Detection of the Unknown Onset Time of Plateau Brain Activation in fMRI by Derivative Temporal Clustering Analysis

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Introduction

For most fMRI experiments, probable assumptions about temporal activation patterns can be made through the experimental paradigm. Paradigm-dependent data processing methods such as group t-test can be employed in such cases. However, in some cases, such as in fMRI studies involving brain activation induced by drugs or sleep, little or no temporal information is available. For these types of experiments, paradigm-independent data processing methods which do not require prior knowledge of event-timing should be used. Among the paradigm-independent techniques, temporal clustering analysis (TCA) (1,2) has comparable ability to the commonly used independent component analysis (ICA) (3,4) in generating functional brain maps in event-related fMRI experiments, and it is advantageous because it is simple in principle and efficient in computation (5). However, TCA was initially developed to detect short, transient brain activation and was found insensitive for detecting long plateau activation patterns (2). In this report, we extend the TCA technique by using its first derivative to detect the unknown onset time of long plateau activation. Here, four different derivative temporal clustering analysis (dTCA) algorithms were tested on simulated fMRI data, and the one with the best performance was further validated on *in vivo* fMRI data.

Methods

Four dTCA algorithms (Direct – Direct Derivative method; Maximum – Maximum derivative value method; Sobel – The Sobel edge operator; Roberts – The Roberts edge operator) were tested on computer simulated fMRI time-series data. The simulated data were created as follows: $72 \times 72 \times 120$ data sets with 1% noise were constructed. A plateau brain activation pattern (onset of the brain activation is at the 60th time point) was added in pre-selected regions of interest (ROI). Three ROIs were considered: 15 pixels, 30 pixels and 56 pixels. The maximum signal changes in the selected ROI were set as 1%, 1.5% and 2%, respectively. Each kind of data set was simulated 20 times, representing 20 imaginary subjects. To demonstrate the dTCA methods in fMRI experiments *in vivo*, three healthy subjects participated in a visual task designed to evoke prolonged brain activation. The 125-second trial began with a 65-second control state followed by a 60-second stimulation state (a checkerboard pattern flashing at 8 Hz). Each trial was conducted twice for each subject. A single slice covering the visual cortex was scanned using a single-shot T_2^*-weighted EPI pulse sequence, TR/TE/θ = 1000 ms/30 ms/90°.

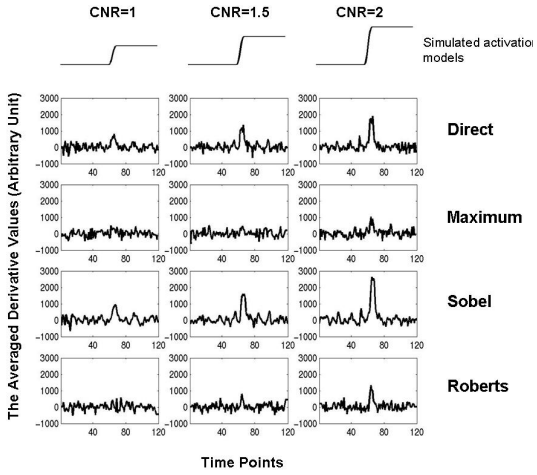

Figure 1. Detection ability of four dTCA algorithms (Direct, Maximum, Sobel and Roberts) on the simulated data in which ROI equals 56 pixels. The first row shows the preset activation models in the simulation studies.

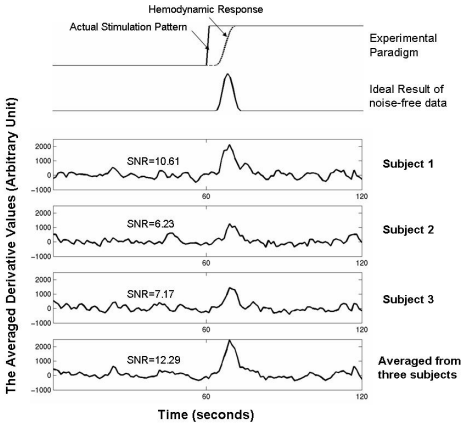

Figure 2. Results from the *in vivo* fMRI experiment in which three subjects performed a 125-second block-designed visual task. Data were analyzed by employing the Sobel edge operator.

Results

The results of the four dTCA algorithms on the simulated fMRI data are presented in Figure 1. From Figure 1, we conclude that the Sobel edge operator gives the best results, and the second-best results are obtained with the Direct derivative method. The Maximum derivative value method and the Roberts edge operator are hardly able to detect the time of activation. The detection ability increases with increasing CNR of the activation.

The Sobel edge operator was applied to the *in vivo* visual stimulation fMRI data of the three subjects. The resultant dTCA curves are shown in Figure 2. From the peak positions of these curves we know the onset time of the brain activation. The peak of the derivative curve averaged from three subjects was more distinguishable than that of any single subject. A brain activation map of the first trial of Subject 1 obtained according to the dTCA curve is shown in Figure 3.

Conclusion

Among the four dTCA algorithms used in the simulation studies, the Sobel edge operator was best at detecting the onset of long-time brain activation with a plateau pattern. The Sobel edge operator dTCA also detected the onset time of the brain activation in an *in vivo* fMRI study. Hence, we conclude that dTCA is a powerful tool to detect the unknown onset time of long-time brain activation in fMRI.

References

1. Liu Y, Gao JH, Liu HL, Fox PT. Nature 2000; 405: 1058–1062.
2. Yee SH, Gao JH. Magn. Reson. Imaging 2002; 20: 17–26.
3. Comon P. Signal Processing 1994; 36: 11-20.
4. McKeown MJ, Makeig S, Brown GG, et al. Hum. Brain Mapp.1998; 6: 160–188.
5. Zhao X, Glahn D, Tan LH, et al. J. Magn. Reson. Imaging 2004; 19: 397–402.

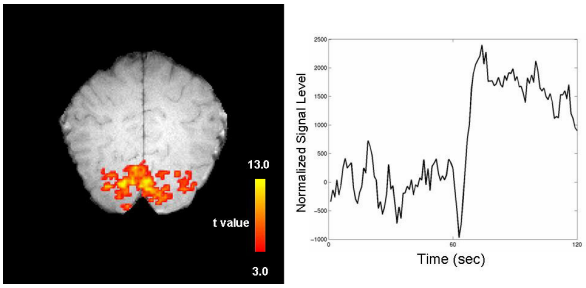

Figure 3. The brain activation map (t threshold is 3.0 and pixel-cluster threshold is 3, $p < 0.005$) and its corresponding time course obtained from the first trial of Subject 1.