# Distortion-free fMRI in the orbitofrontal cortex using RASER

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## Introduction

Gradient-echo echo planar imaging (GE-EPI) sequences are widely used for functional magnetic resonance imaging (fMRI). However, macroscopic magnetic field variations near air-filled cavities result in signal loss and geometric distortions in the images. $T_2$-weighted sequences mitigate such problems. Recently, a novel $T_2$-weighted fast imaging sequence, rapid acquisition with sequential excitation and refocusing (RASER) method, has been proposed [1]. In this paper, RASER is applied to fMRI of brain regions, which are challenging to image with conventional GE-EPI, such as the orbitofrontal cortex.

## Methods

In RASER, magnetization is excited with a 90º chirp pulse sequentially along one spatial dimension and refocused by two slice-selective adiabatic 180º hyperbolic secant pulses in the order of excitation. This method is referred to as time-encoding. The refocused echoes are frequency-encoded using alternating gradient pulses as in EPI. Fourier transform is performed in the frequency-encoded dimension, the time-encoded dimension requires only a linear phase-correction.

Images were acquired with Hahn spin-echo (SE) EPI and RASER on a 4 T Varian scanner using a TEM head coil. The imaging parameters were acquired matrix: 32 x 64, field-of-view: 110 x 220 mm$^2$, slice thickness: 5 mm, sweep width 150 kHz, and echo time: 65 ms. The duration of the 90º chirp pulse was 24 ms and the bandwidth time product 550. Furthermore, a functional study using GE-, SE-EPI, and RASER was run on the 7 T Siemens scanner with a head gradient insert and a 16 channel head coil. Two subjects performed the Stroop task, which consists of word pairs, in which in the color of the upper word has to be matched with the meaning of the lower word printed in black. Two blocks of 30 s of the congruent condition alternated with 30 s of the incongruent condition were presented. Each imaging sequence was used three times in a randomized order to eliminate habituation effects. A single slice through the orbitofrontal cortex was selected at a position at which activation was observed in reference [2]. The imaging parameters were field-of-view: 210 x 210 mm$^2$, slice thickness: 5 mm, matrix 64 x 64, repetition time: 2 s, readout bandwidth: 3906 Hz/pixel. The echo times were 25 ms for GE-EPI and 56 ms for SE-EPI and RASER. The bandwidth time product for the chirp-pulse for excitation in RASER was R = 1114 and the pulse duration was 19.08 ms.

## Results

At 4 T, a single slice, which is marked in $T_1$-weighted FLASH images in Figure 1a and b, was acquired with zoomed SE-EPI (Fig. 1c) and RASER (Fig. 1d) [1]. The average signal-to-noise ratio (SNR) was calculated for the marked regions. The SE-EPI image shows distortions and loss in SNR, which is not present in the RASER image.

For the Stroop task, similar results were found for the two volunteers. Figure 2 shows a single slice acquired with GE-EPI, SE-EPI, and RASER of a single subject. The overlaid thresholded *t*-maps mark differences in the activation of congruent versus incongruent condition of the Stroop-task. In GE-EPI, signal loss and geometric distortions are present in the orbitofrontal cortex. To a lesser extent, distortions are also visible in the SE-EPI image. They originate from residual $T_2^*$-weighting of echoes with high phase-encoding values which are not acquired at the nominal echo time [3]. RASER shows neither distortions nor signal loss since all echoes are acquired exactly at the echo time. Only with RASER, extensive activation is seen in the orbitofrontal cortex reproducing the observation at 3 T using SE-EPI [2].

## Conclusion

At ultrahigh magnetic field, image distortions and signal loss near air-filled cavities are severe, even for SE-EPI. With RASER, activation in critical regions, such as the orbitofrontal cortex, is recovered.

## References and acknowledgments

[1] Chamberlain R *et al*, *MRM* **58**: 794 (2007); [2] Norris DG *et al*, *Neuroimage* **15**: 719 (2002); [3] Birn R *et al*, *Proc. ISMRM Honolulu, HI, USA* 2002: 1324

Financial support by the grants P41 RR008079 and P30 NS057091, and the MIND Institute is acknowledged.

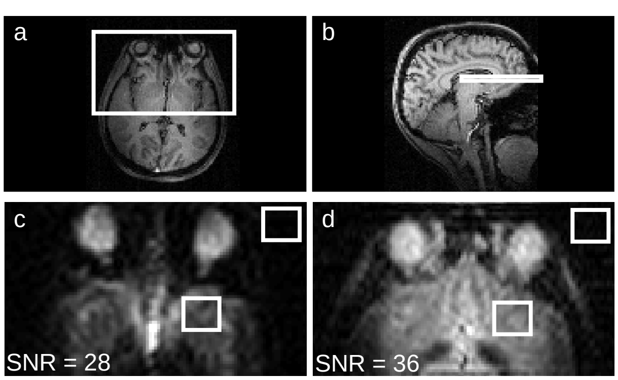


*Figure 1*

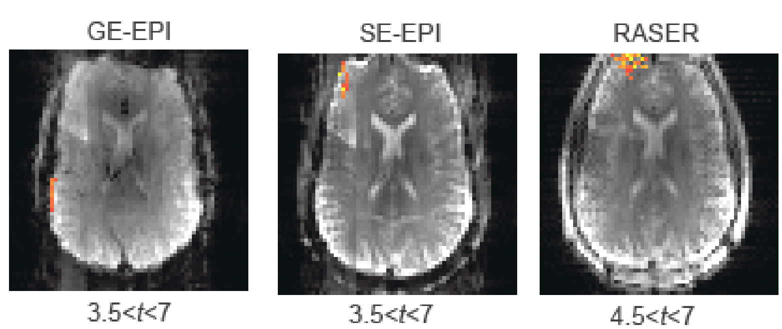


*Figure 2*