Full-Brain Coverage and High-Resolution Imaging Capabilities of Passband SSFP fMRI at 3 T

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Introduction: Passband SSFP fMRI [1-5] is a recently developed method that utilizes the passband (flat portion) of the SSFP off-resonance response to measure MR signal changes elicited by changes in neuronal activity. Here we demonstrate important advantages of this technique that include: (1) distortion-free acquisition (due to short readouts) that allows full-brain coverage including the susceptibility prone areas (near sinus and auditory canal); (2) high-resolution isotropic acquisition owing to distortion-free 3D acquisitions.

Methods: All experiments were conducted using a GE 3 T Excite system.
(1) Hypercapnia Experiment (Fig. 1a): To demonstrate the distortion-free full-brain coverage capability of the passband SSFP fMRI method, we used breath-holding experiments that regulate the oxygen supply and create whole-brain activations [6, 7]. The whole-brain activations were measured with both GRE-BOLD and passband SSFP fMRI methods, with similar FOV (24x24x12 cm^3) and resolutions (2x2x5 mm^3 and 3 s). The GRE-BOLD used a 2D multi-slice acquisition whereas the passband SSFP fMRI methods used a 3D acquisition. The passband SSFP images were collected using the two-acquisition technique [5] to cover the entire off-resonance spectrum.
(2) Visual Field Mapping Experiment (Fig. 1b): The distortion-free nature and 3D acquisition provides important advantages for high-resolution functional imaging. Lack of distortion allows accurate registration to the anatomical image while shorter readout also enables image resolution to be close to the true encoding resolution (no blurring). 3D imaging offers the advantage of thinner slices than multi-slice imaging and provides higher SNR necessary for high resolution acquisitions. To demonstrate such advantages, high-resolution passband SSFP images were acquired during a phase-encoded visual field mapping experiment [8]. Using a small surface coil placed near the occipital lobe, an 8x8x2 cm^3 volume was acquired with a 1 mm isotropic resolution. The temporal resolution of the acquisition was 3.5 s.

Results: ***(1) Hypercapnia Experiment:*** In the GRE-BOLD activations (Fig. 2a), typical off-resonance signal dropout regions have missing activations. The corresponding passband SSFP fMRI images (Fig. 2b) show relatively uniform activation throughout the whole brain. Even though the activations seem generally stronger with GRE-BOLD, passband SSFP activations nicely correspond to grey matter regions and the MR signal changes are comparable (Fig. 2c).
(2) Visual Field Mapping Experiment: In Fig. 3a, b, the phase of the fMRI signal's fundamental frequency is shown. This phase indicates the part of the visual field that is represented by each cortical location (Fig. 3c). In this case, the method reveals parts of the right visual field and in particular the representation of the vertical meridian revealing the boundary of V1/V2, as it is known to occur [8]. Robust, high SNR activations can be observed in the single voxel time series (Fig. 3d).

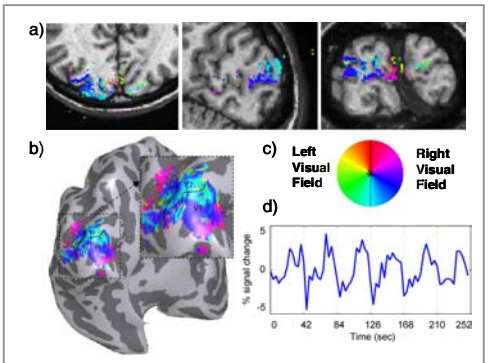

Figure 3 Visual Field mapping results. Activation phase maps overlaid on anatomy (a) and inflated cortical surface (b). c) Color code used for the phase-maps. d) Temporal signal plotted for a single activated voxel.

Conclusion: Passband SSFP fMRI provides an alternative method to conventional GRE-BOLD and solves some of GRE-BOLD's major limitations in terms of coverage (signal dropout) and resolution.

References:

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[6] Thomason et al., Neuroimage 2005, 824-837.
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[8] Engel et al., Cereb Cortex 1997, 181-192.

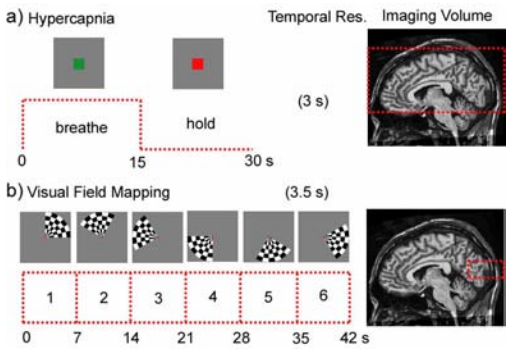

Figure 1 Experiment protocol for a) hypercapnia and b) visual field mapping.

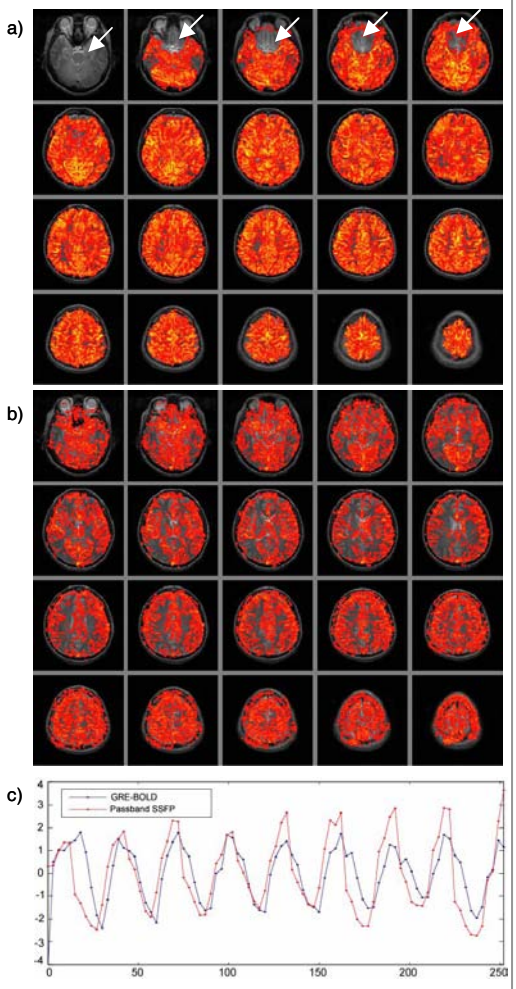

Figure 2 Hypercapnia experiment results. a) GRE-BOLD results show apparent signal loss in areas near the sinus and the auditory canal. b) Passband SSFP fMRI results show uniform activation throughout the grey matter. c) The signal strength for GRE-BOLD and passband SSFP fMRI are comparable.