Discrimination of the t-Statistics Correlation Depends on the Qualitative and Quantitative Task Switching - An Application of Dynamic fMRI to Explore the Cognitive Structures

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Introduction

Temporal changes of t-statistics indicate the dynamic response of brain activation during the task performance. A dynamic map of t-statistics, which consists of a series of activation maps, suggests the status of functional correlation among the brain areas during switching of the task conditions [1]. In our previous study, dynamic fMRI revealed bilateral organization of the higher visual areas during unilateral visual stimulation [2]. However, most of the correlation coefficients (CC) among the brain areas appeared relatively high, and the differences of the coupling strength were not clear among the highly activated areas. To avoid this overestimation, we designed a task sequence to better discriminate the CCs. The potential of dynamic fMRI to evaluate the response characteristics of the neuronal network was investigated by using the optimized task design.

Material and Methods

Ten normal subjects (3 females, all right handed) who gave written informed consent participated in this study. Four sessions were designed to test the effect of quantitative change of motor execution and complexity (Fig.1). The volunteers hit a turnkey according to the digit (2~5) displayed on an LCD panel (IFIS). Each session consisted of 12 task and 13 rest blocks in 500 seconds (20 sec for each block).

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 (FIL). 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 area (PMD, PMV), superior parietal lobule (SPL), supramarginal gyrus (SMG), basal ganglia (BG) and cerebellum (CB) on each side.

Results

An ANOVA ($p < 0.01$; Tukey-Kramer) indicated that the variance of the CCs was larger in the velocity changing simple movements (VC; mean 0.38 ± 0.31) than the random order (RA; 0.70 ± 0.22), sequential order complex movements (SQ; 0.71 ± 0.20) and combination of these two (CB; 0.76 ± 0.13) (Fig.2). Table 1 lists the CCs between the PMD on each side and representative higher motor areas. The CCs were processed by Fisher's z'-transformation, and their difference was evaluated by the χ^2 test ($p < 0.01$). Although the motor execution in each session was the same pattern and amount of movements on both sides, the L-PMD presented higher correlation with other motor areas including those on the contralateral side. The activation in the R-PMD more correlated with those on the left side except R-PMD:RSPL. The CCs of the R-PMD with other motor areas were lower in the RA compared with SQ, while such difference was not observed in the L-PMD. Similarly, coupling between R-BG and other motor areas on both sides was mostly lower in the SQ than RA.

Discussion

As hypothesized, the discrimination of the functional coupling (similarity of the response to the ongoing events) depended on the design of the task sequences. However, combination of two different strategies of complex movements reduced the discrimination, since the motor areas recruited were continuously and highly activated. Qualitative difference of complexity was reflected to the coupling potential as observed in the PMD and R-GB. When the motor execution depended on the number-body parts association, the coupling among L-PMD : L-PMV : L-SPL : R-SPL was higher than the homologue network on the right side. This finding is compatible with the role of the left SPL to manipulate the spatial representation of body parts [3]. In conclusion, it was indicated that functional coupling indexing based on the dynamic fMRI has a potential to systematically characterize the cognitive structure supporting the task performance. As a future direction, this method will be applied to individual analysis.

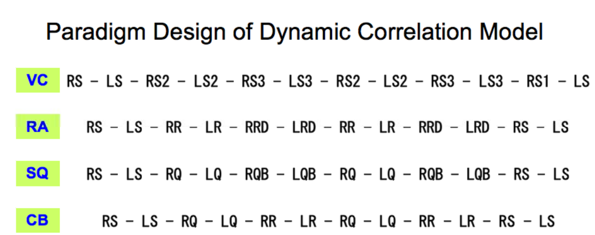

Figure 1 Modulated Task Design

The movement velocity was 1Hz in VC and RA, and 1.5Hz in SQ and CB except specified in the following. R: right, L:left, S: simple movements of the index finger (single click), 2: 2Hz, 3: 3Hz, R: random order, RD: random order with double click, Q/QB: sequential order (2-3-4-5) / (2-4-3-5).

References
[1] Nakai T et al., Proceedings of ISMRM #2861, 2006
[2] Nakai T et al., J Neurosci Methods 157, 158-167, 2006
[3] Weiss PH et al., Hum Brain Mapp 27, 1004-1014, 2006

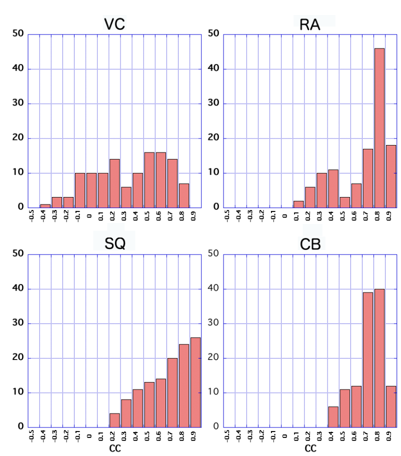

Figure 2 Histogram Analysis of the CCs

Table 1 The Coupling of the PMD

Task Sequence	VC	RA	SQ	CB
R-PMD : L-PMD	0.49	0.59	0.89	0.82
R-PMD : R-SMA	0.58	0.70	0.90	0.95
R-PMD : R-PMV	0.72	0.69	0.72	0.69
R-PMD : R-SPL	0.48	0.73	0.91	0.74
R-PMD : R-SMG	-0.01	0.35	0.60	0.47
R-PMD : L-SMA	0.55	0.82	0.90	0.93
R-PMD : L-PMV	0.64	0.62	0.93	0.81
R-PMD : L-SPL	0.20	0.41	0.84	0.70
R-PMD : L-SMG	0.25	0.52	0.91	0.92
L-PMD : L-SMA	0.81	0.81	0.90	0.81
L-PMD : L-PMV	0.80	0.96	0.96	0.86
L-PMD : L-SPL	0.58	0.88	0.81	0.95
L-PMD : L-SMG	0.75	0.88	0.93	0.84
L-PMD : R-SMA	0.03	0.85	0.86	0.85
L-PMD : R-PMV	0.34	0.78	0.62	0.79
L-PMD : R-SPL	0.73	0.93	0.89	0.96
L-PMD : R-SMG	0.46	0.39	0.51	0.42