Head-Motion Suppression Using Real-Time Feedback of Motion Curves and Its Effects on Performance of Task in FMRI

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Introduction

Subject head motion is a common problem experienced in fMRI experiments. Although various methods such as using supporting pillows or compression pads are applied, the problem is still common. This is especially true for the patient-based studies in which the subjects move substantially due to long time of scanning, unease from experimental procedure, blood drawing or drug injection during data acquisition. Real-time monitoring of the subject head motion parameters using on-line image registration has proved to be a very useful quality assurance tool [1]. If the estimated movements are too large, the subjects may be re-scanned immediately. However, the method is not effective enough for drug administration studies because it is generally impossible to re-administer drug and re-scan immediately. We propose a voluntary head motion suppression method in which subject head motion parameteric curves are fed back to the subjects in real time. In this way, the subjects will have a good indicator of their own head motion that may enhance their head motion control. However, such a voluntary motion control may serve as a secondary cognitive task and alter the response to the primary cognitive task or drug response. A real-time fMRI analysis system was developed for this purpose. The voluntary head motion suppression method was tested and the possible influence of watching head motion curves on the performance of tasks in fMRI study was investigated using an auditory N-BACK task.

Methods

The real-time fMRI analysis system was developed on a Siemens 3T Magnetom Allegra scanner. As shown in Fig. 1, the system hardware involves three computers, the HOST, the MRIR (MR Image Reconstruction) computer and a server (Brain3). The HOST and the MRIR are connected to one another in the internal network. The HOST is also linked to the external server via 100 MBs Ethernet connection. The system software involves an ICE (Image Calculation Environment) program that we developed for real-time image reconstruction & image transfer and the AFNI (Analysis of Functional NeuroImages) package [2] for real-time motion correction and functional analysis. The ICE program achieves the parallel processing of image reconstruction & image transfer with data acquisition. Upon reconstruction of one slice in the MRIR computer, the image will be sent using TCP/IP sockets to the server where AFNI waits for incoming data with its real-time plugin. After each 3D volume is complete, the estimated motion parameters are displayed in a continually updating graph on the monitor of the server. The graph is also simultaneously displayed on the screen in the scanner bore that subjects can watch during the ongoing scan. Due to parallel processing, the motion parameters calculation is finished within a TR and accurate real-time 3D registration and motion display are achieved. On-line activation analysis can be also performed with the system, although it is not used in this study.

An auditory N-BACK paradigm was used for this study. Auditory stimuli are presented in 30-s epochs to subjects via an air-conducted tube. Condition A is a rest period. During the epochs of 1-BACK (Condition B) and 2-BACK (Condition C), subjects listen to a series of 15 neutral words with an interstimulus interval of 2 s. Cycles of alternation between conditions are pseudorandomized within the 9 minute scan, e.g. ABCACBABCACBACBA. The N-BACK tasks are repeated in three scenarios with the subjects watching the real head motion curves (Real-Curve), watching the fake head motion curves (Fake-Curve) and without watching any curves (No-Curve). A head motion index is defined from the 6 motion parameters that the AFNI outputs, ΔA-P, ΔR-L, ΔI-S, Yaw, Pitch and Roll, i.e. $\sqrt{d_1^2+d_2^2+d_3^2+r_1^2\cdot\theta_1^2+r_2^2\cdot\theta_2^2+r_3^2\cdot\theta_3^2}$, where d_i and θ_i stand for the standard deviations of the three translational and the three rotational parameters from their initial values, respectively, and r_i stands for the mean rotational semi-radii around the three directions. The head motion index, the performance accuracy & reaction time, and the activation map are evaluated. The experiments were performed on healthy control subjects at our site. 37 sagittal slices were acquired using the 2D EPI-BOLD pulse sequences with TR/TE=2500/27 ms, matrix size = 64×64, FOV = 220 mm, slice thickness/gap = 4/0 mm, flip angle = 80º, bandwidth = 3552 Hz/pixel, measurement # = 212.

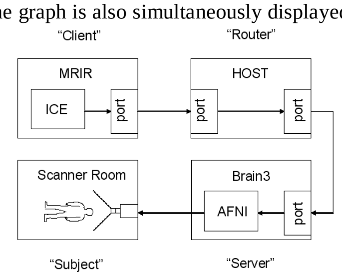

Fig. 1 Configuration of the real-time analysis system.

Results and Discussion

The mean head motion indexes under the three scenarios are shown in Fig. 2. A reduction in mean head motion due to watching the real motion curves was seen. The performance accuracy data are analyzed using a two-way ANOVA where the $F(2, 18)=1.02$, $P=0.381$. The same procedure is repeated for the reaction time data where the $F(2,18)=2.09$, $P=0.153$. No significant differences are found in the behavioral data between the three scenarios. The mean accuracy and reaction time of the 1-BACK and 2-BACK tasks are shown in Fig. 3. The group analyses of the functional MRI data are carried out off-line using the 3dANOVA2 of AFNI. Fig. 4 is the map of activation difference between No-Curve and Real-Curve with $p<0.005$. Differences in brain activation are seen in the lateral frontal and posterior parietal regions that are closely related to the working memory task. The feedback of motion curves in this study does influence brain activation in the N-BACK task, even no effects on behavior performance are observed. Therefore, improvements of the motion suppression method are necessary (e.g. displaying a composite motion index in a small portion of the screen instead of 6 motion curves in the full screen) to minimize the interference on the brain activation.

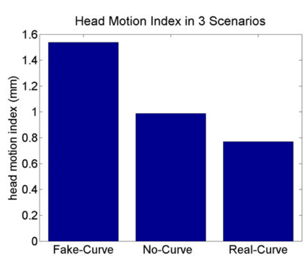

Fig.2 Mean head motion index.

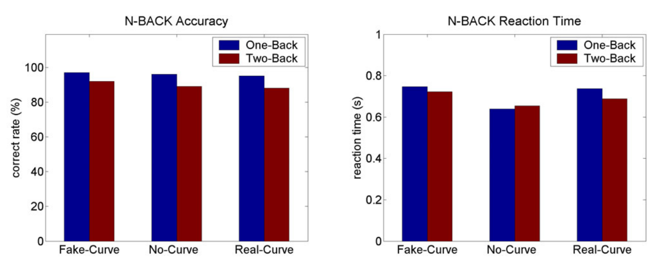

Fig.3 Mean accuracy and reaction time of the N-BACK tasks.

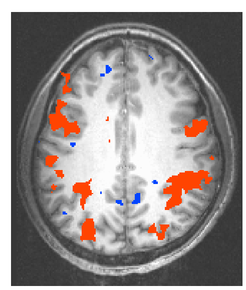

Fig.4. Map of activation difference between No-Curve and Real-Curve.

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References

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