Inflow Effects on Hemodynamic Responses Characterized by Gradient-echo BOLD Functional MRI

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Introduction

Inflow contribution on BOLD-fMRI signal can be significant when a short repetition time (TR) and large flip angle (FA) is used in a single-shot gradient-echo (GE) EPI sequence [1]. Since the inflow effect is different than BOLD in origin, its contribution could distort the hemodynamic response estimated in an event-related fMRI experiment. One important feature of the hemodynamic response (HR) is the latency following stimuli or tasks, which can be potentially linked to timing of neuronal events. Thus the temporal variation of the HR measured within a functional area will be an indicator of temporal resolution of BOLD signal responses [2]. In this study, we investigated the effects of the inflow on the measured HRs by comparing latency, falling time (FT), and full-width-at-half-maximum (FWHM). In addition, HRs obtained in each activated pixels were analyzed quantitatively and the latency variation were compared at the same contrast-to-noise ratio (CNR) level. GE-EPI with different FAs at a TR of 1s was used for experiments on a 3T and a 1.5 T MRI scanner.

Materials and Methods

Seven normal volunteers participated in this study (n=4 at 3T, n=3 at 1.5 T). The experiments were performed on a 3 T Magnetom Tim/Trio and a 1.5T Magnetom Vision MRI scanner. The paradigm consisted of 30 repeated trials with each trial consisting of 1-s visual stimulation followed by 15-s fixation. The BOLD imaging was acquired by using a single-shot GE-EPI sequence with TR=1s, TE = 30 ms for 3T and 60 ms for 1.5T, FA= 30^0,60^0,90^0 in separate runs, FOV = 211 cm, single slice thickness = 7mm covering the visual cortex and matrix size = 64×64. Activated pixels (corrected p<0.05) in visual ROI were used to determine the HRs as averaged over 30 trials. Those HRs were fitted with a gamma variant function from which the BOLD contrast, time-to-half-maximum (TTHM), FT, and FWHM were determined. For comparison, a canonical HR function was obtained using the spm_hrf.m program provided with the SPM2 software package, and the TTHM, FT, and FWHM of the hrf were determined to be 3.11 s, 7.97 s and 4.86 s, respectively. To assess latency variability at different CNR, signal time courses (TCs) from different number of randomly selected trials (30, 20, and10 trials) were averaged and TTHM was determined on a pixelwise basis.

Fig. 1

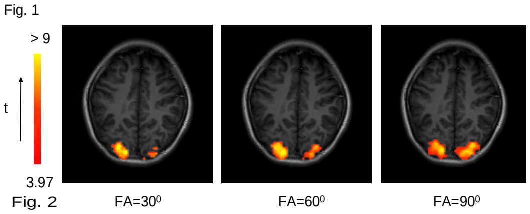


Fig. 2

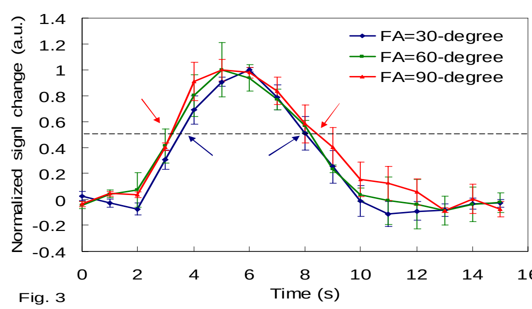


Fig. 3

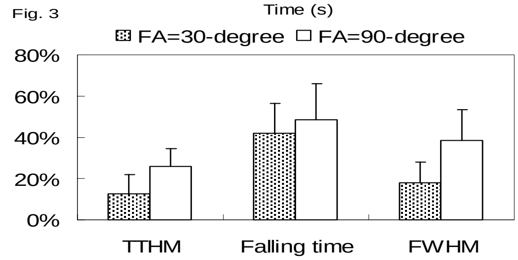
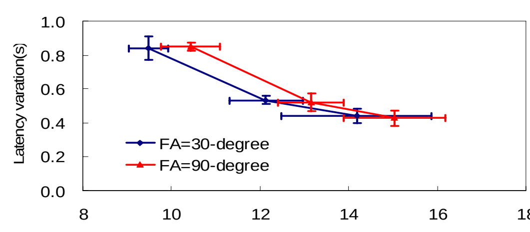


Fig. 4



Results

Results obtained at 1.5 T did not indicate significant signal increases from the inflow, therefore the activated TCs were analyzed for the 3 T datasets. Fig.1 illustrates the functional activations detected in visual cortex ROIs for one of the subjects with different FAs. BOLD contrast increased as FA increased: 0.62 ± 0.02, 0.64 ± 0.19 and 0.72 ± 0.12 % for 30^0, 60^0 and 90^0, respectively. Fig.2 compares the temporal behaviors of the three normalized TCs. BOLD responses with FA = 30^0 exhibited latencies significantly slower than those with FA = 90^0 (3.73 ± 0.16 s vs. 3.39 ± 0.12 s, p = 0.01). In contrast, the FT of the 30^0-FA responses were earlier than that of the 90^0-FA, but the differences did not reached statistical significance (7.86 ± 0.39 s vs. 8.35 ± 0.59 s, p = 0.08). Comparing with the canonical hrf obtained from the SPM2 software package, Fig.3 illustrates the percent activated pixels that have shorter TTHM, longer FT and wider FWHM for both 30^0- and 90^0-FA conditions. The results indicated that the 90^0-FA response was more similar to the canonical hrf, whereas the 30^0-FA response appeared to be sharper. Fig.4 shows the relationships between latency variation and CNR as averaged over four subjects. Comparing at same CNR levels along the curves, the 90^0-FA data showed generally greater latency variations than 30^0-FA.

Discussion

The BOLD contrasts were influenced by inflow effects at short TR and large FA at 3T. However, 1.5 T datasets did not show the same consequence. It might be resulted from the negative inflow effect due to increased CBV during activation [3], thus the inflow contributions averaging across the ROI might be neutralized. Our 3T results demonstrated that the positive inflow signal in the 90^0-FA condition correlated with shorter TTHM, longer FT and wider FWHM, comparing to that in the 30^0-FA condition. These might resulted in an increased latency variation from the inflow. This study suggested that the inflow effect in the GE BOLD signal needed to be taken into account when the timings of HR were of interest.

References

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3. Lu H, et al., Neuroimage., 2002,17:943-955