Dynamic Monitoring of the Brain Activation under Visual Stimulation Using fMRI - The Advantage of a Sliding Window Analysis

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Introduction

The brain activity during an fMRI session may be potentially modulated by attention, optimization of the strategy or learning for task performance. Monitoring of the dynamic changes of the brain activity under ongoing events during a session will be useful to compensate for these biases. In this study, the potential of a sliding window analysis (SWA) [1] to evaluate the transition of brain activation was investigated, since the temporal dynamics of the t-statistics may be applied to estimate the mutual relationship among the brain activation. Furthermore, it may potentially reduce the number of fMRI sessions required in a clinical study. In order to minimize the biases of cognitive interaction among the task conditions, passive visual stimuli were employed, since the activation induced will be relatively reproducible among the subjects based on the well-known retinotopy.

Material and Methods

Six subjects (4 males) who gave written informed consent participated in this study. The visual paradigm consisted of 12 task and 13 rest blocks (each 30 sec). The four conditions of visual stimuli were composed of concentric circle, which flickered at 4Hz, and each condition was repeated for three task blocks (Fig.1A); 1) right hemi-visual field stimuli with black and white color (BW-HLF), 2) right hemi-visual field stimuli with randomly altering color (CL-HLF), 3) BW whole visual field stimuli (BW-WLE), 4) color whole visual field stimuli (CL-WLE). The subjects maintained fixation during the rest blocks.

Functional data were obtained using a T2* weighted gradient recalled echo EPI sequence (TR = 3000 ms, TE = 30 ms, 30 axial slices, 4 mm thick, FOV = 22 cm) on a 3T MRI scanner (GE Signa VH/i3.0T). For each slice, 250 images were acquired in 12.5 minutes. The image data were realigned, normalized into an MNI template and reference activation maps (Fig.1B) to assign the center of ROIs were obtained using SPM2 (UCL, London). The time course of the t-value was extracted for each ROI (5x5x5 pixels) using a Matlab module employing the algorithm of sliding window analysis based on a general linear model (window width = 70 pts) [2, 3]. This method is different from using a design matrix with multiple basis functions, since the computation for SWA needs just one basis function to represent the task performance of any condition, and the onset and transition of the activation can be easily compared among the brain areas. The time series of the t-statistics from the 6 subjects were averaged, and the correlation coefficient (CC) of the two dynamic curves on each side was obtained.

Results

The t-value in the V1 (BA17) was higher during AC-HLF than BW-HLF and during AC-WLE than BW-WLE on the left side, and higher during AC-WLE than BW-WLE on the right side (Fig.1C). This observation agrees with the report that the activity in the V1 was more strongly detected by chromatic stimulation than isochromatic stimulation [4]. The dynamic curve of the t-value in the right V4 presented a similar change to that in the left V4, although the color stimuli was not given during AC-HLF to the right visual field. The CC of these two curves was 0.65, indicating the similarity of the two response curves in the V4 on each side, whereas the CC between those in the V1 was -0.12.

Discussion

The time series of t-statistics obtained by the SWA enables to estimate the similarity of the response function of the activation to the task performance across the brain areas. The high CC of the response in the V4 on each side during hemi-visual field stimulation suggested that V4 is bilaterally organized. This finding was supported by the previous reports of primates [5], but only a few reports suggested it in humans [6]. This property of dynamic analysis may be an advantage to evaluate the systematic response of the functional units.

As a future direction, this technique may be applied to reveal the fluctuations in brain activity during the ongoing task performance, such as learning or optimization of the strategy. With combined task design, dynamic analysis may also be useful to estimate the cognitive interactions within a complex task design.

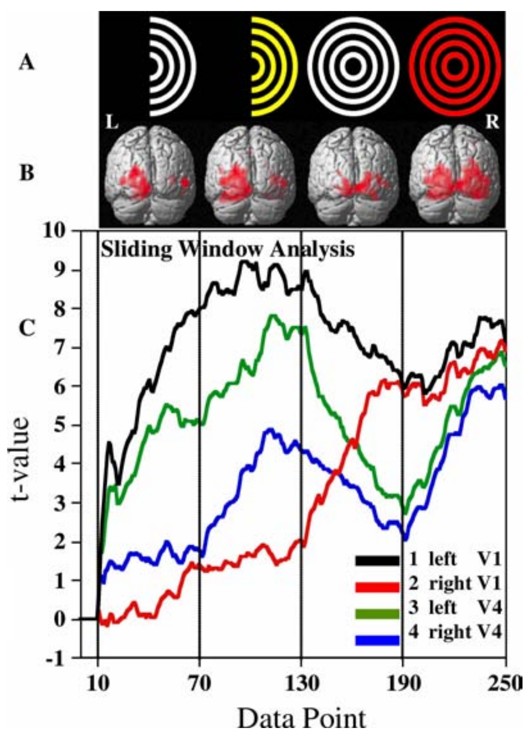

Fig. 1

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