Extracting the Resting-State BOLD Signal from an Event-Related fMRI Study

M. Wu[1], R. Tamburo[2], G. Siegle[2], and H. J. Aizenstein[2,3]

[1]Department of Electrical and Computer Engineering, University of Pittsburgh, Pittsburgh, PA, United States, [2]Department of Psychiatry, University of Pittsburgh, Pittsburgh, PA, United States, [3]Department of BioEngineering, University of Pittsburgh, Pittsburgh, PA, United States

Introduction

Resting-state fMRI has drawn increased attention since being hypothesized to represent the default network of the human brain during rest. Correlations among low-frequency (0.01-0.1 Hz) fluctuations in the blood oxygenation level-dependent (BOLD) signal have been hypothesized to reveal the baseline or resting state of brain activity. For resting-state-related research, most of studies have used subjects scanned while at rest (i.e., no explicit task) [1, 2]; others have suggested using the fMRI data from the fixation periods of block-design tasks [3]. For fMRI with simple tasks such as finger tapping, the subjects being scanned are at a resting state during most of the scan time. We propose a method for extracting resting-state data by removing the event-related BOLD signal from the available fMRI task data. This method is of interest because it makes use of the available event-related fMRI data and all of the time points in the dataset. The effectiveness of the method in extracting resting-state signal is validated by comparing the spatial correlation of the posterior cingulate cortex (PCC) from the extracted resting-state data against from the task data.

Methods

Subjects. Ten control subjects (mean age = 66.5, age standard deviation = 10.5, 8 females) were scanned on a 1.5T GE Signa scanner while performing a finger tapping visual motor task. A one-shot spiral pulse sequence was used [TR =2000ms, TE= 35ms, flip = 70, FOV = 24cm]. A high-resolution SPGR image was also acquired on each subject for co-registration. Subjects were instructed to perform a key press with both index fingers every time they saw the word "tap" appear on the screen. The stimulus appeared every 16 sec and remained on the screen for 1 sec, so for most of the scanning time, the subject is at a resting-state. There were 24 trials in a 6.4min block.

Image Analyses. The subject's SPGR images were mapped to a standard Montreal Neurological Institute (MNI) template space (colin27) using a fully deformable model [4], and then the functional images across subjects were normalized into the common space using the computed deformations.

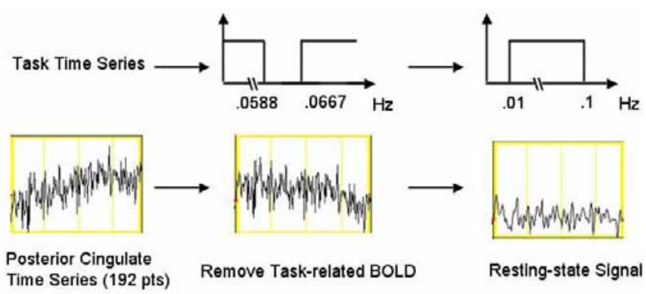


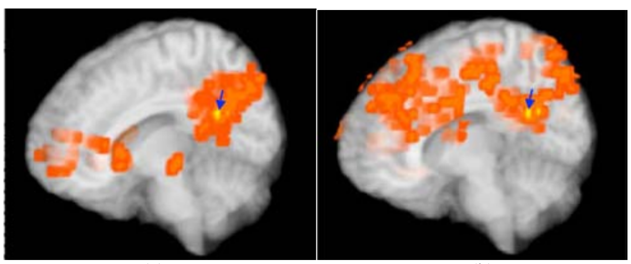
Fig. 1. Steps for extracting resting-state data from the task data

The steps to extract the resting-state data are shown in Fig. 1. Since stimuli were presented every T=16s, a notch filter was used to remove the task-related BOLD signal with the lower cutoff frequency: 0.0588Hz (1/(T+1)) and higher cutoff frequency of 0.0677 Hz (1/(T-1)). A band-pass filter with the cutoff frequencies of [.01 .1] was then used to extract the resting-state signal, which also effectively removed the linear trend in the data.

The time series of a seed in posterior cingulate cortex (PCC) was extracted, and a correlation map between PCC seed and whole brain was computed for each subject using 3dDeconvolve (AFNI). The correlation map for each subject was statistically compared to the baseline 0 using a 1-sample t-test. The resulting T-map was then thresholded at $T(9) > 5.04$, $p < .001$, with an 8-voxel contiguity threshold. This statistical analysis was performed for both time-series datasets (the event-related and extracted resting-state datasets).

Results

The thresholded T-maps ($T(9) > 5.04$, $p < .001$, with MNI colin27 template as the underlay image) from (a) the extracted resting-state data and (b) the task data are shown in Fig. 2. The blue arrow indicates the location of the PCC seed for the correlation analyses. For the resting-state connectivity map (Fig. 2(a)), we found that the PCC showed significant resting-state connectivity with the medial prefrontal cortex (MPFC), including the ventral anterior cingulate cortex (vACC), which agrees with the previous research findings in the literature on the default network of resting states. In contrast to the resting-state connectivity map, the event-related map showed activity in motor and sensory areas, as expected for a tapping sensory-motor task (Fig. 2(b)). Compared to the original data, significantly increased correlations with PCC activity for the notch-filtered data were observed in the rostral anterior cingulate ($p < .05$); decreased correlation with motor activity was also observed ($p < .05$).



(a) (b)

Fig. 2. The functional connectivity results for the PCC seed from (a) the resting-state data and (b) the task data.

Conclusion

Resting-state fMRI is an interesting tool for studying functional connectivity in the human brain. In this study, we describe a method for extracting the resting state signal from event-related task studies (e.g. finger tapping). We evaluated the method by examining the functional connectivity (i.e., voxel-wise correlation) of the modified time-series to a seed voxel in the PCC. As predicted, the functional connectivity for the extracted resting state matched the previous reports of the default network better than did the event-related data.

References

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