Multiband EPI in brain functional mapping – an fMRI study with rhyme judgment tasks

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Introduction

Accelerated multi-slice MRI techniques are able to acquire a whole brain image within sub-second with reasonable signal quality [1,2]. Recent studies showed advantages of multiband and multiplexed EPI techniques in brain functional connectivity [3,4] and diffusion imaging [5] studies. In the current work, we investigate the potentials of the fast imaging techniques in task-based fMRI studies. Specifically, we utilized conventional and multiband (MB) EPI techniques to study brain functional mapping under phonological processing with rhyming judgment tasks. With higher temporal sampling rate in the MB EPI, we expected to achieve stronger statistical power and obtain similar functional mappings with much reduced scanning time, compared to conventional acquisition techniques.

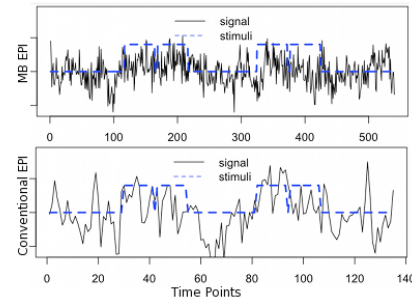

Fig.1. An example of MRI time courses at a voxel in the left IFG during the rhyme task.

Methods

Image Acquisition. Ten healthy native English speakers (6 males, age range 22-48 years) were recruited under an Institutional Review Board approved protocol. Subjects were scanned using a 32-channel head-coil on a 3T Siemens Trio scanner. Three 8-min sessions of resting-state fMRI were acquired using conventional EPI, high temporal MB EPI, and high spatial MB EPI to investigate image quality under various parameter settings. The high temporal MB was used for the task fMRI experiment. Two 5-min sessions of task fMRI data were acquired using conventional and MB EPI, respectively. Conventional EPI acquisition uses a single-shot gradient-echo EPI sequence with TE/TR=27/2000ms, BW=3906 Hz/Pix, in-plane matrix=64x64 (resolution=3.44x3.44mm^2), slice thickness=4mm without interslice gap, flip angle (FA)=77^o, acceleration factor (AF)=2. Five slices were simultaneously excited (MB=5) for MB EPI. High temporal MB EPI has the same spatial resolution with TE/TR=27/500ms, BW=3906Hz/pix, FA=46^o, AF=2. For high spatial EPI, we set the spatial resolution to 2x2x2mm^3 with TE/TR=27/1000ms, BW=2368Hz/Pix, FA=62^o, AF=2. Anatomical images were also acquired using a 3D MPRAGE T1-weighted sequence with TR=2.5s, TE=4.38 ms, FA=7^o, and voxel size=1x1x1 mm^3.

Stimuli and Tasks. The fMRI experiment used a rhyme judgment task. Each task session contains four blocks of rhyme judgments and four blocks of font size judgments as baseline [8]. Each block consisted of a 2s instruction and 12 trials. In each trial, a pair of English words was displayed synchronously for 1,500 ms followed by a 500 ms interstimulus interval. Presentation of words was randomized and presentation of blocks was counterbalanced across subjects.

Image Processing and Analysis. Data were processed and analyzed primarily using AFNI. The preprocessing steps of the conventional and MB EPI resting and task fMRI data include slice-timing correction, volume registration for corrections of head motion, linear detrending, spatial normalization to Talairach space. Brain masks were extracted from the average conventional EPI volume across all time courses to estimate the spatial (sSNR) and temporal SNR (tSNR) (mean signal over normalized standard deviation across the time course) for the conventional, high temporal and high spatial MB data. The conventional and high temporal MB task fMRI data was resampled to 3x3x3 mm^3, smoothed with a 6mm FWHM Gaussian kernel. Individual activation maps were generated by the general linear model with boxcar regressors convolved with a hemodynamic response function. For MB task fMRI, we generated individual activation maps under three conditions: using the full time course, one-half of the time course (the first 2.5min of a session), and one–fourth of the time course (the first 1.25min). The contrast images of rhyme and font size tasks from each subject were sent to two-factor mixed effect ANOVA to estimate group activation.

To compare the performance of conventional and MB techniques, we computed the average t statistics of the contrast images of rhyme minus font size in four regions: bilateral inferior frontal gyrus (IFG) (x=±47,y=14,z=19), and bilateral middle temporal gyrus (MTG) (x=±56,-35,1). The left IFG and MTG were two converging regions reported in the alphabet phonological processing circuit, whereas the right IFG and MTG were used as control regions. Each region was generated by drawing a sphere with a radius of 6mm centered at the location described above. Typical fMRI time courses with conventional and MB EPI at a voxel within the left IFG were shown in Fig. 1.

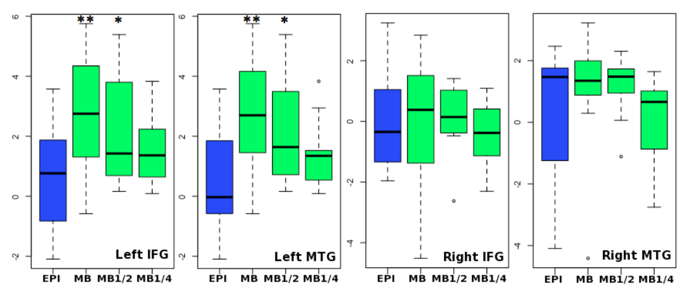

Fig.2. Comparison of activation t statistics in two task involved regions (left IFG and MTG) and two control regions (right IFG and MTG) under four acquisition conditions . **p<0.05, *p<0.07.

Results

The sSNRs of conventional, high temporal and high spatial MB resting fMRI data are: 74.64±16.88, 44.43±5.69, and 24.26±2.65, and their tSNRs are: 156±38.90, 163.91±28.35, and 94.73±21.15. The sSNRs of conventional and MB task fMRI are: 70.05±14.92 and 41.81±5.58, and their tSNRs are; 155.69±38.90 and 162.90±29.41. The average t statistics of the rhyme task in the four cortical regions under different acquisition conditions are shown in Fig.2. For the task-involved regions, i.e., the left IFG and MTG, the full session MB provides significant stronger statistics compared to the conventional technique. By reducing the time course to half, the MB still shows marginal stronger statistics. There is no statistical difference between the conventional and MB techniques in the two control regions. Fig.3 shows the group activation maps under the conditions of conventional EPI, full session MB, half session MB and one-fourth session MB. The maps were thresholded by voxel-based p<0.005 with cluster size>35 voxels. Regions of left IFG and left middle frontal gyrus were detected under all conditions with the MB showing higher statistics. Left MTG was only detected under full session and half session MB. Activations in subcortical regions of caudate and putamen that are less frequently reported in previous studies were also found using full and half session MB.

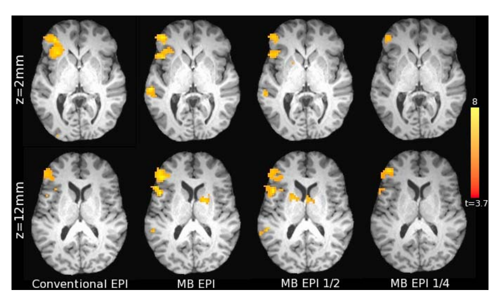

Fig.3. Comparison of group activation maps under four acquisition conditions.

Discussion and Conclusion

In this study, the potential advances of simultaneous multislice acquisition techniques were examined in brain functional mapping. Despite the lower spatial SNR per image volume due to the faster TR acquisitions, the MB EPI produces stronger statistical power in activation detection because of much more densely sampled time series and higher temporal SNR. Results also demonstrated that the MB technique produces stronger or similar detection power with much reduced acquisition time or number of task repetitions. Although the gains in neuronal information are limited by the slow hemodynamic response of BOLD and by neurovascular coupling differences between different brain regions, the fast fMRI techniques show great potentials in brain functional mapping studies with improved statistics and much less acquisition time.

References: 1. Feinberg et al., *PLoS ONE,* 2010. 2. Moeller et al., *MRM* 2010. 3. De Martino et al, *Neuroimage*, 2011. 4. Smith et al., *PNAS* 2012. 5. Setsompop et al., *MRM* 2012. 6. Tan et al., *Human Brain Mapping*, 2005. 7. Bitan et al., *J of Neuroscience* 2005. 8. Siok et al., *PNAS* 2008.

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