Orientation mapping in visual areas at Ultra High Field

Keren Yang[1], Rosa Sanchez Panchuelo[1], Denis Schluppeck[2], Richard W. Bowtell[1], and Susan T. Francis[1]

[1]*Sir Peter Mansfield Magnetic Resonance Centre, University of Nottingham, Nottingham, Nottinghamshire, United Kingdom,* [2]*School of Psychology, University of Nottingham, Nottingham, Nottinghamshire, United Kingdom*

TARGET AUDIENCE: Neuroscientists and neuroimage community with an interest in ultra-high field MRI or visual neuroscience.

PURPOSE: Ultra-high field (UHF) MRI provides increased signal-to-noise ratio and BOLD contrast-to-noise ratio for fMRI. This can be used to increase the spatial accuracy of fMRI signals for improved detection of functional cortical units in the brain. In the primary visual cortex (V1), for example, orientation preference is known to show a columnar organisation [1, 2], but a more recent study suggests that biases in orientation preference are also mapped at a coarser spatial resolution and are correlated with angular-position in the V1 retinotopic map [3]. However, the amplitude of BOLD signal variation produced by the varying orientation full FOV gratings is significantly lower than that due to the rotating wedge, meaning that the intrinsic contrast to noise ratio (CNR) of the orientation maps is lower than in retinotopic maps and many repeat scans must be combined to produce comparable CNR in orientation maps.

Aim: To use UHF (7 Tesla) fMRI to explore orientation mapping in the visual cortex (V1, V2, V3 dorsal (d) and ventral (v) regions) and compare with angular-position from retinotopic maps. To correlate the phase of orientation and angular-position maps within visual areas and assess BOLD CNR.

METHODS: *Data Acquisition:* Four healthy subjects were scanned on a Philips Achieva 7T scanner using a 32-channel receiver coil. Subject 2 was scanned twice to test the repeatability. In each scan session, two fMRI paradigms were performed for a) *Retinotopic mapping* using a single rotating wedge and b) *Orientation mapping* using full field of view (FOV) gratings changing orientation throughout each cycle (Fig. 1). All stimuli were presented using a projector, the stimuli subtended a visual angle of 9.6°.fMRI data were collected using a 2D-EPI acquisition with FOV 192 x 192 mm^2, 1.5 mm isotropic spatial resolution, 34 slices, TE=25 ms, TR=2000 ms, flip angle = 78^0, BW=27.4 Hz, 96 dynamics collected in ~3.5 minutes. Two retinotopic mapping scans and 11-14 orientation mapping scans were collected in each session, with modulus and phase data recorded. A fixation task was carried out during the fMRI scans to maintain the subject's attention throughout. A T_1-weighted whole-head MPRAGE (1 mm isotropic spatial resolution, 144 slices, TE = 3.8 ms, TR = 15 ms, flip angle = 8^o) was collected for registration with functional data and cortical flattening. In addition, a B_0-field map was formed from the average of 10 GE-EPI acquisitions acquired with echo times differing by 3 ms (25 ms and 28 ms) and used for dynamic correction of distortions introduced in the PE direction, thus providing improved image alignment for flat mapping.

Data Analysis: All EPI datasets were first distortion-corrected using the simulated phase evolution rewinding distortion correction method (SPHERE) coded in Matlab [4]. Datasets were then processed in mrTools (http://www.cns.nyu.edu/heegerlab/). Data were motion corrected and the 2 retinotopic data sets and 11-14 orientation data sets were then averaged, in order to increase the BOLD CNR prior to correlation analysis. Visual areas (V1d/v, V2d/v and V3d/v) were defined from the retinotopic map according to the colour phase map on the flat patch for each hemisphere (Fig. 2). Phase values from the orientation map against angular-position from the retinotopic map in each visual area (for voxels with a coherence value greater than 0.3) were plotted to assess any correlation, and data was assessed for repeatability. The BOLD CNR, given by the peak Fourier amplitude divided by the noise floor, was plotted for increasing numbers of orientation scans used to form the average.

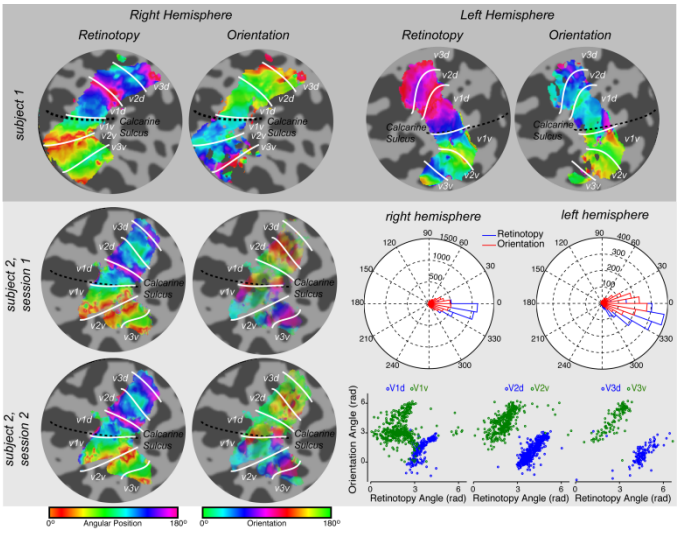

Figure 2: (*Top*) Retinotopic and orientation maps in visual areas (V1d/v, V2d/v and V3d/v) in both hemispheres for Subject 1. *(Bottom-left)* Right hemisphere maps for the two sessions on Subject 2. *(Bottom-right)* Phase differences across sessions are plotted for both types of stimulation; the small deviation angles suggest that the reproducibility of both retinotopic and orientation maps is good. A strong linear relationship (dorsal in blue, ventral in green) between orientation and retinotopy angles is evident, especially in V2 and V3.

Figure 1: (*Top*) Rotating wedge and (*Bottom*) full FOV oriented grating used for retinotopic and orientation mapping.

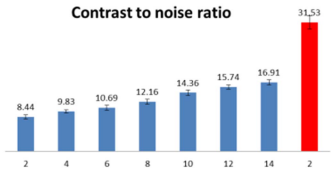

Figure 3: CNR for orientation data (blue) averaged across subjects for different numbers of scans (n= 2 – 14) compared with 2 retinotopy data (red).

RESULTS: Retinotopic and orientation maps are shown for both hemispheres for Subject 1 in Fig. 2. For Subject 2, the phase values from the orientation maps are plotted against the angular position from retinotopy for each visual area, a strong linear dependence was found (the Pearson coefficient V1d/v:0.54/0.21, V2d/v:0.83/0.59, V3d/r:0.54/0.59, P <0.0001 for all regions), showing these measures are highly correlated. To test the repeatability, Subject 2 was scanned twice and the phase difference between scan sessions was then plotted for each hemisphere for both orientation and retinotopic maps. The small deviations highlight the good repeatability of both the retinopy and orientation maps. The CNR for orientation mapping was lower than that of retinotopy (For 2 scans, CNR = 8.4 orientation and 31.5 retinotopy). Figure 3 shows the effect of increasing the number of orientation scans (mean± sem across subjects), however even with 14 scans the CNR for orientation mapping is relatively low compared to retinotopy.

DISCUSSION: Results have confirmed the presence of coarse-scale orientation maps which are strongly correlated with the angular component from retinotopy across V1, V2, V3 dorsal (d) and ventral (v) regions. Due to the reduced BOLD CNR of the orientation paradigm compared to retinotopy, (a factor of 2 reduction in CNR even when 14 orientation scans are combined) the organization is not always clear in all of the visual areas inspected. **CONCLUSION:** Future work will assess combining scans across sessions, taking advantage of improved realignment having used phase correction, and increasing the spatial resolution to determine whether orientation columns can be resolved.

References: [1] Valois & Valois, Spatial Vision. Oxford Psychology Series [2] Yacoub et al., PNAS, 105 (30):10607-10612. [3] Freeman et al., J Neurosci., 31(13):4792-4804. [4] Harmer et al., ISMRM 19th Annual Meeting, 4576.