

Comparison of SSFP and multiband EPI in functional MRI at 7 Tesla

Zhongwei Chen¹, Rong Xue¹, and Danny JJ Wang²

¹State Key Laboratory of Brain and Cognitive Science, Institute of Biophysics, Chinese Academy of Sciences, Chaoyang District, Beijing, China, ²Department of Neurology, University of California Los Angeles, Los Angeles, CA, United States

Target audience: Neuroimaging scientists.

Purpose: Blood oxygenation level dependent (BOLD) functional MRI (fMRI) based on gradient-echo echo planar imaging (EPI) has been the most widely used method for neuroimaging studies. The technique, however, has inherent limitations, such as susceptibility artifacts and limited spatial and temporal resolutions. Recently, alternative fMRI methods have been proposed to overcome these limitations including steady-state free precession (SSFP) and multiband EPI sequences (1-3). In this study, we systematically evaluated the sensitivity of fast gradient echo (GRE), passband and transition band balanced SSFP, and multiband EPI to visual cortex stimulation at 7 Tesla using both block and event-related designs. We also hypothesized that the initial dip can be reliably detected using these novel fMRI methods with improved spatiotemporal resolution at 7T. (4)

Methods: Experiments were performed on 6 participants using a 7 Tesla Siemens system with a 24-channel Nova Medical coil. The block design experiment used 6 cycles of alternating 20s' full-screen checkerboard stimulus and 20s' resting state, and the event-related fMRI (ER-fMRI) experiment used 8 repetitions of a 2s' full-screen checkerboard stimulus followed by a 20s' resting period. During the fMRI experiment, a series of functional images (N=488/360 for block and ER-fMRI, TR=500ms, FOV=19.2x19.2cm², 5mm slice thickness) were acquired at flip angles of 8°(GRE), 15°(p-SSFP), 5°(t-SSFP), 70°(M-EPI) respectively based on simulation results. Standard gradient-echo EPI images (N=112/90 for block and ER-fMRI, TR=2s, FA=80°) were acquired for comparison. Each data set was analyzed using SPM8. SSFP sequences focused on a single slice through the visual cortex while EPI sequences covered the whole brain. FFT of the mean time courses of each method was performed to evaluate the effects of physiological noise.

Results: Fig.1 displays SPM t-maps of the 5 methods using block design of a representative subject. Fig.2 shows peak and average t-values of the 5 methods for both block and event-related designs, which can reflect the sensitivity and SNR of the functional images. Hemodynamic response function (HRF) curves of all 5 methods were derived from event-related designs. Fig.3 shows the HRF curve from the relatively higher sensitivity methods – GRE and passband SSFP, and the arrow in the figure indicates the stimulus on period. The initial dip can be clearly seen. All methods have only one peak in the frequency spectrum except the transition band SSFP (Fig.4), suggesting its sensitivity to physiological noise.

Fig.1 Functional related response onto T1-weighted anatomical images with 5 methods, as displayed left to right: GRE, P-SSFP, T-SSFP, M-EPI, GE-EPI.

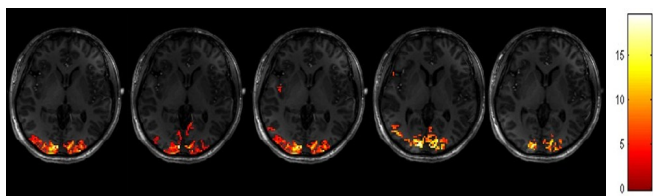


Fig.2 Comparison of peak and average t values of 5 methods on both designs.

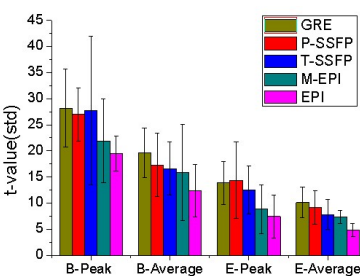
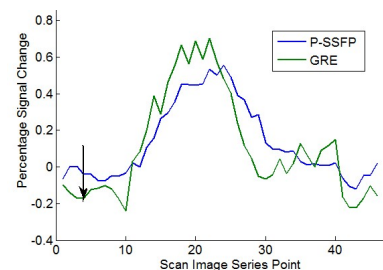


Fig.3 HRF curves fitted by GRE and P-SSFP.



Discussion: Both SSFP methods and multiband EPI improved the sensitivity of fMRI, and passband SSFP and GRE were the most effective methods. We utilized these two methods to fit the HRF curve. As shown in Fig.3, the initial dip can be reliably detected. Based on FFT analysis, the transition band SSFP was most sensitive to physiological noise including respiratory pulsation effects (~0.15 to 0.20Hz). Future work will focus on improving the imaging coverage of SSFP methods.

Conclusion: SSFP and multiband EPI offer high promises for fMRI at ultrahigh magnetic fields (7T).

References: (1) Miller et al, MRM 2003; 50:675–683;(2) Miller, Neuroimaging 2011;62:713-719;(3)Moeller et al, MRM 2009;63:1144-1153; (4)Hu, et al Neuroimaging 2011;62:1103-1108.

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Fig.4 HRF curves acquired by transition band SSFP (left) and passband SSFP (right) on block design and their frequency spectrums.

