Hemodynamic Properties of Passband b-SSFP fMRI

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Introduction: Passband b-SSFP fMRI [1-10] is a promising new fMRI method that utilizes the passband (flat portion) of the b-SSFP off-resonance response in order to measure MR signal changes elicited by changes in neuronal activity. Important advantages of the method include the distortion-free, high resolution imaging capabilities [7]. While its advantages have been demonstrated earlier, the hemodynamic properties of the b-SSFP method in terms of its response amplitude, response time and the linearity of the response remain to be studied. The study of the hemodynamic response is of great importance for the design of the experiments as well as the data analysis. Here, we show initial results characterizing the hemodynamic response of passband b-SSFP fMRI.

Methods: All experiments were conducted using a GE 3 T whole-body Signa Excite system. *(1) Pulse Sequence* Hemodynamic response functions (HRF) were measured with both GRE-BOLD and passband SSFP fMRI methods, with same FOV (22x22x3.6 cm^3) and resolutions (2x2x3 mm^3 and 1.5 s). The GRE-BOLD used a 2D multi-slice spiral acquisition (T_R = 1500 ms) whereas the passband SSFP fMRI methods used a 3D stack-of-spirals acquisition (T_R = 8.928 ms: minimum T_R for given spatial, temporal resolution and volume coverage to maximize small scale vessel selectivity [6, 8]). *(2) Stimulus* Full-visual field flashing checkerboard was used in a pulsed format (Fig. 1a) while an oblique imaging volume through the primary visual cortex was scanned (Fig. 1b). For the HRF analysis, voxels in the primary visual cortex were selected from the passband SSFP fMRI raw image (Fig. 1 c) using a coherence threshold of 0.3. *(3) Experiments* Flip angle dependency of the passband b-SSFP fMRI method was tested by using flip angles ranging from 20° to 70°. To test linearity [11], BOLD and passband b-SSFP acquisitions were performed with four stimulus durations (3 s, 6 s, 12 s, 24 s) and two contrast levels (high, low).

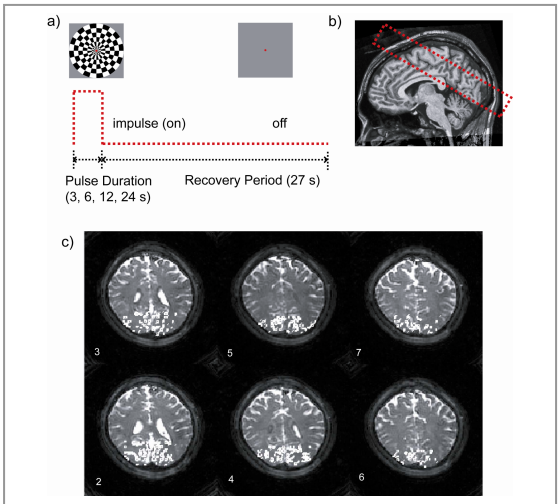

Figure 1 HRF measurement. a) A full visual field flashing checkerboard was played followed by a 27 sec recovery time to capture the delayed hemodynamic responses. b) A volume through the primary visual cortex was scanned. c) Voxels in the primary visual cortex were selected and averaged for the HRF analysis.

Results: *(1) Flip Angle Dependency* Figure 2c shows that the HRFs do not strongly depend on flip angles. The HRF shows the combined effects of flip angle dependent contrast and signal stability that depends on the flatness of b-SSFP off-resonance profiles (Fig. 2b). Two-gamma function fit [12] of GRE-BOLD and passband b-SSFP methods revealed a rise-to-half maximum time and maximum amplitude of 5.4 s, 1.86 % and 2.7 s, 0.56 % respectively (Fig. 2a, d). *(2) Linearity* The two gamma function fit [12] of 3 s HRFs (Fig. 3a, b) of GRE-BOLD and passband b-SSFP methods resulted in a rise-to-half time and a maximum amplitude of 3.3 s, 2.23 % and 2.25 s, 0.97 % respectively. Increase in impulse durations show increase in the duration and amplitude of HRFs for both methods (Fig. 3c, d). HRF amplitude also scales with changes in stimuli contrast for both methods (Fig. 3 e, f).

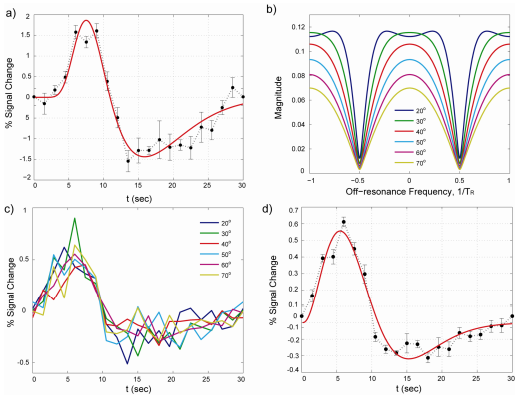

Figure 2 Flip angle dependency. GRE-BOLD HRF (a), b-SSFP signal over a range of off-resonance frequencies (b), passband b-SSFP HRFs with flip angles ranging from 20° to 70° in 10° steps (c), and average of all 6 HRFs in c (d). (Subject A)

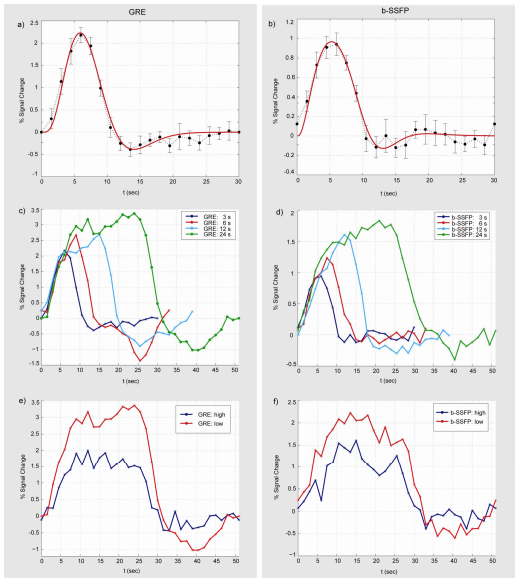

Figure 3 Linearity. Figures on the left column show GRE-BOLD measurements (a, c, e) and the figures on the right show corresponding passband b-SSFP measurements (b, d, f). (Subject B)

Conclusion: The results show that with a T_R of 8.928 ms and spatial resolutions on the order of 2-3 mm, passband b-SSFP fMRI has a ~1-3 s shorter delay and ~2-3 times smaller maximum amplitude compared to GRE-BOLD. Furthermore, the flip angle dependencies in practical imaging settings seem to be minimal while the HRF response is linear with respect to stimulus duration and amplitude. HRF response time and magnitude are expected to be a function of TR and spatial resolution. Future studies conducted in different TR and spatial resolutions will provide a more complete understanding in terms of the passband b-SSFP method's spatial scale selectivity [1, 2, 6, 8].

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