance of the handwriting tasks. Compared to the "with VFHP" condition, "without VFHP" exhibits an increase in the number of motion-correlated voxels, especially in brainstem, and frontal edges of the brain. Fig.2 illustrates the group contrast activation maps for "without VFHP" minus "with VFHP". The contrast maps include motor planning regions associated with the difference between the two conditions, e.g., arm-centered motor planning regions and premotor cortex. In addition, there are active regions in brainstem and edges of the frontal lobe that match those observed in Fig.2 and are significantly correlated with the motion parameters. This suggests that these regions may be falsely active due to the excess head motion in the group of subjects who performed the task without VFHP compared to those who performed the task with VFHP.

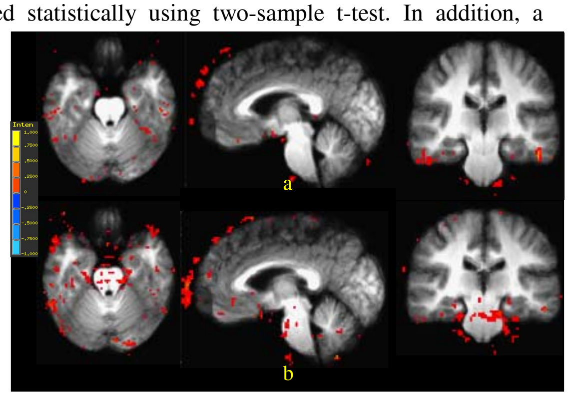

Fig.1: Brain maps of significantly motion correlated voxels , a) with VFHP; b) without VFHP

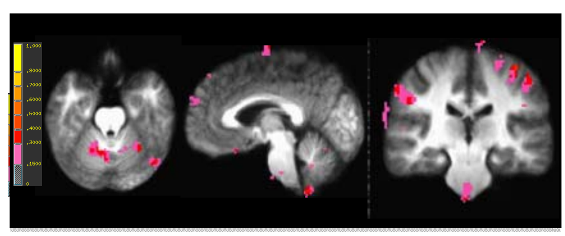

Fig.2: Contrast brain activation maps (without VFHP – with VFHP)

Discussion and Conclusion: These results imply that use of visual feedback of the hand position reduces head motion and associated motion-induced spurious signal changes during performing the handwriting task. This suggests that use of the new fMRI compatible tablet integrated with VFHP produces more naturalistic behavioural performance that facilitates improved fMRI acquisition. These observations are preliminary given the small sample size, and additional fMRI of subjects is ongoing.

References: [1] Lezak et al., Neuropsychological assessment (4th ed.) 2004; [2] Tam et al. Hum Brain Mapp 2011 32: 240–248; [3] Ghilardi et al., Neurosci Lett. 1999 Jan 22;260(1):45-8; [4] Ghilardi et al., Brain Res. 2000 Sep 8;876(1-2):112-23.; [5] J. Kovac et al., in EUROCON 2003; [6] P. Werner et al., *The Journals of Gerontology,* 2006; [7] Cox R.W, Comput Biomed Res. 1996.