Exploring Spatiotemporal Pattern of Human Motor Cortex from FMRI by Self-Clustering Independent Components with Partner Matching

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It has been agreed that the human motor cortex may include three interacted regions, namely primary motor cortex (M1), supplementary motor area (SMA) and premotor area (PMA), as illustrated in Fig1. However, the spatial patterns of these areas have not been exactly exhibited by reconstructing activation maps of neuronal activities under a cognitive motor task. And the temporal patterns and relationships between the spatial and temporal patterns in these areas remains unclear or elusive. The aim of this study was to investigate the spatio-temporal patterns of neuronal processing in human motor cortex using functional magnetic resonance imaging (FMRI). **Subjects and Methods:** This study was conducted on 9 healthy subjects (5 men; 4 women; ages: 31.5±11.6) who underwent a cognitive task by pushing a button with right hand about every 25 seconds. Four sessions were repeated on each subject. For each session, 102 images were acquired using a GE 1.5T Signa LX Scanner (TR=1.2s, TE=60ms, flip angle=60, matrix=64x64, FOV=20x20cm, slice thickness=7mm, 10 slices). After performing preprocessing procedures (motion correction, slice timing, brain extraction, spatial normalization and smoothing), 4 sessions of 408 images from each subject were analyzed using spatial independent component analysis (ICA) with a fully-exploratory manner where a self-clustering algorithm, namely Partner Matching (PM), was developed to automatically identify the most consistent components which were most reproducible across the largest number of subjects. **Results:** We have identified two most consistent and reliable spatially independent components from all the 9 subjects, as shown in Figs 2-3 where component 1 was displayed in red and component 2 in blue. The volume rendering of the two components as shown in Fig 2 could exactly exhibit the spatial patterns of M1-SMA (red) and PMA (blue); Figs 3 and 4 illustrated the slice-overlay maps of the two components at axial and sagittal directions, respectively. Figs 5 & 6 showed the time courses of component 1 and component 2, respectively, where the upper panel showed the stimulus and the lower showed the time course. To examine the correlation between the task stimulus and the time-course of each component, we computed the mutual information (MI) between the stimulus and the time-course; and the correlation coefficient of the power spectral density (PSD) between the stimulus and the time-course. Compared with component 2 relating to PMA, component 1 relating to M1-SMA had a significantly larger correlation with the task stimulus measured by MI (0.13±0.09 vs. 0.024±0.028, $p<0.004$), ratio of MI (RMI) (0.86±0.20 vs. 0.19±0.18, $p<0.000001$) to the peak, and PSD correlation (0.83±0.05 vs. 0.62±0.11, $p<0.0002$), as shown in Fig 7 . **Conclusion**: The spatial patterns of human motor cortex could be recognized using FMRI combined with ICA with a fully-exploratory manner; M1 and SMA are combined more tightly than PMA corresponding to the motor task. Our data suggest that the spatiotemporal pattern in the human motor cortex may represent a fundamental principle for analyzing motor-task-induced activities and functional connectivity.

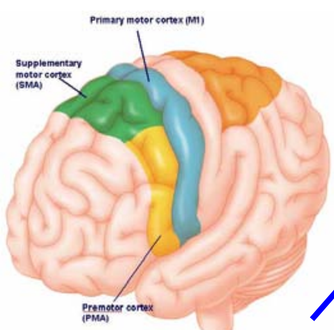

Fig 1

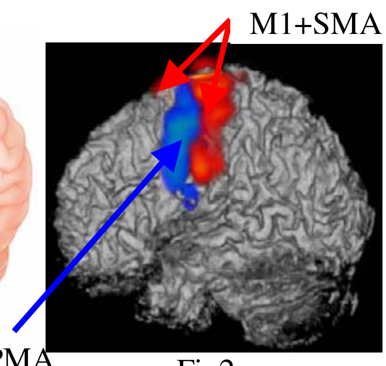

Fig2

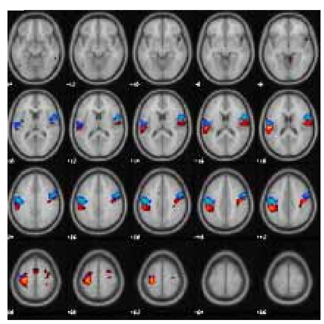

Fig3

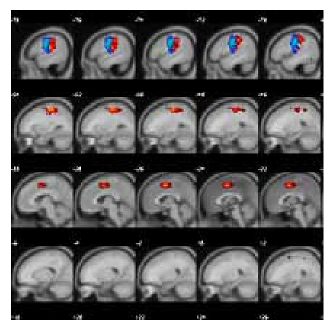

Fig4

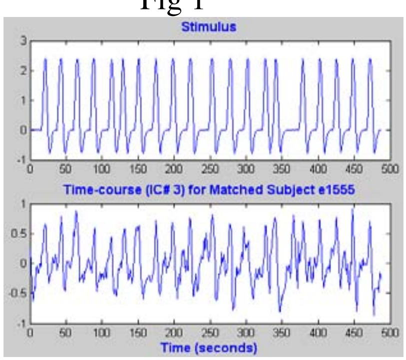

Fig 5

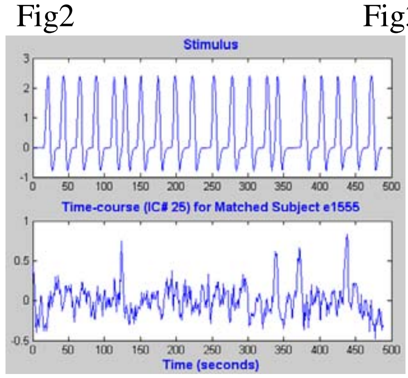

Fig 6

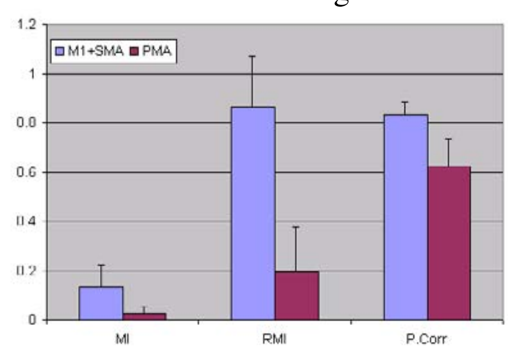

Fig 7