DISTORTION FREE, BOLD-CONTRAST FMRI USING A K-T ACCELERATED SPIN-ECHO BASED APPROACH AT 7 TESLA

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Introduction

As imaging at ultra high field strengths becomes a reality, motivation increases to maximally exploit the signal to noise ratio (SNR) advantage, and minimise problems associated with increased B_0 inhomogeneity. Measuring T_2* weighted blood oxygen level dependent (BOLD) signal changes for functional MRI using echo planar imaging (EPI) presents a particular challenge(1). Spin-echo based approaches do not suffer from the signal drop-out and distortion that plague EPI(2), but demand longer acquisition times and higher RF power deposition. The aim of this study was to establish the feasibility of the spin-echo based method, displaced UFLARE(3), for fMRI at 7 Tesla. Spatio-temporal correlation (k-t)(4) parallel imaging was applied in order to reduce the specific absorption rate (SAR) and to achieve the temporal resolution necessary for fMRI.

Methods

Normal volunteers were imaged at 7.0 T (Achieva, Philips Medical Systems, Best, Netherlands), using a sixteen channel receive- and a volume transmit coil (Nova Medical, Wilmington, MA, USA); two slices of thickness 3.5 mm; 128x128 matrix; 230x187 mm FOV; with TR 4000 ms. T_2*-weighting generated by TE = 20 ms for EPI (SENSE(5) factor 3), and echo shift (τ) = 20 ms for UFLARE (with 5 dummy echoes). Displaced UFLARE was combined with k-t data reduction factors of 2, 5, 8 and 16 to measure neuronal activation using a paradigm of six blocks (11 scans on/ 11 scans off) of right handed finger tapping.

Results

Displaced UFLARE images acquired at 7.0 T are of excellent quality, even at k-t factor 16, while significant image distortion is apparent in EPI (*Figure 1*). BOLD signal intensity time courses in a region of interest (ROI) in the motor cortex of a volunteer performing finger tapping are shown in *Figure 2*. Brain activation maps are seen in *Figure 3*. Echo train lengths were 73 for full data acquisition; 36, 14, 9 and 4, at k-t factors of 2, 5, 8 and 16, resulting in SAR of 1.3, 0.8, 0.7 and 0.6 Wkg^{-1} respectively. The refocusing flip angle was $\alpha=100^0$ for accelerated acquisitions, but was restricted to 80^0 for full data, in order to remain within SAR limits (2.1 Wkg^{-1} compared with 1.4 Wkg^{-1} in the head with $\alpha=100^0$ and $\alpha=80^0$).

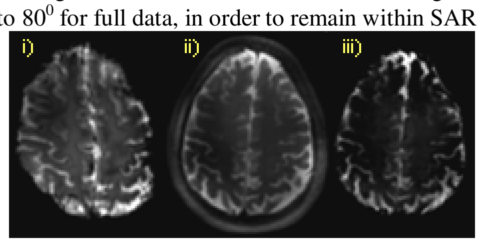

Figure 1: Comparison of EPI (i) with k-t accelerated displaced UFLARE, k-t factor = 16 with T_2- (ii) and T_2*- (iii) weighting (τ = 0 ms, 20 ms respectively). Gross distortion of EPI is apparent, whereas even at a k-t data reduction factor of 16, excellent image quality is achieved in the spin-echo based images (ii and iii).

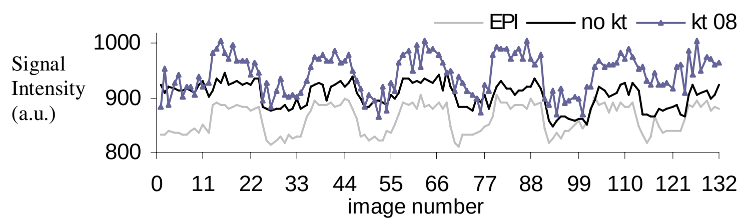

Figure 2: Signal intensities in a ROI in motor cortex during finger-tapping in a single volunteer: EPI with SENSE factor 3, displaced UFLARE without data reduction (no kt) and with k-t factor 8 (kt 08). Signal changes of approximately 6 % were observed in each data set.

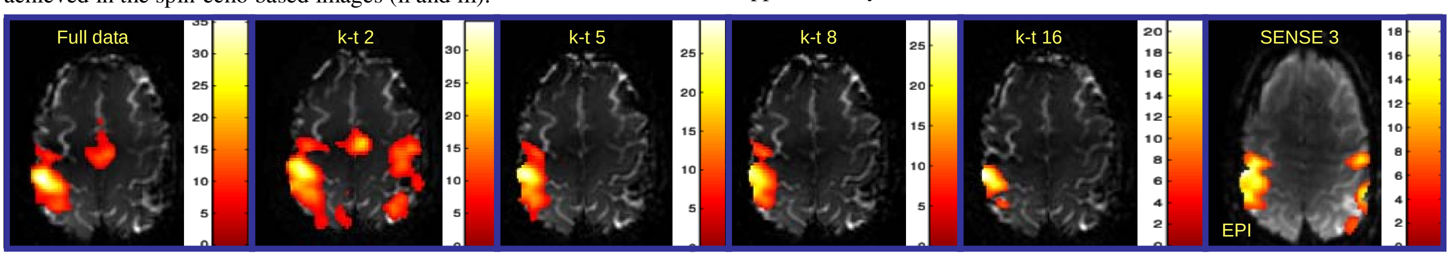

Figure 3: BOLD signal responses to block design finger tapping using displaced UFLARE without ("Full data") and with k-t BLAST factors 2, 5, 8 and 16. Results from EPI at SENSE factor 3 are shown for comparison. Differences in activation patterns may be attributable to natural physiological variation and training effects (the k-t 2 images were the first to be acquired). Analysis: spm5 (www.fil.ion.ucl.ac.uk/spm/) using $p < 0.0005$, FWE-correction, threshold = 100 voxels.

Discussion and Conclusions

Results of this study demonstrate the successful combination of k-t BLAST with a spin-echo based approach to reduce acquisition time and SAR for fMRI at 7 Tesla. Functional brain activation has been measured at k-t data reduction factors as great as 16, albeit with diminished sensitivity relative to that with k-t $\leq$ 8 and limited reduction of SAR, due to the need to acquire training data. k-t accelerated displaced UFLARE presents new possibilities for investigations of brain function, for example through regionally optimized T_2* weighting to maximise BOLD sensitivity, and exploiting the potentially superior spatial specificity of T_2-weighted BOLD fMRI (6). The exciting possibilities of applying k-t methods to event related functional paradigms and to the acquisition of high spatial resolution T_2- and T_2*- weighted BOLD contrast fMRI remain to be explored.

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