Somatosensory fMRI at 1.5, 3 and 7 T: Measuring BOLD Signal Changes

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Introduction

With ever increasing magnetic field strengths available for fMRI, it is important to explore the advantages that such high fields can bring to functional MRI experiments. Here, a comparison of the BOLD signal changes in somatosensory fMRI experiments carried out at three field strengths (1.5, 3 and 7 T) is presented. Images were acquired at an isotropic spatial resolution of 3 mm, as is commonly employed in current fMRI studies.

Methods

fMRI acquisition Six subjects were scanned on 1.5, 3 and 7 T Philips Intera Achieva scanners with the standard T/R head coils. Images were acquired using a FFE-EPI sequence with a 64 x 64 matrix and 3 mm isotropic resolution. fMRI experiments were performed at four echo times at each field strength (1.5T: 30, 50, 70 and 80 ms; 3T: 20, 35, 50 and 65 ms; 7T: 16, 25, 34 and 43 ms). The order of data acquisition of the fMRI experiments was randomised for each subject across field strengths and echo times. 14 contiguous transaxial slices covering the primary somatosensory cortex (SI) were acquired every 2 s throughout the fMRI paradigm. Physiological data from a respiratory belt and pulse oximeter attached to the index finger of the right hand, were logged to allow subsequent correction of data for signal fluctuations linked to respiratory and cardiac cycles. Following the fMRI experiments, T_1- weighted-3D anatomical images and a whole-head EPI data set were also acquired to aid spatial normalisation to MNI space.

Paradigm: A piezoelectric bender element with a contactor of 8 mm diameter was used to deliver vibrotactile stimulation of 400 µm peak-to-peak amplitude at 30 Hz to the tip of the thumb of the left hand. The paradigm consisted of eight cycles each made up of an 8 s ON-period followed by a OFF period of 20.25 s duration.

Analysis: fMRI data were corrected for the effects of signal variation linked to respiratory and cardiac cycles using RETROICOR [1] before further processing in SPM2. The following procedure was applied to all fMRI data sets. Image data were first corrected for slice timing and realigned. Images acquired at different echo times were co-registered to the whole-head EPI dataset and then normalised to the MNI space. Spatial smoothing with a Gaussian kernel of 4.5mm FWHM and high-pass temporal filtering with a cut-off period of 128 s were applied. The data were then modelled by convolving the paradigm time course with a canonical HRF with the motion parameters being used as confounds. Statistical parametric maps were thresholded at an uncorrected p–value of 0.001. An ROI in SI was then formed for each subject using these SPM's. This involved generating an ROI from the SPM cluster at the echo time showing the largest extent of activation, at each field strength. The conjunction of these ROI's was then generated using the MarsBaR add-on to SPM2 [4], and the signal time-course at each echo time for each field strength extracted from this region for subsequent analysis. The average fractional signal change between the ON and OFF conditions was obtained fom each extracted time course, at each echo time and field strength. These data were then averaged across subjects. Simple analysis indicates that the fractional signal change due to BOLD effects scales as $|\Delta R_2^* \times TE|$ [2] so that linear regression against TE allowed evaluation of the value of ΔR_2^*.

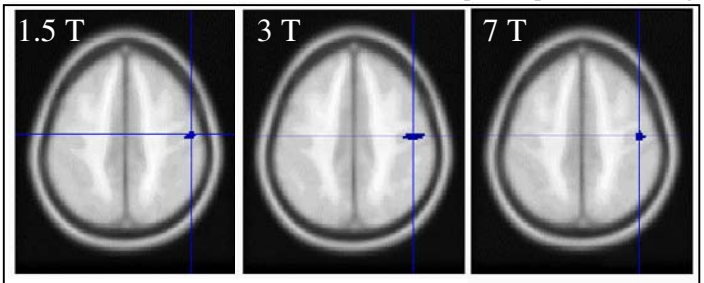

Figure 1 Activated areas in SI at the three field strengths in one subject.

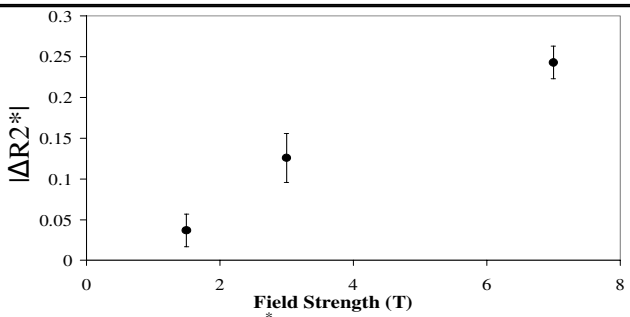

Figure 2 Variation of $|\Delta R_2^*|$ with field strength.

Results and Discussion

Figure 1 shows the clusters in SI identified in the first stage of analysis for one subject at the three field strengths indicating significant overlap of activated areas. The centres of mass of the clusters in MNI space are: 1.5 T (54, -12, 44), 3T (48, -14, 44) and 7T (48, -14, 46). Percentage signal changes found in the ROI's from the four subjects analysed to date are small (< 2 %) even at the highest field strength, but are found to increase with increasing echo time and field strength. By fitting the average signal change as a function of TE, the following ΔR_2^* values were found : 0.04± 0.02 s^{-1} @ 1.5T, 0.13± 0.03 s^{-1} @ 3 T and 0.24 ± 0.02 s^{-1} @ 7 T, as shown in Fig. 2. Largest signal changes occurred in the data acquired at echo times of 70 ms @ 1.5 T, 35 ms @ 3 T and 25 ms @ 7T.

The ΔR_2^* values found here are smaller than those described in previously published work [2,3], which has focussed on visual stimulation and employed high spatial resolution. However, there are several factors to explain this difference. In this study, activation is measured in the somatosensory cortex, with relatively weak, focal stimulation. The BOLD effect is further reduced by partial volume effects at the coarse spatial resolution used here. Finally, the ROI's were not chosen using the voxels with maximum Z-scores, but from the areas of overlap in activation maps at different field strengths. The signal change found, and thus the ΔR_2^*, is likely to increase when smaller ROI's are selected.

Conclusions

ΔR_2^* measured in the somatosensory cortex at 3 mm isotropic resolution during vibrotactile stimulation is shown to increase with field strength. This leads to an increase in absolute BOLD signal change with B_0 in experiments carried out at the optimal echo time ($TE = T_2^*$). In conjunction with the gain in SNR offered by high field imaging, this increase can be translated into a reduction of the minimum number of cycles needed in fMRI experiments.

References

(1) Glover G *et al. Magn Reson Med.* 44 162-7 2000. (2) Gati, J. *et al. Magn Reson Med.* 38 296-302, 1997 (3) Yacoub E. *et al. Magn Reson Med.*38 296-302, 1997 (4) Brett, M. *et al* Proc. HBM 2002, Vol 16, No 2