Optimization of diffusion-weighted fMRI at 3T MRI compare with BOLD-fMRI

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Introduction:

Functional MRI (fMRI) using high b-value diffusion weighted gradient provides the chance to represent the cellular microstructure change relating to neuronal activation by detecting the water motion in tissue (1). Several studies showed that diffusion-weighted functional MRI (DfMRI) technique could provide finer spatial accuracy and faster response of neuronal activation comparing with BOLD-fMRI (2, 3). However, low signal-to-noise ratio (SNR) due to long echo time and signal decay at high diffusion sensitivity causes the increase of scan time for a sufficient statistics power, and hence handicaps the applications of DfMRI on clinical and psychological fields. Therefore, the aim of this study is to optimize the b-value for DfMRI by considering the temporal and spatial performance during a visual stimulation at 3T MRI. The results showed that a b-value of 1,200 s/mm^2 should be a better choice for DfMRI comparing to b-values of 600 and 1,800 s/mm^2.

Methods and material:

All MRI images were carried out on a 3T system (Siemens, Germany) with a 12 channel-arrayed head coil. Each scanning session consisted of one gradient-echo (GE) fMRI (TE = 30 ms), three spin-echo (SE) fMRI (TE = 70 ms), and 20 DfMRI (TE= 95 ms) with same b-value (600, 1,200, or 1,800 s/ mm^2). Eight oblique slices centered on calcarine fissures were acquired for functional images. In each run, 10 seconds initial scan with TR=1000 ms was followed by a five-trials visual stimuli, containing 10 seconds stimulation (black-and-white flickering checkerboard at 7.5 Hz) followed by 20 seconds resting period in each trial. Total 18 healthy males (every six males for each single b-value) participated in this study. After acquisition, fMRI data were initially corrected for slice-acquisition order and motion, and then registered to the individual high-resolution anatomic images followed by spatial smoothing with a Gaussian filter by using SPM5 software.

The region of interest (ROI) for evaluating temporal and spatial performance were defined as the overlap of largest contiguous regions (P<=0.001) activated in SE, GE, and Diffusion fMRI. Three parameters, CNR (contrast-to-noise ratio), rise time and decay time, were adopted to compare the temporal characteristics between SE, GE, and diffusion fMRI. CNR equals the temporal SNR (tSNR) multiplied by signal change (SC) as in (4). The group averaged signal was used to calculate the rise and decay times by comparing fMRI time course to experimental design using normalized root-mean-square (nRMS) method (3). The points during the stimulus time frame (0~10 secs) and the points between the stimulus offset and the point of the diffusion time course crossing the baseline were selected for the analysis of rise time and decay time, respectively. Furthermore, to investigate the performance of spatial localization, we discussed the ratio of activating volume in brodmann area 17 and 18, well-known as the primary visual cortex and the extrastriate cortical areas, over whole activating volume.

*Table 1. The rise and decay times of SE and diffusion fMRI at different b-values compared with GE-fMRI. (P<0.05 *, P<0.005 **)*

Parameters	GE-fMRI	SE-fMRI	DfMRI (b-value = 600)	DfMRI (b-value = 1200)	DfMRI (b-value = 1800)
Rise time	4.5±1.45	4.5±1.03	2.6±1.14 *	2.4±0.67 **	2.4±0.95 **
Decay time	6.2±1.26	6.1±1.01	4.7±1.63	4.6±0.29 **	5.1±0.88 *

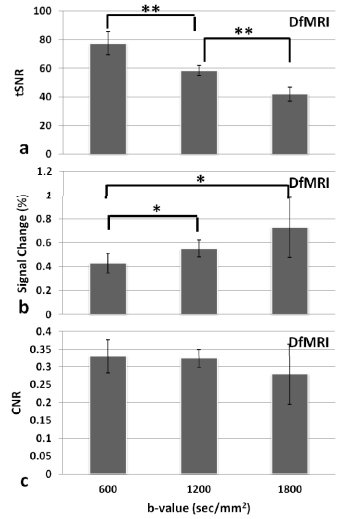

*Figure 1. DfMRI image quality of (a) tSNR, (b) SC, and(c) CNR with DfMRI at different b-values. (P<0.05 *, P<0.005 **)*

Results:

Figure 1 presents the tSNR(Figure 1a), SC(Figure 1b), and CNR(Figure 1c) of DfMRI at different b-values. The tSNR decreases and SC increases as the increase of b-value, but no significant difference in CNR. Figure 2a showed the group averaged time courses of SE, GE, and diffusion fMRI at different b values. The normalized time courses were shown in Figure 2b. Table 1 listed the rise and decay times of SE, GE and diffusion fMRI at different b-values. The results in figure 2b and table 1 showed the rise times of the DfMRI with all b-values were faster than GE-fMRI significantly and has no significant difference within DfMRI. Figure 3 presents the activation maps (figure 3a), cluster sizes (figure 3b), and volume ratios in BA17 and BA18 (figure 3c) between SE, GE, and DfMRI at three b values. The cluster sizes of all DfMRIs were significantly smaller than that in GE and SE trials (Figure 3a and 3b). Figure 3c showed that the volume ratios in BA17 from DfMRI at b=1200 and 1800 s/mm^2 (22% and 28%, respectively) were significantly greater than that from GE-fMRI, SE-fMRI, and DfMRI at b=600 s/mm^2 (11%, 13%, and 11%, respectively).

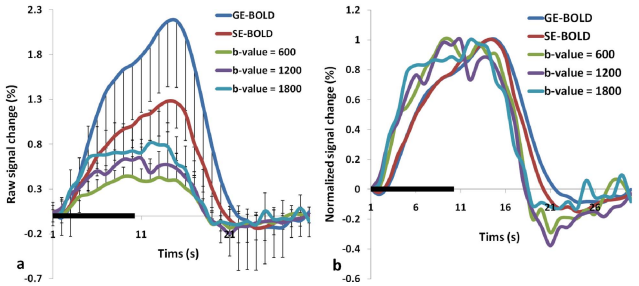

Figure 2. The mean signal time course (a) and normalized signal time course (b) in fMRI.

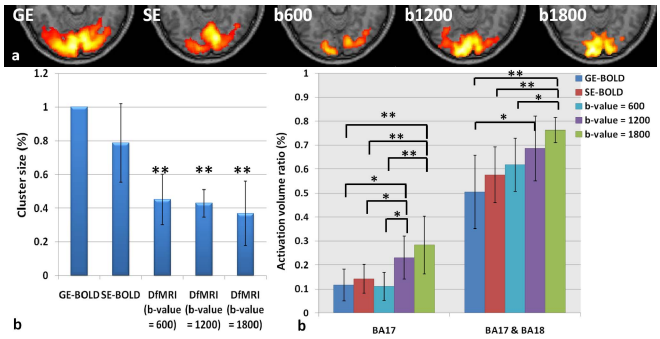

*Figure 3. The upper row (a) shows the SPM activation maps in one subject. DfMRI mean cluster sizes (b) and activation volume ratio in BA17 and BA17&BA18(b) (P<0.05 *, P<0.005 **)*

Discussion and Conclusion:

The results showed that DfMRI at b=1,200 s/mm^2 provide similar performance in rise time, decay time and spatial localization as DfMRI at b=1,800 s/mm^2. Although the result of CNR showed no significant difference between DfMRI at b=1,200 and 1,800 s/mm^2, we observed that the variation of CNR at b=1,200 s/mm^2 is smaller than that at b=1,800 s/mm^2. Furthermore, a lower TE, reducing the vascular component and increase image SNR in DfMRI, could be achieved at b=1,200 s/mm^2 comparing with b=1,800 s/mm^2. Therefore, we suggest that b=1,200 s/mm^2 is a better choice for DfMRI. In addition, higher volume ratio in BA17 from DfMRI implies that DfMRI probes the mechanisms closer to neuron activation than hemodynamic response and might provided the chance to approach the neuron activation.

References:

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