Mapping neuronal 'stripe' sub-divisions in human extra-striate visual cortex at 7T

Natalia Petridou[1,2], Brian Wandell[3], Ben M Harvey[4], Wietske Zuiderbaan[4], Peter Luijten[1], and Serge O Dumoulin[4]

[1]*Radiology, UMC Utrecht, Utrecht, Netherlands,* [2]*Rudolf Magnus Institute, UMC Utrecht, Utrecht, Netherlands,* [3]*Psychology, Stanford University, Stanford, United States,* [4]*Experimental Psychology, Helmholtz Institute, Utrecht University, Utrecht, Netherlands*

Introduction The advent of high fields in recent years has allowed the delineation of function in cortical columns in human striate cortex (V1) [1,2]. However the ability to delineate spatially detailed functional organization in extra-striate visual cortex remains unclear. Histological evidence suggests a functional sub-division of the extra-striate visual area V2 [3,4]. In non-human primates, V2 contains neurons arranged in a regular 'stripe'-like repeating pattern perpendicular to the V1/V2 border belonging to different information pathways of the visual system. In humans, histological evidence suggests a similar distinction though these sub-divisions may be more patchy than 'stripe'-like. Here we show in vivo evidence of these detailed functional sub-divisions in human V2 and V3, using 3D EPI BOLD at 7T.

Methods Scanning was performed at 7T using a volume transmit (Nova Medical) and a custom-built 16-channel receive surface coil. Data were acquired using a T2*w 3D segmented gradient-echo EPI with SENSE factor = 3.5 (RL), TR/TE: 35/25ms, flip-angle: 20^0, FOV: 120x120 mm, 0.9x0.9x1 mm resolution, volume acquisition time: 2.6s (80 volumes/run), and 29 coronal slices spanning the visual cortex. Subjects were secured in place with foam pads under the neck and within the coil. Stimuli were presented via back-projection onto a screen mounted on the head coil that was visible through prisms. Two subjects were scanned twice (separate days). The visual stimulus consisted of concentric rings whose contrast reversed at 1.5Hz or 7.5Hz in a block design (13s/cycle), designed to elicit differential activation in pale (parvo-cellular pathway) and thick (magno-cellular pathway) 'stripe' sub-divisions in V2. The stimulus was grayscale (20% contrast) with a spatial frequency of 1 cycle/degree for both conditions (visual field of view: 11degrees diameter). Four or more runs were obtained per subject and per session. We calculated the phase-specified coherence of each fMRI time series, which is a measure of the amplitude of the fMRI response at the stimulus frequency and phase, adjusted for the hemodynamic delay. The values ranged between -1 and 1; positive values reflect stronger responses to 1.5Hz, and negative values reflect stronger responses to 7.5Hz temporal frequency. Retinotopic scans, i.e. rotating wedge stimuli, were also acquired in both sessions in order to delineate the visual areas.

Results Figure 1 shows the activation patterns elicited by the two temporal frequencies localized across early visual cortex. A patchy pattern was revealed in dorsal V2 (V2d) and V3 (V3d), while a predominantly uniform activation pattern was obtained in V1 and V3A. Maps show the phase-specified coherence collapsed over the cortical thickness. The activation pattern was consistent across the two sessions for each subject (results are illustrated for one subject). This activation pattern, including the spatial frequency of the patch alternation, is consistent with histological observations [3].

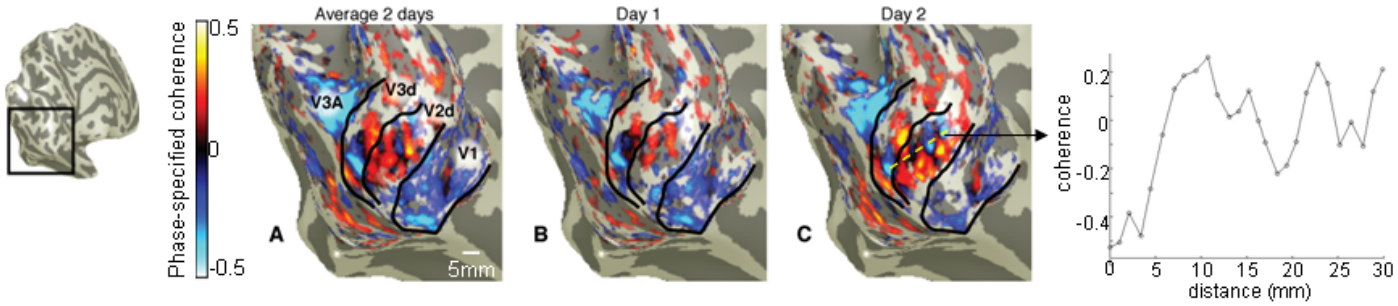

Figure 1. Left to right: Inflated view of the left hemisphere for subject 1. Box, positioned over the early visual cortex, marks the location of panels A-C. Phase coherence map shows negative values for stronger responses to 7.5Hz stimulation (magno-) and positive values for stronger responses to 1.5Hz stimulation (parvo-). A: Map obtained by averaging results from the two sessions (B: Day 1, C; Day 2). The visual area borders (retinotopy) are marked in panel A. Right panel illustrates a profile across the yellow line in panel C, with a spatial frequency of ~3-6mm across patches at that location.

Discussion Our results show a patchy activation pattern elicited by different temporal frequencies in V2d and V3d but not V1 and V3A, consistent with the histological evidence of the spatial distribution of neuronal stripes in the human visual cortex. This is the first in vivo evidence of spatially detailed neural subdivisions in early extra-striate visual cortex in humans. Additionally, our results show that at 7T, 3D gradient-echo EPI has the sensitivity for detailed topography of brain functions.

References 1)Yacoub E. et al. NeuroImage 37:1161–1177, 2007. 2) Cheng K et al, Neuron 32; 359–374, 2001. 3) Tootell RBH & Taylor JB Cerebral Cortex 1:39-55, 1995. 4) Sincich LC et al J Neurosci 30(20):6963– 6974, 2010.