SIMULTANEOUS MAPPING OF FUNCTIONAL CONNECTIVITY AND ACTIVATION USING REAL-TIME FMRI

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Introduction Functional connectivity has been defined by the temporal correlation between spatially remote neurophysiological events (Friston et. al., 1993). To date, conventional strategy for functional connectivity is usually performed after the whole fMRI data acquisition. Moreover, real-time monitoring is important to monitor fMRI data quality and subject's task performance, to get a rapid experimental result, to change fMRI paradigm, and eventually to watch one's own brain activation. The aim of this study is to develop real-time platform for functional connectivity and activation using real-time fMRI. We performed the motion fMRI experiments, and visualized the functional connectivity and activation for the ongoing paradigm using real-time processing.

Methods On the 3.0 Tesla MRI scanner (Siemens, Tim-Trio), real-time fMRI system was composed of four computers: a system management computer with Integrated Development Environment Application (IDEA) programs, a raw MR image reconstruction computer with Image Calculation Environment (ICE) programs, a real-time processing computer where we developed real-time connectivity and activation procedures, and a computer for presenting the fMRI task. Each computer was interconnected on an internal network via Gigabit Ethernet. fMRI scanning was performed for one right-handed adult volunteer using EPI sequences with TR=3,000 ms, TE=30 ms, Voxel=3.0×3.0×4.5 mm, Matrix=64×64×30. The subject was scanned with eye-closed resting state and right foot movement task during 3 minutes. After complete 3D volume reconstruction, subject's head motion was estimated in real-time by the rigid-body transformation providing three translational and three rotational parameters. These motion parameters were displayed in a real-time processing computer monitor, through which we could observe subject head motion. First, all EPI images were realigned to the first image of the session. Next, realigned EPI images were spatially normalized to Talairach space with statistical parametric mapping (SPM2). Online correlation coefficients as regional functional connectivity and task-related activations were calculated and simultaneously visualized for 116 brain regions defined by anatomical automatic labeling (AAL) map from MRICro.

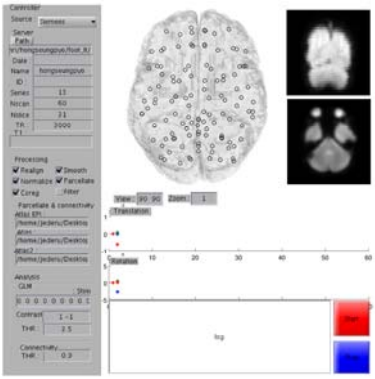

Fig. 1. MATLAB-based graphical user interface (GUI) for real-time processing.

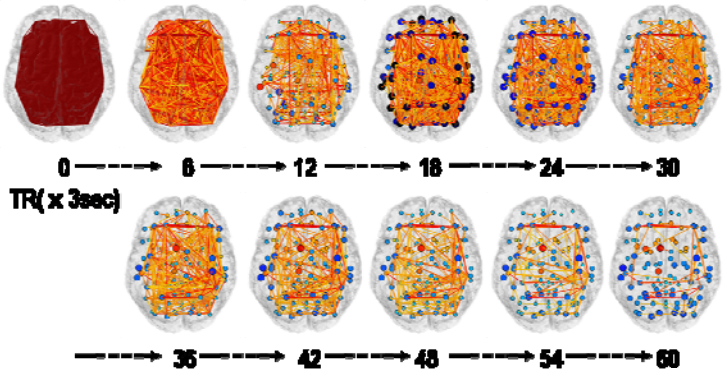

Fig. 2. Functional connectivity with regional correlation coefficients (line) and task-based activation (circle) on real-time monitoring.

First fMRI volume		Next fMRI volumes	
processing	time (sec)	processing	time (sec)
Init. of motion correction	10.2959	Motion correction	0.1044
Normalization	16.2871	Connectivity	0.0126
Connectivity	0.3472	Statistics	0.0043
Visualization	3.7346	Visualization	1.8585

Table 1 Mean computation time for real-time monitoring of functional connectivity and activation.

Results Fig. 1 shows the GUI implemented from MATLAB on a real-time computer, where 3D functional connectivity and activations, 2D fMRI data, and 3D translation/rotation graphs could be displayed. Fig. 2 shows the monitored real-time connectivity with functional coherences. The more EPI images were acquired, the more significant connectivity was detected in the motion-related areas. Table 1 shows the mean computation time for real-time processing on Intel Xeon 1.86G×8 Linux computer. Computation time to preprocess the first fMRI volume was about 30 seconds, usually acceptable for conventional fMRI paradigm with 20~30 seconds of dummy scans. But the time for next fMRI volumes was shorter than 2 seconds, which is successful in this real-time study with 3 seconds of TR.

Discussion Our study demonstrates the feasibility of monitoring fMRI-based task performance using real time processing for the functional connectivity. It was possible to monitor the neural activity in real time environments, and to localize the subject's task performance in this study.