Functional MRI using Super-Resolved Spatiotemporally-Encoded Imaging Techniques

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Introduction

Recently, new single-shot imaging sequences such as RASER [1] and Hybrid SPEN [2] have been proposed, in which the phase-encoding of conventional EPI is replaced with spatiotemporal-encoding (SPEN) by employing frequency-swept excitation pulses. In contrast to EPI, SPEN provides significantly higher immunity to resonance frequency variations, like those caused by B_0-inhomogeneities and chemical-shift offsets. Utilizing the pure T_2-weighting and inherent robustness of RASER, this imaging method has successfully been used for performing fMRI in the orbitofrontal cortex, a challenging region to map using EPI due to strong field distortions near the air-filled sinuses [3]. Still, despite this superior performance, systematic analyses have shown that the signal intensity in SPEN images is lower and the RF power deposition higher, than in EPI-based methods. A recently developed reconstruction approach, based on super-resolution (**SR**) principles, has been shown to alleviate these shortcomings [4]. In this study we explore the SR processing in the context of fMRI of the human visual cortex, demonstrating the abovementioned properties and verifying that the statistical significance of the BOLD response is retained when this post-processing procedure is employed.

Methods

Experiments were performed on a 3T Siemens scanner with a four channels head coil. Seven volunteers participated in the fMRI study after signing a written consent. 10 blocks of 30 sec left and 30 sec right visual hemifield stimulation using a half circular shifting checkerboard pattern (consisting of black and white concentric rings) were used. Functional time series of single oblique slices along the calcarine sulcus were acquired using GE-EPI, SE-EPI and two SPEN based sequences: Hybrid SPEN [2] & RASER [1]. Imaging parameters were: matrix size=48x64, bandwidth=2004 Hz/pixel, TR=2 sec, $TE_{GE\text{-}EPI}$=30 ms, $TE_{SE\text{-}EPI}$=87 ms, TE_{RASER}=87 and $TE_{Hybrid\text{-}SPEN}$=[69..105] ms. Activation maps were computed based on statistical *t-test* of the experimental time series using STIMULATE software package [5].

Results

Significant activation of the left (violet) and right (yellow) visual cortex was observed for all subjects, and all imaging sequences. The attached Figure shows activation maps from one of the subjects, overlaid on anatomical FLASH images. SR reconstruction was used to process the data from which the activation maps in (**c**) and (**d**) were calculated. Quantitative analysis of the data showed an increase of *ca.* 250% in SNR when employing SR along with a decrease of a factor of 4 in the associated RF power deposition.

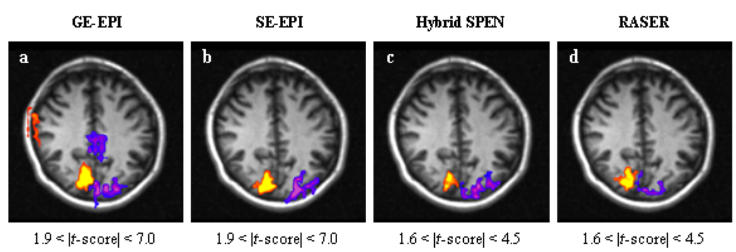

Figure 1: Comparison between fMRI maps arising from alternating left & right visual stimuli, based on the four different sequence schemes. All fMRI responses are shown overlaid on top of a multi-scan T_1-weighted FLASH image. (**a**) Gradient-Echo EPI (**b**) Spin-Echo EPI (**c**) Hybrid SPEN [2] (**d**) Spatiotemporally-Encoded RASER [1].

Discussion

The results of this study demonstrate the feasibility of incorporating SR reconstruction as part of the processing procedure of SPEN based fMRI experiments. Owing to the complete refocusing of T_2^* relaxation in SPEN [1-2], this method produces more spatially-localized activations maps, yet, having relatively lower *t*-score levels [3]. The use of SR is shown to retain the statistical significance of the BOLD response while increasing the calculated *t*-scores, and restoring the SNR to levels that are comparable to EPI. These improvements, along with the associated decrease in RF power deposition, enable to better utilize the immunity of SPEN to field distortion artifacts, and allow carrying out fMRI experiments with high spatial resolution, and at brain regions that are challenging to image using EPI-based techniques. The presented imaging approach is particularly attractive, considering the gain in T_2-contrast and SNR at high magnetic fields (7T) characterized by stronger field distortions, and for mapping functional brain activity of small anatomical structures.

References

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