Diffusion Effects in Passband Balanced SSFP fMRI

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Introduction

Changes in resonance frequency caused by varying deoxyhemoglobin concentrations are the basis of blood oxygenation level dependent (BOLD) MR imaging (1). In functional brain studies mostly T2*-weighted sequences are used to detect BOLD signal levels. It has been shown that also balanced steady-state free precession (bSSFP) imaging sequences may be employed to measure deoxyhemoglobin concentration related frequency changes (2,3). Both methods base on the characteristic dependency of the bSSFP signal on the resonance frequency. Recent work demonstrates that diffusion in inhomogeneous magnetic fields affects the bSSFP signal amplitude depending on flip angle and repetition time (4). Due to this susceptibility sensitivity also the signal amplitude of an on-resonant balanced SSFP sequence depends on deoxyhemoglobin concentrations. The aim of this study was to verify the predicted dependency of measured balanced SSFP signal changes during a visual stimulation paradigm on flip angle and repetition time.

Materials and Methods

7 healthy subjects participated in this study. A visual paradigm was used for functional imaging. After 30 seconds of baseline scanning 3 phases of checkerboard stimulation were alternated with 3 baseline periods. Each phase had a duration of 30 seconds. Subjects had to respond to a number presented during the stimulation phase in order to keep their attention to the paradigm. All experiments were performed on a 3T headscanner (Allegra, Siemens Medical, Erlangen, Germany). To exclude flip angle variations due to non-rectangular slice profiles 3D bSSFP sequences were used for functional imaging. Imaging parameters were: matrix: 128x96x14, FOV: 256x192x49mm3, TR / flip angle combinations: 5ms/70°, 7ms/25°, 7ms/40°, 5ms/70°, 7ms/55°, 7ms/70°, 9ms/70°, 12ms/70°, TE=0.5*TR. One volume was acquired in 3.9s, 5.4s, 6.9s and 9.2s for a TR of 5ms, 7ms, 9ms, 12ms, respectively. The succession of the sequences was randomized for the individual subjects. Two partitions on each side of the 3D volume had to be discarded due to folding artifacts. An additional fMRI experiment was performed with a 2D EPI sequence having the same geometrical parameters, a TR of 2.5s and a TE of 40ms. After realignment a correlation analysis of the EPI data was performed to identify activated regions. A mask containing pixels exhibiting a correlation coefficient above 0.4 was created from 3 slices covering the visual cortex. This mask, comprising about 200 pixels, was then applied to the bSSFP time series in order to obtain signal changes related to the visual stimulation. In addition, temporal signal stability of the sequences was evaluated as standard deviation of the signal time course averaged over an ROI divided by the mean of this signal.

Results

The EPI sequence resulted in an average signal change of 2.93% due to visual stimulation. In the same area, signal changes between 0.63% and 1.05% were measured with bSSFP sequences having different repetition times and/or flip angles (see Fig. 1). No clear trend was observed when varying TR from 5ms to 9ms while keeping the flip angle constant at 70°. The time course obtained with TR=12ms/α=70° did not show a clear on-off activation pattern. However, increased flip angles resulted in higher signal changes. A plateau is reached for α=55° with maximum signal increase of about 1%. The temporal signal stability of the bSSFP sequences decreased with higher flip angles and longer TRs (see Table 1).

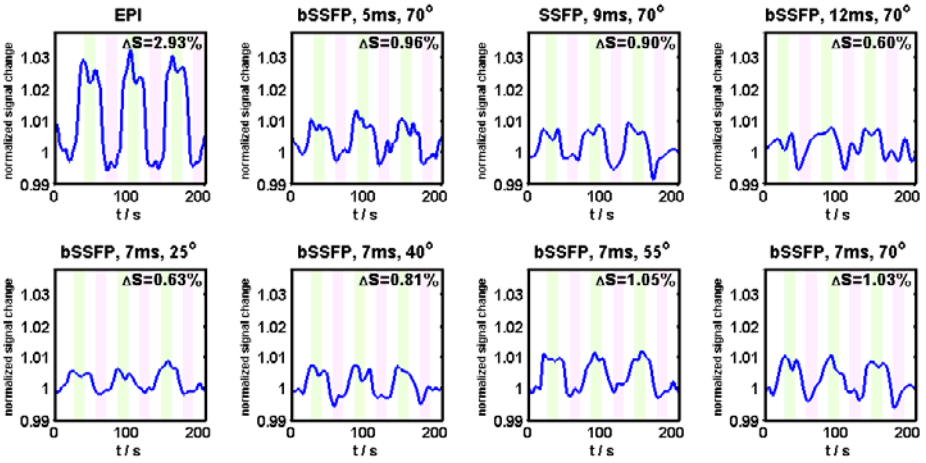

Fig. 1: *Signal time courses acquired with EPI and bSSFP averaged over activated regions in the visual cortex.*

	EPI	5ms/70°	7ms/25°	7ms/40°	7ms/55°	7ms/70°	9ms/70°	12ms/70°
Stability	2.78%	5.02%	2.63%	3.15%	4.09%	5.58%	5.61%	5.46%

Tab. 1: *Temporal signal stability of the different sequences applied.*

Discussion

The obtained flip angle dependency goes in line with predictions reported in (4) for field perturbers having a diameter comparable to the size of capillaries (about 8μm). However, the predicted signal increase of about 15% for the TR change from 5 to 12ms could not be measured. This might be caused by the low sensitivity of the experiment or by off-resonance effects. Off-resonances may also explain the unexpected low signal change for the longest TR of 12ms. Temporal signal stability did not correlate with the amount of signal change and can therefore be excluded as a source of its increase.

References

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