Statistical significance of the BOLD response probed by RASER

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Introduction

T_2-weighted fMRI sequences provide advantages with respect to specificity to the site of neuronal activity at ultrahigh magnetic field since they are dominated by signal components originating from the tissue in the capillary bed. However, in conventional implementations, they suffer from inaccurate non-T_2 (i.e. T_2^*) contributions that arise from EPI which is typically used for spatial encoding. In this paper, the sensitivity of a novel T_2-weighted sequence RASER (rapid acquisition by sequential excitation and refocusing) [1], which eliminates this complication, to the BOLD response is quantified.

Methods

Experiments were performed on a 7 T Siemens scanner with a quadrature surface coil. Three volunteers participated in the fMRI study after written consent. 5 blocks of 30 s of flashing checkerboard alternated with 30 s of rest were presented. Gradient-echo (GE) EPI, spin-echo (SE) EPI, and RASER were separately used to detect activation in the primary visual cortex. In addition, baseline time series without stimulation were acquired. For the noise analysis, time series without transmitting RF pulses were also recorded. Imaging parameters were matrix size: 64x32, bandwidth: 2196 Hz/pixel, repetition time: 2 s. The echo times were 25 ms for GE-EPI and 66 ms for SE-EPI and RASER. *t*-maps were computed from the stimulation experiment. Trial averages were calculated from a region-of-interest (ROI) marking activated voxels in at least one of the *t*-maps for each subject. Temporal fluctuations for the same ROI were derived from the baseline time series and the noise scans to estimate physiological (σ_{phys}) and intrinsic (σ_{intr}) noise, respectively. The signal-to-noise ratio (SNR) represents the ratio of the physiological noise to the mean signal.

Results

In all subjects, significant activation was observed in similar regions of the primary visual cortex with the three pulse sequences. Figure 1 shows images acquired with the respective sequence and overlaid with the *t*-scores for one subject. The images were zerofilled to twice the matrix size and smoothed using a Gaussian filter with a half-width at half maximum of two voxels. The thresholds for the *t*-maps were adapted to optimally display activation for each sequence.

In Figure 2, trial averages of all subjects of a ROI in the visual cortex are plotted. The error bars represent standard deviation between subjects. GE-EPI shows the largest relative signal change as this method is T_2^*-weighted. RASER is purely T_2-weighted because all echoes in the echo train are acquired at exactly the same echo time. Since echoes with high phase-encoding values are not acquired at the nominal echo time in SE-EPI it has residual T_2^*-weighting [2]. The additional T_2^*-weighting of the signal of the SE-EPI causes a higher relative signal change than the one for RASER.

Table 1 shows the average relative signal change (ΔS/S), the ratio of the physiological noise versus baseline signal (SNR), the ratio of the physiological versus intrinsic noise ($\sigma_{phys}/\sigma_{intr}$), and the average *t*-score in a ROI in the primary visual cortex. The errors indicate the standard error of the variation between subjects for the relative signal change and the standard deviation between the subjects for the other parameters. The SNR is similar for all three sequences. However, $\sigma_{phys}/\sigma_{intr}$ for RASER is much smaller than for SE-EPI and GE-EPI. The average *t*-score of RASER is reduced compared to SE-EPI and GE-EPI. However, a much lower threshold can be chosen for *t*-maps obtained with RASER than for the ones generated with SE-EPI and GE-EPI without increasing the number of false positives (Figure 1). These findings suggest that the physiological noise in RASER is significantly reduced and, hence, temporal correlations in the noise in RASER contribute to the *t*-statistics to a much lesser extent than in the EPI sequences.

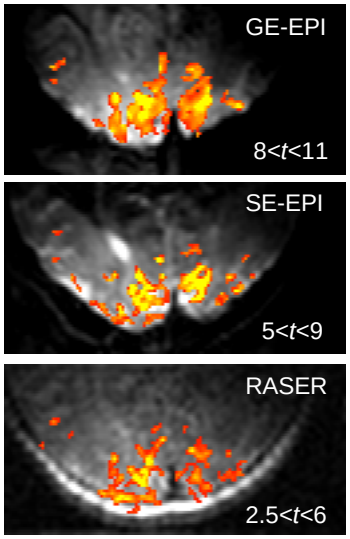

Figure 1

Conclusion

RASER is able to detect activation as well as SE-EPI although its maximal relative signal change is lower. As compared with GE-EPI and SE-EPI, RASER is expected to yield activation maps corresponding more closely with the actual sites of neuronal activation, because T_2^*-weighting is not present.

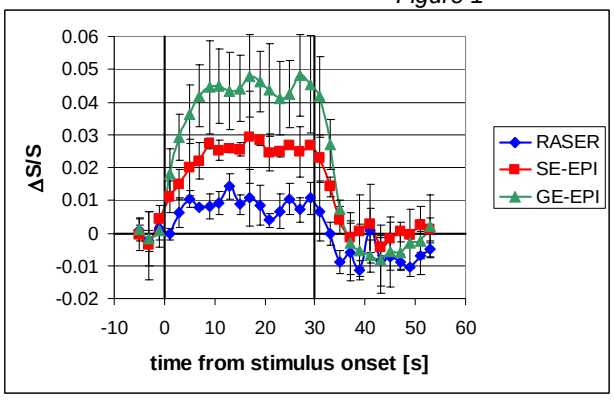

Figure 2

References and acknowledgments

[1] Chamberlain R *et al*, *MRM* **58**: 794 (2007); [2] Birn R *et al*, *Proc. ISMRM Honolulu, HI, USA* 2002: 1324

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Table 1

	ΔS/S [%]	SNR	$\sigma_{phys}/\sigma_{intr}$	$t_{average}$
GE-EPI	4.5±0.4	10±1	24±10	8±3
SE-EPI	2.6±0.1	13±2	9±3	4±2
RASER	0.9±0.1	12±4	1.75±0.07	1.8±0.9