T2-weighted, 3D whole brain fMRI at 3 T and 7 T using S2-SSFP

M. Barth[1,2], S. A. Kannengiesser[3], H. Meyer[3], and D. G. Norris[1,2]

[1]F.C. Donders Centre for Cognitive Neuroimaging, Radboud University, Nijmegen, Netherlands, [2]E.L. Hahn Institute for Magnetic Resonance Imaging, University Duisburg-Essen, Essen, Germany, [3]MR Applications Development, Siemens Medical Solutions, Erlangen, Germany

Introduction The value of T_2-weighted BOLD fMRI increases rapidly with increasing main magnetic field strength. Indeed at 7T numerous articles show a superiority for T_2-weighted BOLD as compared to a T_2*-weighting, particularly with regard to spatial specificity [1]. Unfortunately at 7T the application of multi-slice spin-echo EPI for fMRI with whole-brain coverage is limited by power deposition. A well known alternative method for obtaining T_2-weighted images is the use of the S2 signal component of the SSFP signal. This sequence is attractive because of its low RF power deposition and lack of image distortion, and has previously been shown to have comparable functional sensitivity per unit time to spin-echo EPI [2]. A minimum time resolution for fMRI requires however that the BOLD response be sampled at about every 3s: something that would be impossible with the classic version of this sequence. The development of multi-channel receiver coils and partial parallel image reconstruction algorithms [3] with excellent stability in the temporal domain makes it possible to acquire 3D whole brain data in less than 3s using high acceleration factors (AF). We demonstrate BOLD activation using accelerated 3D imaging at both 3 and 7T and show that at high field strengths functional SSFP imaging represents a viable alternative to spin-echo EPI.

Materials and Methods Following the results from [2] the sequence parameters to achieve optimum sensitivity per unit T_2 change are shown in Tab.1. These parameters were used in the subsequent fMRI experiments based on a modification of the product PSIF sequence (S2-SSFP) such that the reference lines for parallel reconstruction were acquired at the start of the functional run. Data of 3 volunteers were acquired at 3T and 7T each (Magnetom Trio and 7T, Siemens, Erlangen). Setup at 3T: 32-channel phased array coil (Siemens, Erlangen), TR=33ms, TE=25ms, α=35˚, Matrix 64x48x24, slice thickness =5 mm, AF=3x4, partial Fourier (PF) in phase direction=6/8, TA=2.6 sec/volume, time per run: 4:41 min. Setup at 7T: 8-channel phased array coil (Rapid, Wuerzburg), TR=27ms, TE=25ms, α=22˚, Matrix 64x48x16, th=5 mm, AF=4, PF(phase & slab)=6/8, TA=3.3 sec/volume, time per run: 6:02. The functional paradigm consisted of blocks of rest and blocks of an 8 Hz flickering checkerboard (10 volumes per block, 110 volumes per run). The functional data were analysed using a GLM as implemented in Feat (FSL, FMRIB, Oxford), using McFlirt motion correction, 5 mm smoothing, low pass temporal filtering, a z-threshold of 5, and a cluster threshold of p<0.005.

S2	3 T (T_1 1300; T_2 80)	7 T (T_1 2000; T_2 60)
α	35˚	25˚
TR	33 ms	27 ms
dS/dT2	0.0035	0.0019

Tab.1: Optimum BOLD sensitivity for S2-SSFP at 3 T and 7 T. The respective sensitivity for SE-EPI is 0.0042.

Results and Discussion

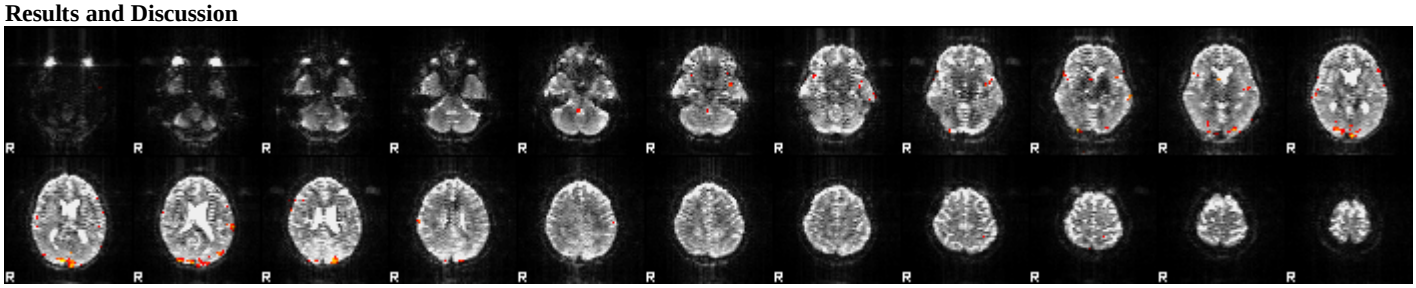

Fig. 1: obtained of the 12-fold accelerated S2-SSFP at 3T, overlaid with the functional activation of a single subject.

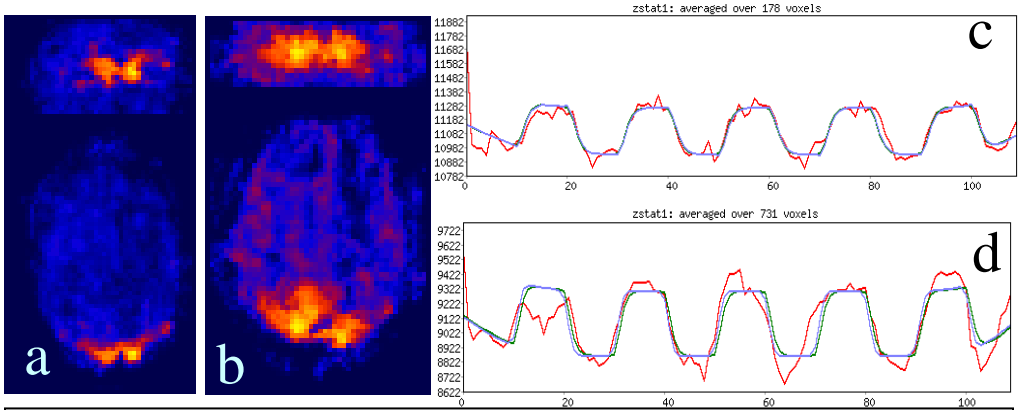

Fig.2: 3D rendered z-map of the activation maps (visual activation) at 3T (a) and 7T (b). The corresponding functional time courses and model fits are shown in (c) and (d), respectively.

Fig.1 shows results of a functional run at 3T overlaid on the original S2-SSFP images (Fig. 1). Note the very high quality and distortion-free images despite 12-fold acceleration and resulting short volume acquisition time (2.6 s). To better visualize the activation z-maps are displayed in Fig. 2a (3T) and 2b (7T). Fig. 2c and d show the respective time courses of the activated voxels. The mean functional signal change was 3.7%±0.6% at 3T and 6.1%±1.0% at 7T. At 3T, the SAR value for SE-EPI as calculated by the scanner software was a factor 4.5 higher than the comparable S2-SSFP with same volume coverage and same temporal resolution, prohibitive for fast, whole-brain SE-EPI at 7T.

Conclusion We conclude that S2-SSFP will be a viable technique for whole brain fMRI coverage particularly at 7T.

References

[1] E Yacoub et al. MRM 49, p. 655-664, 2003. [2] DG Norris and M Barth, Proc. ISMRM Berlin, e-pos #3307, 2007. [3] Griswold et al, MRM p. 1202-1210, 2002.