

# Functional Asymmetry in Human Visual Cortex as Revealed by fMRI

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## INTRODUCTION:

It has been reported that human visual performance is not uniform across the visual field. The origin of this inhomogeneity is not clear. Phenomena of horizontal vertical asymmetry (HVA), implying better performance on horizontal than vertical meridian, and vertical meridian asymmetry (VMA), implying better performance in lower than upper visual field, have been studied in psychophysical terms (1-4). However, there is little fMRI evidence for these two asymmetries. Horizontal overrepresentation in occipital cortex and LGN were observed in two retinotopic studies (5-6) and to our knowledge no imaging study investigating VMA has been performed. Here we explore whether these two asymmetries can be revealed by fMRI consistently across subjects. The results of this study may help us understand the neuronal base of these asymmetry phenomena.

## METHODS:

Data were acquired from seven subjects (three male and four female) with normal vision. Stimuli were composed of three alternating blocks: horizontal, vertical wedges stimulation and fixation period (for HVA experiment), or lower half of vertical wedge, upper half of vertical wedge, and fixation period (for VMA experiment). The presentation orders of different conditions were alternated to counteract possible accommodation effect. Stimuli parameters were: black-white flashing checkerboard, 8 Hz contrast polarity reversal rate, 30° degree polar angle width, 45° visual angle from fixation. Throughout the scans, subjects were required to focus on the fixation cross in the center of screen. Eye tracker was implemented to track the eye movement. fMRI data were acquired on a 3-T scanner (Siemens Trio) using standard head coil. Thirteen axial slices (5mm-thick, 0.5mm gap) covering entire visual cortex, were acquired using gradient-echo EPI with parameters of TR = 1s, TE = 30ms. Additional to BOLD scan, three out of seven subjects were also scanned for perfusion fMRI using continuously ASL sequence (adapted from Dr. Wang, Upenn) with parameters of TR = 3s, TE = 19ms, labeling time = 1.5s post-labeling delay = 0.7s, and same slice profiles as the ones in BOLD scan. Each stimulation block lasted for 20s for BOLD scan and 42s for CASL scan. Each scan lasted 6.67min for BOLD or 8min for CASL. Online motion correction and offline Talairach transformation were used for data preprocessing. BrainVoyager (Brain Innovation, the Netherlands) was used to generate functional activation map. General linear model (GLM) – derived activations were computed with fixation as baseline and overlaid on 3D anatomical data. The activated voxel counts corresponding to each condition were recorded and compared.

## RESULTS & DISCUSSIONS:

In all seven subjects, horizontal stimulation results in significantly larger activation compared to vertical stimulation - see Figure 1(a). The ratio of horizontal vs. vertical activated voxel counts ranged from 2:1 to 13:1, with the median of 3.7 fold. Note that we only compare the results within subjects because BOLD results vary among subjects and sessions. For both HVA and VMA study, statistical threshold was fixed at  $t > 9.8$  (uncorrected p value of  $1.9 \times 10^{-20}$ ). Figure 1(b) shows comparison of the counts of voxel responding to lower half of vertical meridian and upper half of vertical meridian. Six out of seven subjects shows lower-half vertical meridian advantage. The ratio of lower-half vs. upper-half voxel counts ranged from 1.4:1 to 3.4:1, with the median of 2.5 fold. One subject had slightly more activation on upper-half vertical meridian but the difference is not significant. Figure 2(a) demonstrates typical HVA and VMA phenomena observed in our study: the overrepresentations of horizontal (orange) than vertical (green), and lower field (upper green) than upper field (lower green) are clearly shown on a flattened right hemisphere visual cortex. Interestingly, by looking at the ROI timecourse of horizontally activated voxels - figure 2(b), we found that those voxels “deactivate” during vertical stimulation, in other words, their BOLD signals are lower during vertical stimulation period compared to fixation period. Other timecourses (not shown here) of vertical activated voxels, lower-half vertical meridian activated voxels and upper-half vertical meridian activated voxels all more or less show this type of “deactivation” during the opposite conditions. This suggests there might be some inhibitory effects between horizontal and vertical activated neurons, and between lower-half and upper half activated neurons. CASL studies of three subjects (results not shown here) also revealed HVA and VMA. Our fMRI results agree well with behavior results of visual performance in literature (1,5,6). Various factors, including cell density, neuronal distribution, regional blood supplies (6) and anatomical discontinuity (7) may contribute to these two asymmetries. The fact that HVA and VMA can be revealed by fMRI suggests that these asymmetries are more likely due to low-level visual processing. Follow-up study may include investigating whether these two asymmetries exist in all visual areas and whether they are homogenous across different visual areas.

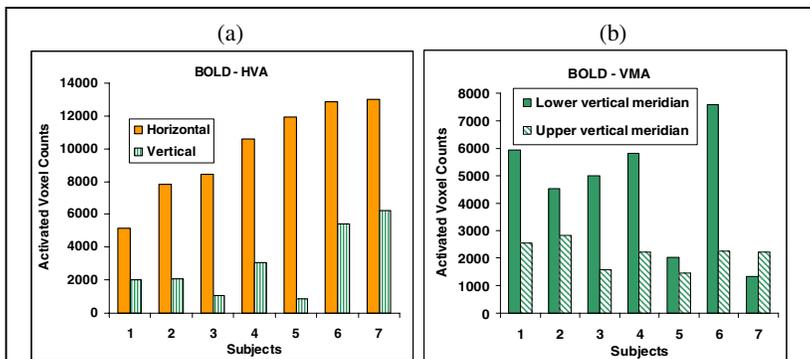


Figure 1. Histogram of activated voxel counts ( $t > 9.8$ ) in BOLD scan for different subjects. (a) Horizontal (orange solid) vs. Vertical (green texture). (b) Lower visual field (green solid) vs. upper visual field (green texture).

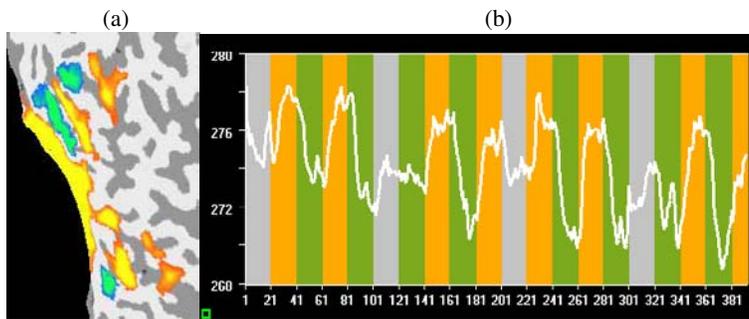


Figure 2. (a) Demonstration of HVA and VMA in a flattened visual cortex. (b) Typical BOLD time course of horizontally activated voxels during three conditions: fixation (grey), horizontal (orange) and vertical (green) stimulation.

## REFERENCE:

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