Averaged-BOSS: feasibility study and preliminary results

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Introduction

New methods for fMRI utilize balanced steady-state free precession (b-SSFP) pulse sequences to overcome BOLD limitations [1]. The profile of b-SSFP magnetization is divided into two parts referred to as transition-band and pass-band that occur periodically [2]. BOSS fMRI creates the functional contrast in the image based on the former, where the phase is highly sensitive to the off-resonance frequency [3]. The contrast is even more enhanced at low flip angles resulting in higher SNR [3]. The crucial challenge in BOSS is its limited spatial coverage, which is resulted from the narrow transition-band in the magnetization profile [3]. Herein, we describe a new method for functional MRI, termed Averaged BOSS (A-BOSS) fMRI, in which the idea of phase transition is employed without the undesirable limited spatial coverage. The basis of this approach is described and feasibility of the proposed method is demonstrated through preliminary experimental results.

Methods

In contrast to BOSS, where an accurate volume shimming is required in the region of interest to minimize the off-resonance variations, here we add an extra constant gradient during imaging to generate a dominant off-resonance frequency with substantially linear variation across the image. This results in a compact SSFP profile with a profile period at the order of pixel size. As a result, the effect of frequency shift on the magnetization is averaged everywhere, creating a more uniform signal with no need for accurate shimming. The experiments were performed on a 3T Trio Siemens scanner using TrueFISP sequence. During the rest and activation states of right-hand finger-tapping task, in 3on/3off blocks, a set of high-resolution ($1\times 1\times 5$ mm^3) b-SSFP acquisitions was performed on a transversal slice that includes the motor cortex area (total number of thirty scans were acquired). TR is set to its maximum available value for this sequence (10 ms) to decrease the profile period across the image. . A small FA of 4° was chosen to achieve a more significant signal change. For the evaluation of the method, we also acquired EPI (19.2×19.2 cm FOV, 64×64, 1 shot, 2000/30 ms TR/TE, FA=90) images for the same task. The EPI data analysis was performed using FSL (FEAT analysis: cluster threshold $Z > 2.3$ and cluster significant threshold $p < 0.005$).

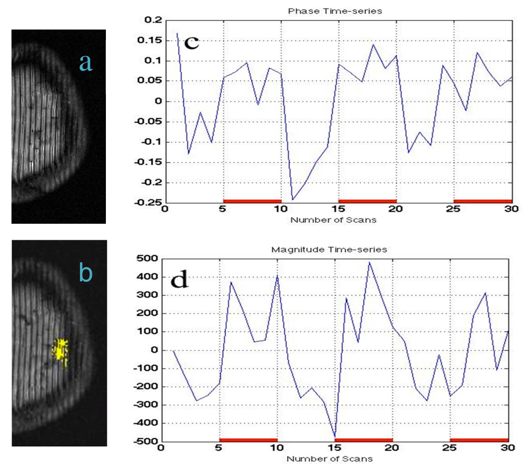

Figure 1 Averaged BOSS fMRI: resulting magnitude image, activation map and time-series. (a) Magnitude image of A-BOSS fMRI with its resulting dark and bright bands at flip angle=4. (b) Activated motor cortex area is depicted in functional activation map. (c) The time-series of a voxel with only phase activation. (c) A voxel time-series with magnitude-only activation. Red lines show activation states.

Results

Figure 1 (a) shows A-BOSS magnitude image. The time series for magnitude and phase, resulted from A-BOSS at two sample active points, is shown in figure1 (c) and (d); At some points, the activation pattern is observed in the phase (phase-only activated voxels figure 1 (c)), while for some other points, magnitude reveals the activation (figure 1 (d)). Panel (b) shows a collection of these active points shown as yellow pixels. These activated voxels are part of motor cortex area due to finger-tapping of the right hand, as verified with the EPI activation map in figure 2. Figure 2(b) depicts time-series of a voxel in the activated area for the EPI analysis. The A-BOSS signal (variation of magnitude in its time-series) was almost 8 times larger than the one acquired from EPI results.

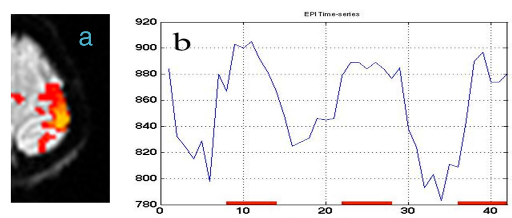

Figure 2 (a) EPI activation map for right-hand finger-tapping task. (b) The time-series of a voxel with maximum activity.

Discussion

In this implementation of the A-BOSS method, it is not practical to exactly set the SSFP profile period equal to the pixel size. Therefore, the signal uniformity within a voxel is hardly achievable as it is evident in the dark lines created in figure 1(a). Another point to be mentioned is the fact that when the extra constant gradient is aligned with the phase encoding direction, the resulting image experiences a geometric distortion. In this work, we performed some statistical and simple prestatistical analysis on A-BOSS functional data to evaluate the feasibility of the method. All the prestatistical processes are needed in order to confirm the effectiveness of the proposed method in detecting all activated voxels due to a brain task.

Conclusion

To overcome the limitations of BOSS method including a need for careful shimming and multiple acquisitions, we proposed an approach, named A-BOSS that does not require exact shimming neither multiple acquisitions. The activated area detected through A-BOSS is in accordance with that of BOLD but with considerably higher signal level.

References

[1] Scheffler, et al. NMR Biomed, 2001; 14: 490-496. [2] Lee, et al. MRM, 2008; 59:1099–1110. [3] Miller, et al. MRM, 2003; 50: 675-683.