

## T<sub>2</sub>-weighted BOLD fMRI at 9.4 T using a S<sub>2</sub>-SSFP-EPI sequence

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**Introduction:** It has been hypothesized that T<sub>2</sub>-weighted BOLD fMRI at ultra-high field shows higher spatial specificity than T<sub>2</sub>\*-weighted BOLD, since the main signal contribution is expected to come from the extravascular spins of the microvasculature [1-3]. Unfortunately, the number of slices that can be acquired in multi-slice SE-EPI is often highly limited at ultra-high field due to SAR constraints [1]. T<sub>2</sub>-weighted steady-state sequences, such as balanced SSFP and unbalanced S<sub>2</sub>-SSFP, have been previously used as an alternative to spin-echo based sequences in BOLD fMRI [4-6]. In this work, we present a 3D S<sub>2</sub>-SSFP sequence that is accelerated using an EPI readout in slice direction and show first results from finger tapping experiments at 9.4 T.

**Methods:** All experiments were performed at 9.4 T on a healthy volunteer with informed consent and approval by the local ethics committee. A custom-built head coil [7] was used for signal transmission/reception (16 transmit / 31 receive channels).

In order to allow for a short readout train, a 3D S<sub>2</sub>-SSFP-EPI sequence was developed with EPI blips applied in slice direction (foot-head). The acquisition of 12 slices required 11 phase-encoding steps (using slice oversampling and partial Fourier) that were acquired with an echo spacing of 0.84 ms (ETL = 9.24ms). Due to an imperfect slice excitation profile and the additional problem of EPI distortions/chemical shift artifacts in slice direction, it was necessary to use high slice oversampling (50%) in order to prevent fold-over artifacts in the outer slices. The other phase-encoding direction (RL) was acquired as in a conventional GRE (i.e. one step in each TR). The S<sub>2</sub>-SSFP-EPI was repeated twice (TR<sub>1,2</sub> = 15/25 [ms], TE<sub>1,2</sub> = 11/19.3 [ms], 1.5 mm isotropic resolution, TA per volume = 1.44/2.4 [s]). The flip angle was set to the highest possible value allowed by the SAR monitor (approx. [20°, 28°] in the motor cortex area). A simple finger tapping paradigm consisting of 20 s of rest followed by 20 s of tapping with the right hand was used in two 5¼ min functional scans (240/144 volumes).

For comparison, a SE-EPI with point spread function distortion correction [8] was acquired. Due to SAR limitations, it was only possible to fit 6 slices in a TR of 2 s (1.5 mm isotropic resolution, TE = 40 ms, GRAPPA R = 3, 6/8 partial Fourier). 160 volumes were acquired in a functional scan analog to the S<sub>2</sub>-SSFP experiments.

For analysis, the data were processed with FSL FEAT after brain extraction, using a standard hemodynamic response function and temporal filtering (no spatial smoothing). Resulting activation maps were registered to a high-resolution T<sub>2</sub>\*-weighted anatomical image (resolution = 0.19x0.19x1.0 mm<sup>3</sup>, TE/TR = 14 ms / 0.5 s, FA = 25°).

**Results:** Fig. 1 shows representative time frames from the SE-EPI and the two S<sub>2</sub>-SSFP experiments. Resulting activation maps overlaid on the reference image are presented in Fig. 2. Strong activations were found in all three datasets. However, BOLD signal from veins seems to be higher in the S<sub>2</sub>-SSFP data than in SE-EPI. Comparing the S<sub>2</sub>-SSFP datasets, activations from the long TR scan (Fig.2c) appear slightly stronger than in the other scan (Fig.2b).

**Conclusion:** The results show that the proposed S<sub>2</sub>-SSFP-EPI sequence is viable for high-resolution fMRI at 9.4 T. BOLD sensitivity was comparable to SE-EPI. However, preliminary data indicates that BOLD signal contribution from veins is higher in the two S<sub>2</sub>-SSFP experiments (Fig. 2bc) than in SE-EPI (Fig. 2a). Further work is required to examine whether this higher vein signal is caused by inflow effects, residual T<sub>2</sub>\*-weighting, and/or other effects. An advantage of the proposed method is that more slices can be acquired in a shorter time compared to SE-EPI since the latter is SAR limited at 9.4 T.

**References:** [1] Yacoub et al, *NeuroImage* 2005;24:738-50.

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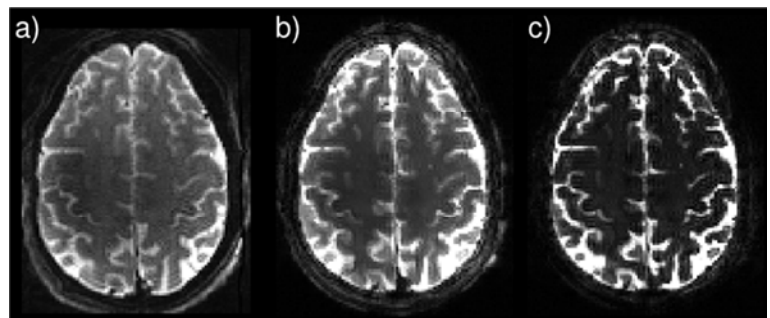


Fig 1: Representative time frames (central slice) for a) SE-EPI, b) S<sub>2</sub>-SSFP-EPI with TR = 15 ms, and c) S<sub>2</sub>-SSFP-EPI with TR = 25 ms.

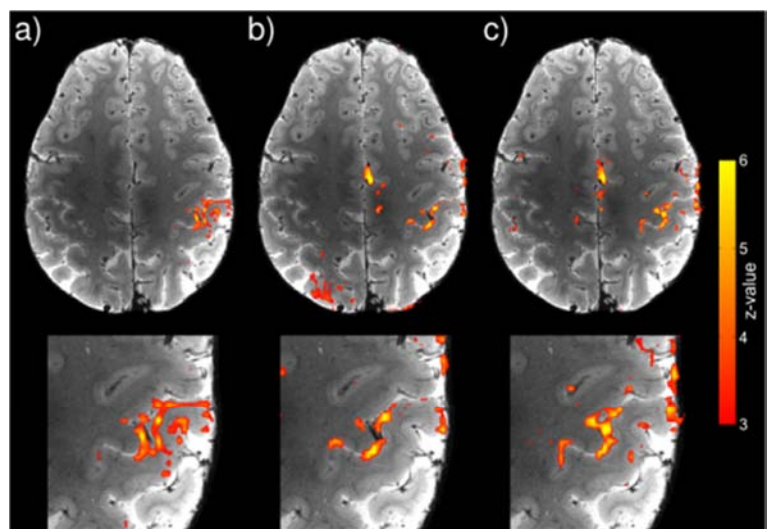


Fig 2: Overlay of high-resolution T<sub>2</sub>\*-weighted reference image with activation maps for a) SE-EPI, b) S<sub>2</sub>-SSFP-EPI with TR = 15 ms, and c) S<sub>2</sub>-SSFP-EPI with TR = 25 ms.