Comparitive evaluation of a multi-echo fMRI acquisition technique using parallel imaging

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Introduction A multi-shot multi-echo EPI has recently been presented for perfusion mapping [1]. Interleaved EPI readouts are acquired, which reduces the well-known blurring and susceptibility distortions of EPI. Temporal localization is provided by an autocalibrating PI reconstruction, where each interleaf of the first echo is combined to form a fully sampled k-space, which is then used for PI calibration. The shortened readouts also allow multiple gradient echoes to be acquired between the excitation and normal fMRI TE time. The use of PI and multi-echo EPI for fMRI has recently been explored [2], and it was found that by using T2* weighted echo combination the BOLD signal loss caused by the lower SNR from the reduced sampling times in PI could be compensated. Here, a multi-shot multi-echo EPI sequence has been used to examine the impact of PI reduction factor (R) combined with multi-echo T2* mapping on fMRI BOLD activation.

In this study, we compared PI reduction factors of 2 and 4 using multi-shot acquisitions with single-shot (R=1) acquisitions, as well as used an interleaved 4-shot acquisition that allows reduction factors of 4, 2, or 1 from the same data. The lower reduction factors increase SNR, but at the penalty of temporal resolution. The multi-echo acquisition as performed here can be used for calculation of a T2*-map. Its temporal variation can be taken as a basis for assessing potential activation in the brain.

Methods A multi-echo multi-shot EPI sequence was implemented on a 1.5T unit (GE Signa 12X EXCITE, grads = 50 mT/m, SR=150 T/m/s). Four different scans were performed using an 8-channel phased-array coil (MRI Devices, Waukesha, WI): 1) a single-shot single-echo acquisition (TE=50ms) with R=1, 2) Two-shot two-echo (TE=19.4, 49.7 ms) with R=2, 3) 4-shot 4-echo acquisition (TE=12.4, 27.3, 42.2, 57.1 ms) with R=4, and 4) a 4-shot 4-echo acquisition (TE=12.4, 27.3, 42.2, 57.1 ms) that allowed R=4, 2, or 1. The parameters for all scans were: matrix = 96×96, FOV = 24 cm, slice thickness 5 mm (skip 0.5 mm), 20 slices, TR = 2000 ms, flip angle 80°. As an fMRI paradigm, a combined auditory and visual stimulus was presented to the volunteer during which they were asked to perform bilateral finger tapping. This paradigm was repeated 8 times for 24 seconds, interrupted by a 24 second long rest period, starting with rest, totaling 6:32 minutes scan time including 4 discarded initial acquisitions. For the scans with R>1, parallel imaging reconstruction was performed using GRAPPA [3], where the first R shots of the first echo image were combined to form a fully sampled k-space. Afterwards each shot of each echo, slice, and timepoint was separately reconstructed into a full FOV image using the determined GRAPPA weights from this first fully sampled volume. For postprocessing, the voxel-wise temporal signal curve was correlated with a sine wave (phase-offset adjusted in order to get maximal correlation using a similar method as described in [4]).

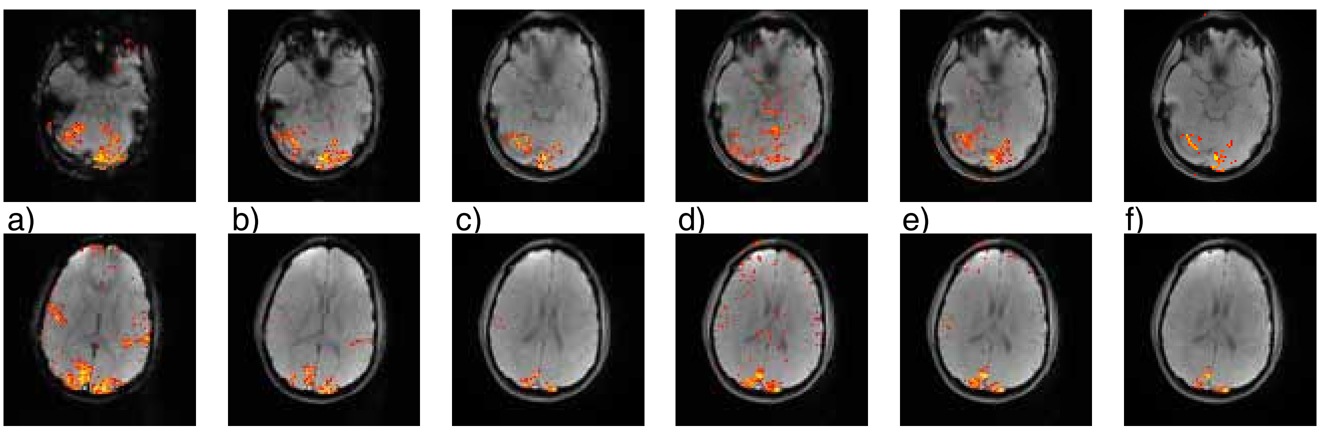

Fig. 1: Comparison of single shot R=1 (a), R=2 (b), R=4 (c), and multi shot R=1 (d), R=2 (e) and R=4 (f) for two selected slices

Results and Discussion Figure 1 shows the fMRI activation for two out of 20 slices. The most activation is seen in the single shot EPI images, however, there is considerably more false-positive activation in those images as well and large signal dropouts due to T2* susceptibility effects. Multi-shot images greatly reduced these areas of dropouts, as the shorter readouts reduced the susceptibility effects and the earlier echoes afforded the ability to estimate T2* in these areas. The least number of activated pixels are seen in the 4-shot images with reduction factor of 4, as the smaller activation for bigger reduction factors can be explained by the smaller SNR. Nevertheless, the activation seen in these images shows few, if any false positive voxels, but also much smaller regions of activation. Interestingly, the activation profile seems to be more accurate with the larger reduction factors, which are also the images which were acquired with more interleaves. This can be explained by reduced signal distortions due to the shorter readout time. The combination of the multi-shot acquisitions into smaller reduction factors shows much less BOLD signal, which is likely explained by the lower temporal resolution of the resultant datasets. Multi-shot, multi-echo acquisitions, however, do show promise for use in fMRI experiments, especially in studies of areas normally affected by susceptibility. Here, PI allowed the greatly reduced readout lengths, though at an SNR penalty, which may have been compensated by the multiple echoes.

	R=1	*R=2*	*R=4*	*R=1 MS*	*R=2 MS*	*R=4 MS*
Echo times (in ms)	50	19, 50	12, 27, 42, 57	12, 27, 42, 57	12, 27, 42, 57	12, 27, 42, 57
Nr of activated voxels (threshold r=0.4)	3401	1359	750	1730	1404	552

References [1] Newbould *et al.*, MRM in review, [2] Poser *et al.*, MRM 55:1227-1235, 2006, [3] Griswold *et al.*, MRM 47:1202-1210, 2002, [4] Glover *et al.*, MRM 39:361-368, 1998

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