Retinotopic mapping in human visual cortex using Vascular-Space-Occupancy (VASO) dependent fMRI

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INTRODUCTION: Recently, we introduced a Vascular-Space-Occupancy (VASO) dependent fMRI technique that detects brain activation based on focal blood volume changes (1). Compared to the BOLD approach, it was shown to provide better spatial localization and contains less contamination from large vessels, because the vessels capable of dilating during brain activation are predominantly microvasculatures (diameters <100-200 microns) (1, 2). Such an fMRI method is expected to significantly improve the specificity of functional maps, and thereby the interpretation of activation results. Human visual cortex is known to be retinotopically organized and retinotopic mapping using BOLD fMRI has been well established (3-5). Due to different contrast mechanisms (blood oxygenation vs blood volume), the VASO fMRI may result in slightly different retinotopic maps and can potentially provide complementary information. Here we use VASO fMRI to test its feasibility for retinotopic mapping studies and compare it with BOLD results.

METHODS Experiment: Studies were performed on a 3.0T MR scanner (Philips Medical Systems) using body coil transmission and SENSE head coil reception. Visual stimuli for retinotopic mapping consisted of 18 seconds of vertical wedges (polar angle=30º, diameter=25º visual angle) interleaved with 18 seconds of horizontal wedge, often referred to as meridian mapping. Such stimuli will result in two activation patterns, corresponding to vertical and horizontal wedge stimulations. Due to the intrinsic mirror representation of the visual field in early visual areas, it is known that the center line of each activation pattern specifies the boundary between adjacent visual areas. VASO fMRI was performed with: GE-EPI, TR=3s, TI=889ms, TE=8.7ms, FA=90º, matrix=80x80, SENSE factor 2, FOV=240mm, 9 slices (3mm thickness, no gap) parallel to calcarine fissure. Each run lasted for ~5 min and was repeated 3 times to improve signal-to-noise ratio (SNR). One BOLD experiment (TE=45ms) with the same stimulus paradigm and slice position was performed for comparison. A 3D SENSE-MPRAGE image (1x1x1mm^3, 6min30sec) was acquired for anatomical references. **Data processing:** Data were processed on a PC using BrainVoyager (Brain Innovation, the Netherlands). Preprocessing included baseline drift correction, spatial smoothing (FWHM=4mm) and spatial transformation into Talairach coordinates. Activation detection was based on cross-correlation (cc>0.1) between signal time-courses and temporally shifted stimulus paradigm (shift range=-1 to 7 timepoints) (3). The activation map was color-coded (Fig. 2) according to the phase shift at which the maximum cc was achieved. Ideally, the horizontal wedge stimulation should produce maximum cc at shift=0, while the vertical wedge should correspond to shift=6 (block duration/TR=18s/3s=6 points). To allow for noise contamination and hemodynamic response variations, the shift range was extended from [0,6] to [-1,7], which resulted in the horizontal wedges coded in red-yellow (Fig. 2) and vertical wedges coded in blue-green. The activation maps were overlaid on inflated cortical surfaces (from MPRAGE images) for clear delineation of retinotopic maps.

RESULTS and DISCUSSION: Fig. 1 shows the cortical surface of a left hemisphere. The region in and around the calcarine fissure (yellow box) is known to contain the early visual areas and was selected as a region-of-interest (ROI). Fig. 2a shows the retinotopic maps in the ROI of Fig. 1 using VASO fMRI. Consistent with previous findings (3-5), multiple retinotopic representations of the visual field can be identified in these early visual areas. In our results, dorsal and ventral V1 and V2 as well as V3 and VP were delineated. V3A and V4v were not identified due to limited slice coverage (3mmx9slices=27mm). Fig. 2b shows the retinotopic maps using BOLD in the same ROI. Interestingly, the V1 areas in the BOLD maps appear to have a trapezoid shape, narrower in the posterior part and broader in the anterior part. Further investigation is needed to test whether such differences between BOLD and VASO maps are reproducible and significant, and, if so, what are the possible reasons. Our initial results shown here demonstrate that it is feasible to use VASO fMRI for advanced functional brain mapping. VASO fMRI experiments can be performed as an alternative to BOLD method and may provide verification or additional information to BOLD.

REFERENCES: 1) Lu et al. MRM 50: 263 2003; 2) Harrison et al. Cereb Cortex 12: 225-233 2002; 3) Slotnick et al. HBM 18: 22 2003; 4) Engel et al. Cereb Cortex 7: 181 1997; 5) Tootell et al. J Neurosc 17: 7060 1997.

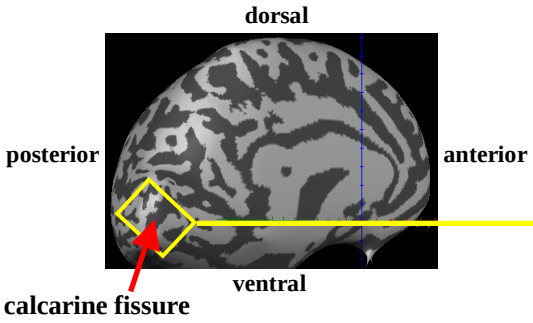

Fig. 1: 3D cortical surface of a left hemisphere (medial view) obtained from a high-resolution MPRAGE. Dark regions indicate sulcal gray matter; bright regions gyral gray matter. Red arrow: location of V1. Yellow box: ROI corresponding to Fig. 2.

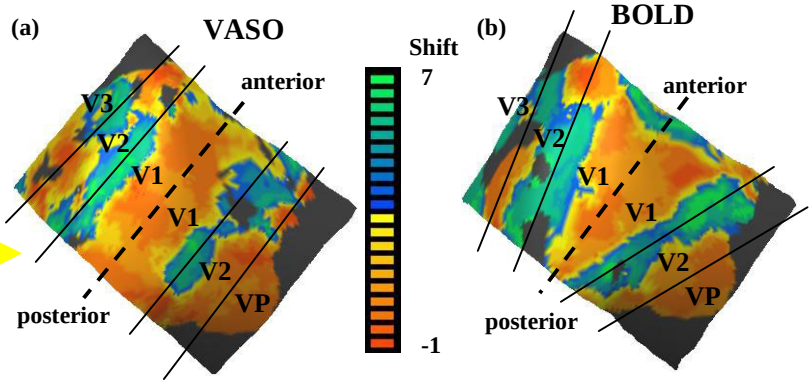

Fig. 2: Retinotopic maps using (a) VASO and (b) BOLD. The color bar indicates the phase shifts at which the stimulus paradigm had maximum correlation with the signal time series. Lines were manually drawn to be the center of the red-yellow pattern or the blue-green pattern, and were used to define the boundaries between adjacent visual areas. Dashed line: middle line in the calcarine fissure separating the upper and lower visual hemifield.