Schematic Correlation Mapping of the Response Similarity among the Brain Areas using Dynamic fMRI

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Introduction

Experimentally, it is assumed that the activity in each brain area is evaluated under constant performance of the task conditions. However, the strategy to complete the cognitive or motor output may change during a session or across sessions. Furthermore, the actual tasks we perform in our daily life are very heterogeneous, including interactive processes, which are not predefined or predicted. We propose that dynamic monitoring of t-statistics [1, 2] may be useful to monitor the ongoing the brain activities by extracting the response of brain activities during switching of task conditions. In this study, the role of schematic correlation mapping (SCM) was evaluated. Instead of overlaying the raw correlation coefficients (CC) over anatomical images, SCM summarizes the extent of correlation during a complex task performance.

Material and Methods

Ten normal subjects (3 females, all right handed) who gave written informed consent participated in this study. The volunteers hit a turnkey according to the digit (2~5) displayed on an LCD panel (IFIS) at 1.5Hz. The following three movements were performed by the right (R) or left (L) hands in a session. R1/L1: simple movement on the right or left side, RQa/LQa: sequential order movements (2-3-4-5), RQb/LQb: alternative sequential order (2-4-3-5). The order of the conditions was R1-L1-RQa-LQa-RQb-LQb-RQa-LQa-RQb-LQb-R1-L1. These 12 task blocks were interleaved with 13 rest blocks, and each of the task and rest blocks lasted 20 seconds.

Functional data were obtained using a T2* weighted gradient recalled echo EPI sequence (TR = 3000 ms, TE = 56 ms, 30 axial slices, 4 mm thick, FOV = 22 cm) on a 1.5T MRI scanner. The 167 volumes of functional images were realigned, normalized and the center coordinates of the ROI (3x3x3 pixels in the MNI coordinate normalized at 3mm) for each motor area were determined by using SPM5 (UCL, London). The time series of the t-statistics (TRF) was extracted using a Matlab module (Baxgui [1, 2]) for sliding window analysis (window width = 30 pts) based on a general linear model. ROIs were set in the primary motor area (M1), supplementary motor area (SMA), dorsal and ventral premotor areas (PMD, PMV), superior parietal lobule (SPL), supramarginal gyrus (SMG), basal ganglia (BG) and cerebellum (CB) on each side.

Results

The motor task employed is testing the response to switching of the finger movement order. Figure 1 shows the representative activation of the motor areas in each condition. Ipsilateral PMA and SPL are not strongly activated by the movements on the right side (RQa/RQb), while they are strongly activated by left hand movements (LQa/LQb). The CCs of the t-statistics response function (TRF) among the motor areas were obtained and schematically labeled on a wire-frame map (SCM), which includes pairs of the CCs (Fig.2). The network analyze on the left side (a) visualized global high correlation of the response, while only the SMA-SPL and PMD-SPL correlation is prominent on the right side (b). Inter-hemisphere analysis indicated that the response of the right M1 (c) or the M1-SMA-PMA network on the right side (d) is significantly correlated with that on the left side. These observations systematically indicates the dominance of the left higher motor areas.

Discussion

Several brain areas, which are detected as an activation set, are recruited for the task performance as a system. Although correlation mapping based on TRF analysis does not necessarily represent the direct interaction among the brain areas, similarity of the response potentially suggests that activation in those areas depends on the same source of information processing. Since effective connectivity is based on the known anatomical connections, it is a strict modeling method to test a pre-defined hypothesis. SCM is more data driven analysis without pre-defined restriction. Another property of SCM is that it summarizes several correlation maps, each of which corresponds to one ROI as a seeding volume of correlation. SCM will be useful to conceptually organize the dynamics of functional network including several brain areas.

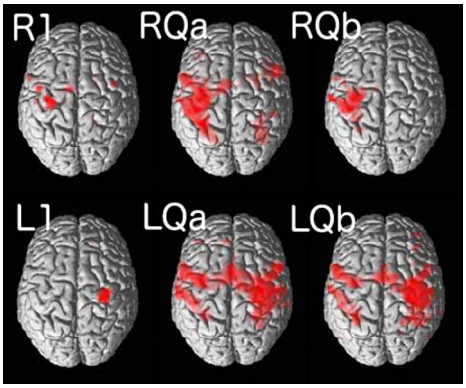
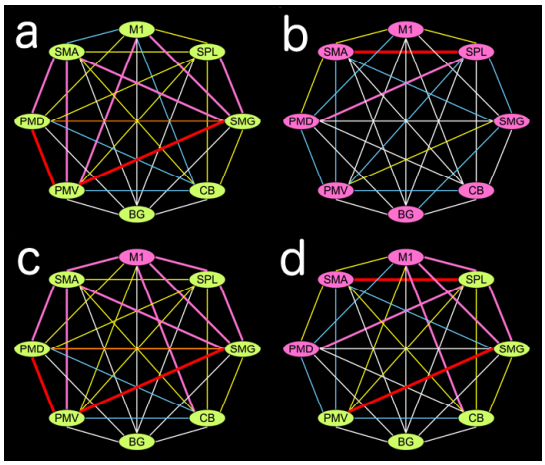


Figure 1 Activation in Each Condition



Labels of the brain areas
Green: left
Red: right

The CCs are
White < 70%
70% < Blue < 80%
80% < Yellow < 90%
90% < Pink < 95%
95% < Red

Figure 2 Schematic Correlation Mapping

References
[1] Nakai T et al., Proceedings of ISMRM #2861, 2006
[2] Nakai T et al., J Neurosci Methods 157, 158-167, 2006