A Multi-Resolution Comparison of Single-Shot EPI, 3DFFE and PRESTO for fMRI at 7T

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INTRODUCTION

Single-shot Echo-Planar Imaging (EPI) is the sequence most commonly used for fMRI experiments. At high field, e.g. 7T, magnetic field inhomogeneities cause spins to become out of phase quickly, and distortion and signal dropout become severe [1]. Consequently, single-shot EPI fMRI suffers technical limitations at high field. Here we consider two alternatives to EPI for high field fMRI: 3D Fast Field Echo (FFE), a multi-shot EPI sequence, and 3D PRESTO (Principles of Echo-Shifting with a Train of Observations), a 3DFFE-based sequence that uses echo-shifting to achieve efficient T2* weighting [2][3][4]. Recently Neggers et al. (2008) have demonstrated increased fMRI sensitivity in 3D PRESTO-SENSE compared with single-shot EPI for a low-resolution, full-brain scan at 3T [5]. Even though the observed percent signal change was lower for 3D PRESTO-SENSE compared with EPI, the time course was more stable, leading to better fMRI sensitivity [5]. In light of the SNR benefits associated with increasing B_0 and the difficulties facing full-brain single-shot echo planar fMRI at high field, a detailed comparison of EPI and alternate sequences for high field fMRI is warranted. Here we consider the fMRI performance of EPI, 3DFFE, and 3D PRESTO at four different resolutions for a visual and motor fMRI task at 7T.

METHODS

Seven healthy adult subjects were scanned on a Philips Achieva 7T scanner with a 16 channel SENSE receive-only head coil with an outer quadrature transmit coil. Subjects were presented with a flashing checkerboard wedge (8Hz) which occupied 30 degrees of the left visual field. Subjects were instructed to ignore the wedge and to press a button with their right index finger when a small dot appeared in the center of their visual field. This stimulus was presented in seven forty-second intervals (20s of rest followed by 20s of stimulus, with an additional 20s rest at the end for a total of 300 seconds). Data were acquired for both EPI and 3DFFE or 3D PRESTO at four different isotropic resolutions (EPI/3DFFE: 1mm^3, 1.2mm^3, 1.75mm^3; EPI/PRESTO: 3mm^3), for a total of 8 runs per subject. All sequences used TE = 25ms and SENSE acceleration of ≈2 in the phase encoding direction. The 1mm^3 and 1.2mm^3 geometry covered roughly the same area over the visual cortex with 26 and 24 slices, respectively. The 1.75mm^3 geometry covered the visual cortex and primary motor area with 33 slices. The 3mm^3 geometry covered the entire brain with 32 slices. Other parameters: EPI 1mm^3: TR = 2s, EPI factor = 41; EPI 1.2mm^3: TR = 2.5s, EPI factor = 35; EPI 1.75mm^3: TR = 3.33s, EPI factor = 41; EPI 3mm^3: TR = 3.33s, EPI factor = 27. All 3DFFE scans had an EPI factor of 13. The 3DFFE scans had TR = 3.33s for 1mm^3 and 1.2mm^3, 4s for 1.75mm^3, and 1s for 3mm^3 3D PRESTO. SPM5 (Wellcome Department of Cognitive Neurology, London, UK) was used to correct the EPI data for slice-timing and to measure fMRI activation. Whole-brain maximum t-values and number of activated voxels were measured for each run with activation maps thresholded at $p < 0.00001$ and a minimum cluster size of 5 voxels.

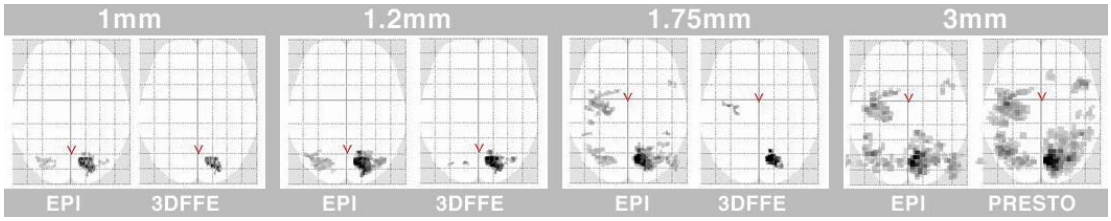

Fig. 1: Activation maps for each acquisition in one representative subject.

RESULTS

Figure 1 shows activation maps for each acquisition in one subject. Figure 2 shows the maximum t-values for EPI, 3DFFE, and 3D PRESTO for four different resolutions. For voxel sizes ≤ 1.75mm^3, the EPI scans showed an average of 55% higher maximum t-values and 210% more activated voxels than their 3DFFE counterparts. At 3mm^3, PRESTO had an average maximum t-value of 48% larger, and a mean activated voxel count of 17% greater, than that of EPI.

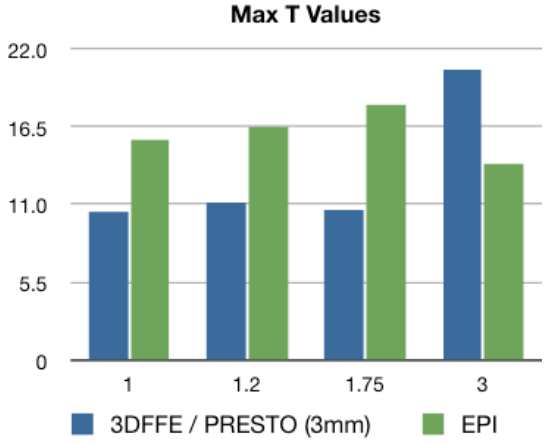

Fig. 2: Maximum t-values, averaged across subjects.

DISCUSSION

While the activation maps produced by both EPI and 3DFFE/PRESTO were qualitatively similar, we observed that single-shot EPI produced larger numbers of activated voxels and more highly significant activations than 3DFFE in our high-resolution, limited field-of-view (≤1.75mm^3) fMRI trials. The opposite was true for low resolution, full-brain fMRI. However, more activated voxels and higher t-values do not necessarily mean that one sequence is superior. For example, we have observed decreased distortion in the 3DFFE and PRESTO scans compared with EPI, and the ability of the 3D sequences to benefit from parallel imaging acceleration in two directions instead of just one makes these sequences potentially more time-efficient than EPI. This is especially true of PRESTO, which further maximizes scan time efficiency through the use of echo-shifting. On the other hand, multi-shot techniques are inherently more sensitive to between-shot motion and phase errors [5]. These results demonstrate that 3DFFE and PRESTO are strong candidates for high field fMRI applications at a variety of resolutions, and that in some cases these sequences appear to be more sensitive to BOLD activation than single-shot EPI.

REFERENCES

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