Measuring Task-Modulated Contrasts by Transition-Band bSSFP fMRI: A Rate-Dependence Study of Human Visual Cortical Response

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Introduction

Recently, both transition-band and pass-band balanced steady-state free precession (bSSFP) has been shown a practical tool for functional MRI (fMRI) applications [1,2].TB-bSSFP has been shown able to detect the local proton frequency change caused by the altered concentration of the paramagnetic deoxyhemoglobin during brain functional activation. On the other hand, the fMRI sensitivity of the pass-band method is based on the intrinsic T2/T2* contrast of bSSFP[3], which is close to the BOLD mechanism. The bSSFP methods are free of geometry distortion and therefore suitable for high resolution fMRI studies [1]. However, for the TB-bSSFP method, the functional contrast depends on the complex and nonlinear phase behavior, which is quite different from the BOLD methods. Whether the functional-contrast studies using the BOLD methods and TB-bSSFP can reach the same conclusions is still not investigated. To answer this question, in our study, we designed a visual experiment to compare the stimulus-rate dependency of the functional contrast of both BOLD-EPI and TB-bSSFP.

Material and Methods

Five healthy volunteers participated in the study. The experiments were performed on a 3T whole-body MR system (Trio, Siemens) using an eight-channel head phase-array. Single-shot gradient EPI and TB-bSSFP sequences were applied with the following parameters. (FOV: 220 x 220 mm^2, matrix size:64 x 64, slice thickness=4 mm; EPI: TR/TE: 1000/40 ms, flip angle:90°, slice number:10; TB-bSSFP: TR/TE=5/2.5ms, flip angle=4°, slice number:3). The system frequency drifts that affected the TB-bSSFP signal were reduced by real-time frequency tracking with an additional navigator echo[IIR,Wu] and the data feedback mechanism provided by Siemens ICE environment. The checkerboard stimulation paradigm consisted of nine blocks (block size:20 s, OFF: 5, ON: 4). For each scanning method, five sessions were performed with the flicker frequencies of (8,8,8,8 Hz), (6,2,4,8 Hz), (2,8,4,6 Hz), (6,4,8,2 Hz), (4,6,2,8 Hz).

The sessions of (8,8,8,8 Hz) were analyzed with the SPM2 software package. Then, an activation mask (i.e. regions covering the activation region) were extracted from t-test ($p<0.001$) maps generated from SPM2. To eliminate the large vessel regions, the pixels with signal change higher than 5% were excluded [4]. A time-intensity curve of each session was calculated by averaging the pixel values covered by the mask. Finally, the signal changes corresponding to the flicker rates (2,4,6,8 Hz) of both methods (BOLD-EPI and TB-SSFP) were extracted and averaged.

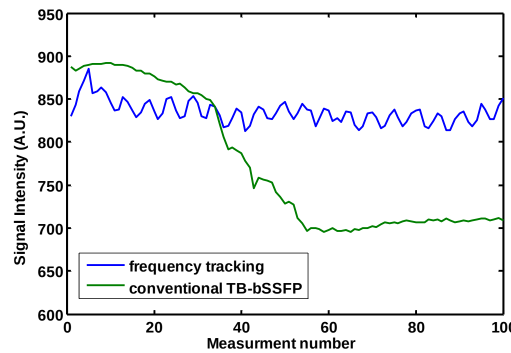

Figure 1: The stabilization of TB-bSSFP signal by the feedback control of system frequency. (green line: without feedback, blue line: with feedback).

Results

Figure 1 shows effect the frequency tracking method of TB-bSSFP. Using this method, the signal drift(green line) was effectively reduced (blue line) as previously reported [2]. Figure 2 shows the stimulus-rate dependencies of the averaged functional contrasts obtained by BOLD-EPI (blue line) and TB-bSSFP (red line). The TB-bSSFP curve shows highly correlated (CC=0.87) to the BOLD-EPI curve. Furthermore, the averaged functional contrasts obtained by TB-bSSFP are 1.75±0.1 times higher than that obtained by BOLD-EPI.

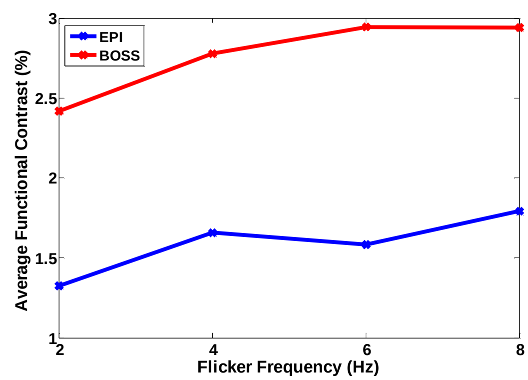

Figure 2: The averaged signal changes obtained with TB-bSSFP (red line) and BOLD-EPI (blue line) sequence versus flicker frequencies of the visual checkerboard stimuli.

Discussion and Conclusions

The recently proposed TB-bSSFP is based on the steady-state phase alteration caused by the activation-related local frequency shift. The resulted phase dispersion of this technique is not linearly related to the local frequency, which is different from the conventional gradient-echo EPI. In this study, we designed an visual fMRI experiment to compare the stimulus-rate dependent contrasts obtained by two methods (i.e. gradient-echo EPI and TB-bSSFP). The order of flicker frequencies (2,4,6,8 Hz) were not fixed to avoid the potential bias of the system drifts and the feedback control of the system frequency was implemented to reduce the known signal drifting of TB-bSSFP. In our result, the data obtained by the both methods showed highly correlated. This infers that TB-bSSFP can be applied to the studies of functional contrasts while the task-modulated brain-perfusion changes are under the perfusion elevation induced by the 8Hz-stimulus (i.e. ~46% CBF changes [4]). The comparison of both methods with higher perfusion level change (e.g. hypercapnia challenge) needs further investigation. On the other hand, the functional contrasts of TB-bSSFP show higher than that of BOLD-EPI. This suggests that, using the experiment setup (TR/TE, visual cortex) in this study, the functional sensitivity of TB-bSSFP is higher than that of BOLD-EPI. In conclusion, combined with less geometry distortion, the high functional sensitivity, and the similar contrast behavior to BOLD-EPI, TB-bSSFP is a practical tool to measure the task-modulated functional contrasts.

References

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[3] Miller KL et al. MRM (2008) 60:661-73. [4] Zhu XH et al, MRM (1998) 40:703-711.