Neuronal Activation of 3D Perception Monitored with Functional Magnetic Resonance Imaging

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Introduction

Different visual cues such as disparity, occlusion, shade, texture gradient, or motion [1-6] result in a perception of depth. Julesz random dot stereograms allow to vary the relative disparity parametrically as a separate cue to investigate the neuronal response to different depth perception levels. Only some studies investigated a parametric response to disparity levels [1,2] using only few volunteers. We present first results of a random effects analysis of 9 volunteers to analyze the dependence of the neuronal activity of increasing disparity levels to detect only those neuronal populations correlating directly to the varying perception of depth.

Material and Methods

The paradigm consisted of stereo random dot checkerboards with 8x8 squares presented with 8 Hz flicker frequency. Disparity regions were displayed as shifted red vs. green random dots while non-disparity regions were displayed as the sum of both colors. Images were presented through red/green goggles. In each run 5 disparity conditions (flat,1',2',3',4' shift) were shown in a pseudo-randomized sequence using a block design with 20 s activation vs. 20 s rest (gray background). Two runs with different order of disparity conditions were presented. Prior to examination the volunteer's depth perception was confirmed by their ability to discriminate the different levels of disparity as different depth perceptions. 9 volunteers were examined. The MRI protocol (Magnetom TRIO, 3 T, Siemens) comprised T1-weighted 3D MPRAGE (1x1x1 mm) for anatomical data, and EPI (64×64 matrix, 40 axial slices, 3.4x3.4x4 mm, TR = 2s) for functional imaging. Post-processing was performed using SPM2. Data were realigned, normalized to 3x3x3 mm, and smoothed with a Gaussian filter (9 mm FWHM). In the "flat vs. disparity" condition, zero disparity was tested against all stereo contrast conditions. In the parametric analysis the checkerboards were weighted linearly with increasing disparity. For both evaluations the resulting contrast images were analyzed using a random effects analysis with p=0.001 uncorrected.

Results

All subjects exhibited a clear activation in the primary and extrastriate visual cortex. In the random effects analysis of comparing flat and disparity conditions only extrastriate areas (presumably V3A) were tested as significant (tab. 1). In the single subject analyses 5 of the 9 subjects exhibited activated areas similar to the second level analysis. To separate the neuronal population that responded with increasing activation to increasing levels of disparity a parametric analysis was performed (tab. 1). The results (fig. 1) that were similar to random effects analysis for the flat vs. disparity condition (table 1) showed no activation in the primary visual area (V1) but only in extrastriate areas (V3A).

Cluster		Talairach coordinates				location
	size/mm^3	Z	x	y	z	
Regions with higher activation for disparity as compared to non-disparity conditions						
1	1249	3.90-3.60	-16±2	-85±4	27±5	Left occipital lobe, cuneus (BA 19)
2	3237	3.64-3.54	22±5	-86±6	33±5	Right occipital lobe, cuneus (BA 19)
Regions with activation linearly correlated to increasing disparity (cf. fig. 1)						
1	3699	4.06-3.46	-22±8	-86±3	28±7	Left occipital lobe, cuneus to superior occipital gyrus (BA 19)
2	2358	3.66-3.37	25±5	-83±3	39±7	Right parietal lobe, precuneus (BA7) to occipital lobe, cuneus (BA 19)

Table 1: Results of the random effects analysis

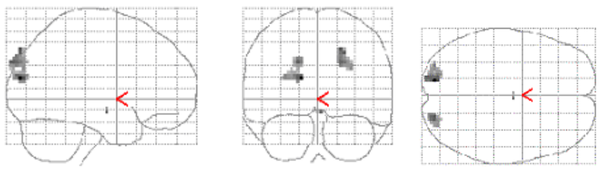

Figure 1: SPM2 glass brain with regions linearly activated with increasing disparity.

Discussion and conclusion

Neuronal activation that correlates to depth perception was investigated in several studies leading to the result that disparity-selective neurons are located primarily in extra striate areas [1-6]. Our finding that disparity-related activation is not located in V1 but only in extrastriate areas confirms these studies. The study of Rutschmann et al. [1] is similar to the presented study. Although their analysis of the parametric response to increasing disparity is based on the analysis of only 2 persons our random effect analysis of 9 volunteers agrees well with their results, except the activated areas in our study are less extended than in [1]. To avoid the problem of an increased perception of form due to its 3D separation from its environment, Backus et al. [2] used two transparent random dot planes separated by different levels of disparity. Although their data analysis used a different approach [7] which does not easily allow a comparison across several persons they also found activated areas in the extrastriate areas with most remarkable activations in area V3A. It may therefore be summarized that depth perception caused by relative disparity is mainly located in extrastriate areas.

References

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