

Different Contribution of Early Visual Areas to Perceptual Process of Contextual Modulation

L. Zhang^{1,2}, K. Zhong¹, J. Hennig¹, and O. Speck^{1,3}

¹Dept. of Diagnostic Radiology / Medical Physics, University Hospital Freiburg, Freiburg, Germany, ²MRI Division, Dept. of Radiology, Beijing 306 Hospital, Beijing, China, People's Republic of, ³Dept. of Biomedical Magnetic Resonance, Otto-von-Guericke University, Magdeburg, Germany

INTRODUCTION: A fundamental question in human visual perception is how local image features are integrated into global configurations and perceived as visual shapes. Traditionally, the visual system is thought to be hierarchically organized in early visual area (V1, V2, V3, and V4) that are involved in the analysis of simple local features and in higher visual areas that are implicated in the processing of complex global shapes [1]. There is accumulated evidence that early visual areas (e.g., V1, V2) may respond to global rather than simple local features, and in recent experimental paradigms, contextual modulations within spatially limited regions (beyond classical receptive fields, but from relatively neighboring regions or within one of the visual quadrants) have been argued [2]. In this work, two small sectors with varying spatial distances were used to investigate if, where, and how modulations occur in early visual areas.

METHODS: Three volunteers (ages 26-33; one male) participated in the experiment. Imaging was conducted on a 3T system (Siemens Magnetom Trio). High-resolution anatomic images (MPRAGE, 256x256x160, 1 mm isotropic resolution) were obtained for each participant. Functional images were collected with gradient echo EPI (TR 2000ms, TE 30ms, matrix size 128x104x23, 2 mm isotropic resolution) with retrospective motion and distortion correction. Three functional scans were performed for every subject; the participant viewed the display through an angled mirror attached to the head coil. Retinotopic maps were acquired with standard "rotating wedge" and "expanding ring" stimuli [3]. Inverting checkerboard sectors (shown in figure 1) with 5 different conditions were measured. In order to fixate subject's attention, the subjects were instructed to press a button when the color of the central fixation point changed pseudorandomly from red to green (transiently for 200ms). All data sets were processed with the FreeSurfer software package. The individual ROI localizations in V1, V2d and V2v were determined by the activations of trial 1 stimulus (Figure 2) and the ROIs were used to extract signal changes of each trial condition.

RESULTS: The averaged percentile signal changes in V1, V2d and V2v of each trial condition are shown in Figure 3. The comparison of BOLD signal activations during each trial revealed modulatory trends in different early visual cortex (V1 and V2). Interestingly, significant result were observed in area V2v, which corresponded to the presentations in the upper visual field, and the strongest response was evoked in trial 2, despite the fact that it presented the closest spatial arrangement between two wedges in the visual field and on the cortical surface. The responses descend gradually with increasing distance of the second wedge. Slight modulation was also observed in area V2d, and the response was lowest in trial 2, nearly reversing the curve of V2v. No significant changes were found in primary visual cortex V1.

DISCUSSION: Contra-lateral dominance in sensory representation is a fundamental property of the primate sensory system. In human vision, retinal inputs from the right or left visual hemifield are separately projected to the primary visual cortex of the contralateral hemisphere, without any evidence of continuous representation across the junction between the two hemifields [4]. It is thus assumed that, in bottom-up visual hierarchy, dissociated representations of an object located across the visual vertical meridian should be combined only in the higher visual areas in which the receptive fields of neurons are large enough to cover ipsilateral as well as contralateral visual hemifields. Results from this study suggest that the primary visual area V1 does not contribute to the modulation of contextual integration. This is consistent with the fact that the receptive fields of neurons in V2 are significantly larger than those in V1 [5]. It has been shown that V2 neurons with selectivity to rather complex texture elements like arcs or circles, and cells with comparable receptive field properties could not be identified in V1 [6]. These neurons seem to be well suited to detect the relative positions of the wedges in our stimuli. The comparisons of monkey's neuronal responses in V1 and V2 to abutted line gratings and other stimuli also found a significant response in V2, but not in V1 [7]. A relatively smooth linear correlation was shown in V1 with variation of the stimuli, the ROIs of BOLD responses in visual cortex can be distinguished on flattened surface avoiding analysis errors of overlapping. Therefore, our results suggest that the contextual modulation may be processed in the V2 area. Our results also show that spatial linearity does exist in V1 but that 2 distinct activations in V2 do not necessarily add linearly.

REFERENCES:

[1] Maunsell, JHR, et al. *Annu. Rev. Neurosci* 10:363-401(1987)
[3] Tootell, RB, et al. *Proc Natl Acad Sci USA* 95:811-817(1998)
[5] Smith, AT, et al. *Cereb Cortex* 11:1182-1190(2001)
[7] Von der, HR, et al. *J Neurosci* 9:1731-1748(1989)

[2] Zipser, K, et al. *J Neurosci* 16:7376-7389(1996)
[4] Tootell, RB, et al. *Proc Natl Acad Sci USA* 95:818-824(1998)
[6] Hegde, J, et al. *J Neurosci* 20:RC61(2000)

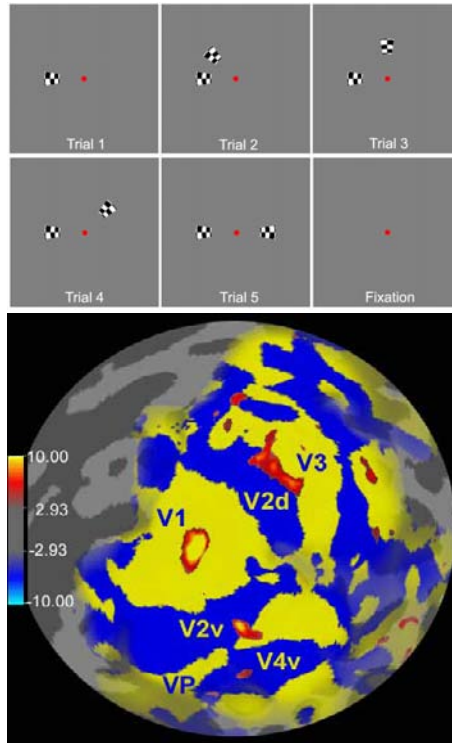


Figure 1. Visual Stimuli. Two inverting checkerboard sectors in five different configurations in upper visual field were used. Each configuration was presented for one trial with 20sec ON and 20sec OFF (background with fixation point). The whole scan lasted 400sec with two presentations of each trial arranged pseudorandomly. The two sectors had identical eccentricity. The sector located at 0° in left visual field as trial 1 was identical in all trials, the other sector is located clockwise at different angles of 45, 90, 135 and 180 degrees.

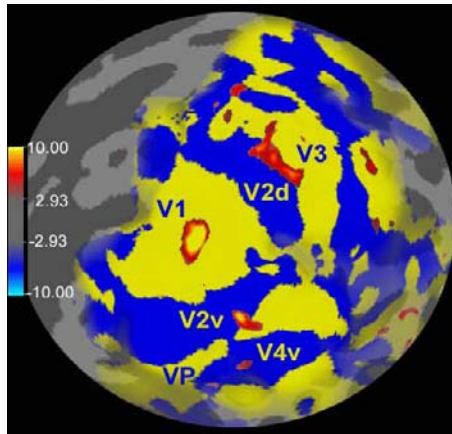


Figure 2. Localization of activations and ROIs. A standard "rotating wedge" and "expanding ring" stimuli were used to generate retinotopic maps on the flattened surface of the occipital lobe (right hemisphere). Areas of V1, V2d, V2v, V3, VP are labeled. Functional mapping of trial 1 activations on the cortical surface revealed precise localization and anatomic separation from the representation of the other areas. The ROI locations for BOLD signal analysis were determined by the activation location of trial 1 in V1, V2d and V2v.

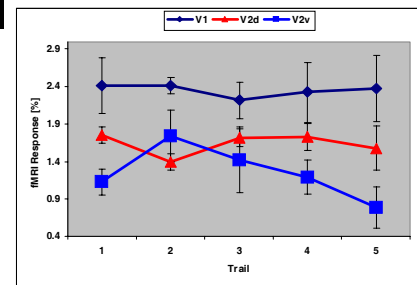


Figure 3. Average estimated BOLD response amplitudes (percent signal change) and the standard deviations of each trial within the ROIs. Significant changes were observed in V2v, slight significant changes occurred in V2d and no obvious changes were detected in V1.