Background: Previous studies have demonstrated that visual stimuli can be uniquely identified by examining the distributed pattern of BOLD activation that they evoke across large regions of visual cortex. In these studies, the activity evoked within individual voxels is not sufficiently reliable to accurately decode a particular stimulus, and accurate decoding can only be accomplished by employing distributed algorithms such as support vector machines[1]. However, it is not clear whether the inability to accurately decode individual voxel activity reflects variability in the underlying local brain activity or the limitations of traditional BOLD imaging techniques to accurately reflect that activity[2,3]. For example, while low resolution (3 mm isotropic), low field measurements of GE BOLD activation across V1 suggest a distributed encoding of orientation, recent very high resolution studies employed spin-echo sequences at 7T suggest an encoding of orientation at sub-millimeter scales consistent with columnar organization[4]. Because this columnar level organization can only be visualized over very limited extents of V1 in which the surface of the cortex is relatively flat, it is unclear whether this local encoding of visual information is prevalent throughout human visual cortex. In this study, we examine whether 7T GE BOLD measurements at an intermediate resolution might be capable of revealing functional organization patterns over multiple cortical areas. Specifically, we looked for the local encoding of orientation in areas V1, V2, and V3, by measuring visual activation using 1.5 mm isotropic resolutions over the posterior 36 mm of the visual cortex. Orientation specificity was assessed by measuring the temporal modulations in individual voxels that corresponded with the frequency of a continuously rotating stimulus.

Methods: fMRI studies were done on a 7 T magnet (Magnex Scientific, UK) equipped with a Siemens console (Erlangen, Germany). GE BOLD images were acquired using a small quadrature surface receive coil and a separate large quadrature transmit coil. Single shot EPI images were acquired coronally using a TE/TR of 20/1500 msec, a 64 x 128 matrix (FOV: 9.6 x 19.2 cm^2) and 25 slices yielding 1.5 mm isotropic voxels. Three subjects viewed a large field (> 30 deg) counter-phasing sinusoidal grating (4 Hz, 1 cyc/deg) whose orientation slowly varied with a frequency of one cycle every twelve seconds and a total of 13 cycles per scan, which was repeated several times to improve SNR. To ensure vigilance, subjects performed a change detection task in which they were required to quickly respond to a brief change in spatial frequency (0.5 cyc/deg, 83 ms). The time course of each voxel's BOLD signal was Fourier transformed, and orientation specificity was defined according to significant modulation at the frequency of orientation rotation (Hartley, $p<0.01$) as compared to all other frequencies present. Voxels with significant orientation selectivity were then analyzed according to the phase and amplitude of their orientation-related modulation. No spatial or temporal smoothing was performed at any point. Early visual area boundaries were localized using a standard traveling-wave retinotopic mapping protocol: a dynamic checkerboard stimulus was masked by wedges subtending 22.5 degrees of visual angle that rotated through the visua field at a rate of 1 cycle per 24 s.

Results: Voxels with significant orientation tuning were observed in multiple visual areas in all subjects. Figure 1 shows the time course of BOLD activation, sorted according to the voxels' preferred orientation (phase). Temporal modulations were robust and consistent in both phase and amplitude throughout the session. We then plotted the orientation selectivity of individual voxels with respect to the borders of early visual areas as defined by retinotopic mapping (Fig 2). Individual voxels with significant orientation selectivity were found in all the early visual areas. However, the size of iso-orientation regions even those in V1, is much larger (~10s of mm^2) than the size of iso-orientation regions found in very high resolution spin-echo imaging (<1 mm^2).

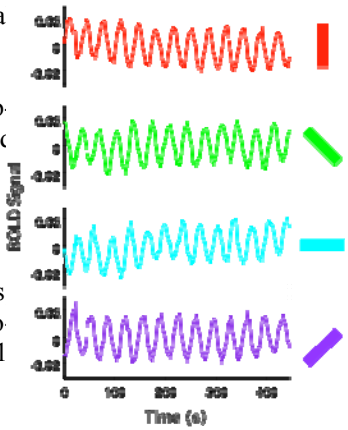

Fig 1 Orientation specific activity sorted according preferred orientation in one subject. Each plot contains at least 100 voxels with significant modulation at the rotation frequency.

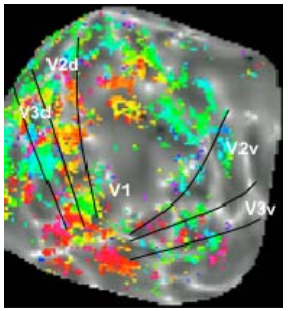

Fig 2 Large orientation specific regions in areas V1, V2, and V3.

Conclusions: Consistent with non-human primate electrophysiology we find orientation selectivity throughout the early visual system. In contrast to previous studies employing lower resolution sampling at 3T, we find that individual voxels show significant orientation selectivity. This suggests that the local encoding of visual information is a common theme of functional organization which may not be accurately reflected by traditional BOLD measurements at low resolutions. **References:** [1] Kamitani Y and Tong F, Nat Neuro, 2005 [2]Gardner JL et al. SFN Meeting,2006 [3] Shmuel A et al. Neuroimage 2009 [4]Yacoub E et al. PNAS USA 2008.

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