Dynamic Monitoring of the t-value to Evaluate the Activation in a Single Subject Study Using a Real-Time fMRI System

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Introduction

Although functional magnetic resonance imaging (fMRI) is a powerful tool to explore the brain function, the reliability mostly depends on the statistical power of a group study with multiple subjects in neuroscience researches. For clinical purposes, it is indispensable to augment the reliability of a single subject analysis. An fMRI technique to monitor the dynamic process of the brain activity based on a real-time analysis would reveal the detail of the temporal change in each area and may be useful to evaluate the detection of the brain activity in a single subject study. In this study, the advantages of dynamic monitoring of the t-statistics based on a general linear model (GLM) were investigated.

Material and Methods

Ten subjects (5 males / 5 females) who gave written informed consent participated in this study. Three block designed language tasks (4 task and 5 rest blocks, each 30 seconds) were employed; 1) L-task: listening comprehension of news paper articles (40 words / min), 2) N-task: covert naming of the objects visually presented on a LCD panel, 3) W-task: covert word generation starting with the visually presented characters. 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). Ninety images per slice were acquired in 4.5 minutes. During the scan, the EPI images were transferred to a real-time analysis system using a PC cluster [1]. The image data were realigned (6 parameter rigid body transformation) and the t-statistics ($p < 0.001$) for each time point of the series were estimated using an incremental analysis algorithm [2]. As a post processing, the time course of the t-value was extracted for 3 regions of interest (ROI, each seize 5x5x3 pixels), which was determined by a reference activation map obtained by SPM2 (UCL, London). The t-value from the 10 subjects was averaged for each ROI, and the time series from each subject were evaluated using a linear approximation between the 21st (end of the first task block) and the 90th (the last) data points.

Results

In the active region, the average t-value linearly increased after the end of the first task block. Fig.1 shows the dynamic change of the t-value in the left pre-motor area (PMA) under the 3 task conditions. Fig.2 shows an example plot of individual data in the lt PMA. In this case, the significance of the activation depended on the timing of the data acquisition, since the t-value by L-task drifted around the threshold. By W-task, the t-value increased more linearly, and it reached the significant level (for example, T=3.14 uncorrected, $p < 0.001$) almost at the end of the time series. Fig.3 summarizes the correlation between the initial t-value at the end of the first task block (21st point) and the increase of the t-value (Δt) during the 4 task blocks (R^2= 0.66). Among the 90 samples obtained from the lt PMA, lt BA44 and the lt BA22, the data points within the area encircled by the red triangle (i.e. $t+\Delta t$ is close to the threshold) represent such boarder line cases. Since the significance at the last data point, at which the activation maps are usually calculated, will depend on the number of the data points in these cases, analysis of the t-value curve in real time will assist the detection and evaluation of the activation around the threshold in a single subject analysis.

Discussion

Continuous monitoring of the activation map using fMRI in real time (dynamic fMRI) will be useful to monitor the temporal changes of the functional units during the task performance. Although the temporal resolution is at several seconds order, d-fMRI provides us with the information to 1) evaluate the reliability of the activation around the threshold level, 2) estimate the temporal change of the activity in a complex task design, 3) monitor the influence of the motion artifact, 4) correlate with the performance data. These features will be useful to conduct clinical brain mapping, especially when the detection of the known activation by the task is the main purpose of the neuroimaging.

References

[1] Bagarinao E et al., Magn Reson Engineering, 19, 14-25, 2003

[2] Bagarinao E et al., NeuroImage, 19, 422-429, 2003

Fig.1

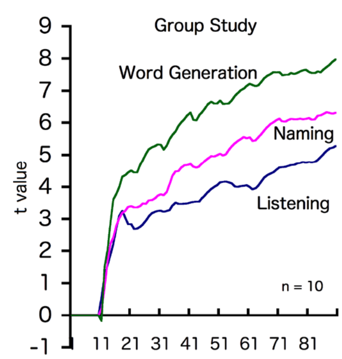

Fig.2

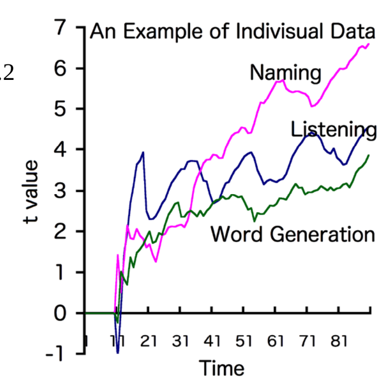

Fig.3