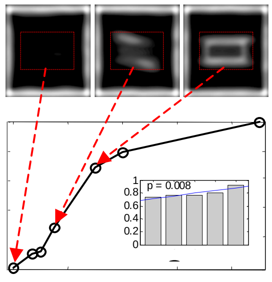
Texture segmentation in human perception revealed by fMRI

A. P. Wunderlich[1], A. Thielscher[2], H. Neumann[3], G. Grön[4]

[1]Diagnostic Radiology, University Clinic Ulm, Ulm, Baden-Württemberg, Germany, [2]Psychiatry, University Clinic Ulm, Ulm, Baden-Württemberg, Germany, [3]Dept. of Neural Information Processing, University of Ulm, Ulm, Baden-Württemberg, Germany, [4]Psychiatry, University Clinic Ulm, Ulm, Beden-Württemberg, Germany



Introduction. The human visual system segregates textured visual scenes effortlessly into figure and ground (1). Based on known anatomy and physiology of lower-level visual cortical areas we implemented a model of human texture processing (2) along the ventral pathway suggesting that area V4 plays a central role in scene segmentation by detecting texture discontinuities. In particular, the model predicts monotonic increasing V4 activation as a function of increasing texture saliency (Fig 1). This prediction was directly tested using fMRI.

Fig. 1 Model area V4 activation in response to texture bars of different orientation contrasts.

Methods. We scanned six healthy, male volunteers on a 1.5T Siemens Vision scanner using a T2*-weighted EPI with TR/TE 2115/50 ms, coronal acquisition, image matrix 64 x 20 x 64 and voxel size 3.5 mm³. We presented line patterns with different orientation contrast. All textures consisted of a matrix of 12 by 12 line elements that were white rotated bars on black background (3). Pseudrandomized rotation of background line elements varied within a range from 12° to 167° (stepsize: 5°). Dependent on the amount of rotational shift, vertical or horizontal bars popped out frequently in the center of the display. Rotational shifts of bar defining elements were parametrically varied (0°, 7°, 10°, 15° and 30°) resulting in five different conditions of orientation contrasts (36 trials each; vertical/ horizontal bars: 50/50 %). In order to establish a preattentive task, subjects were asked to decide by means of button presses whether the flanking letters besides the displays were identical or not.

Image preprocessing and data analysis was performed by SPM99. Regressors were delta functions convolved with canonical HRF. Main effect analysis was done by means of a one-tailed t-test on spatially smoothed data (FWHM: 6mm) averaging over subjects. Exploration of monotonically increasing activations strengths was done on spatially unsmoothed data by means of an appropriate F-test. Nominal level of alpha: $p < 0.05$ corrected, for all analyses.

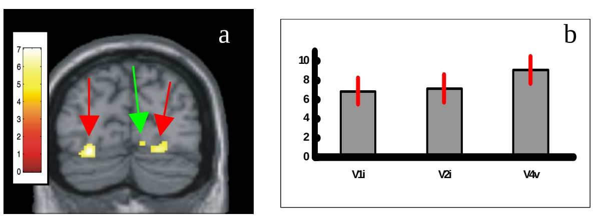


Fig. 2 a) Main effect of texture segmentation in ventral V4. b) Mean effect sizes in areas V1 (not shown), V2 (green arrow) and V4 (red arrows)

Results. Responses were found in cortical visual areas V1, V2 and V4 (Fig. 2a). The main effect of texture segmentation increased from V1 to V4 (Fig. 2b) as previously shown by Kastner et al. (4). The BOLD signal in V4 (Fig. 3) increased with orientation contrast.

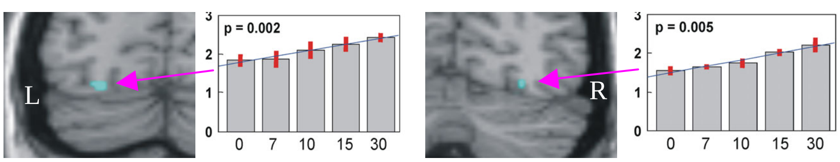


Fig. 3 Monotonically increasing effect sizes with increasing orientation contrast in left (L) and right (R) ventral V4.

Discussion. Our modeling and imaging results indicate that V4 forms a key stage for texture border detection by gradually signaling the salience of texture discontinuities. This graded boundary response may control figure-ground segregation processes via feedback observed as early as in area V1. This demonstrates how both, the modeling and experimental approach, can successfully interact in elucidating higher visual functions.

References
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