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

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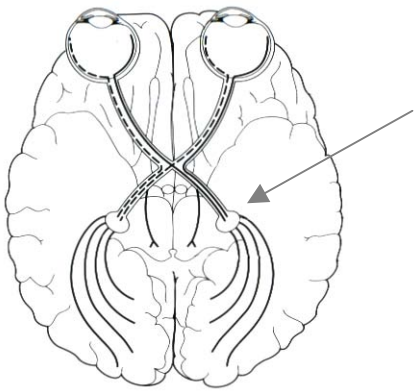
1. Introduction
   - Visual System, Retinotopy
   - Depth Perception
   - Motivation
2. Methods
3. Results and Discussion
4. Conclusion

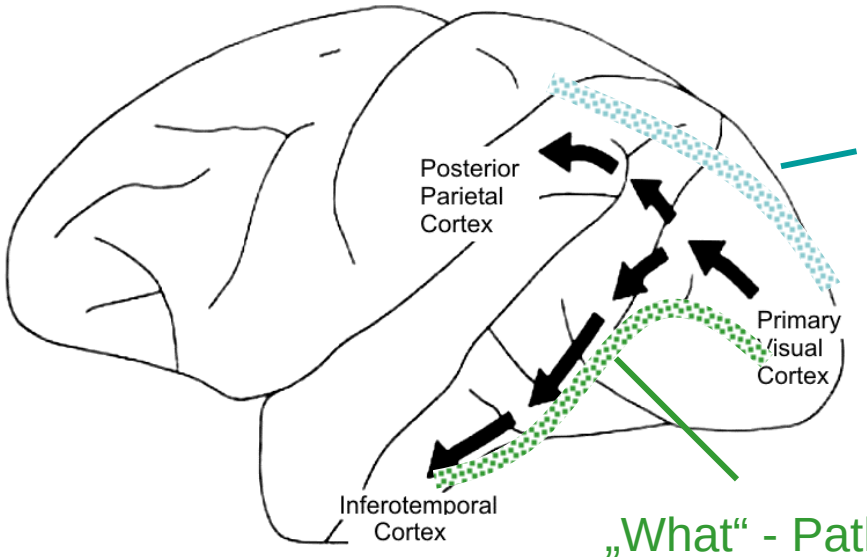
Introduction: Visual System



Corpus geniculatum laterale (CGL)

primary visual cortex (striate cortex)

dorsal



„Where“ - Path

„What“ - Path

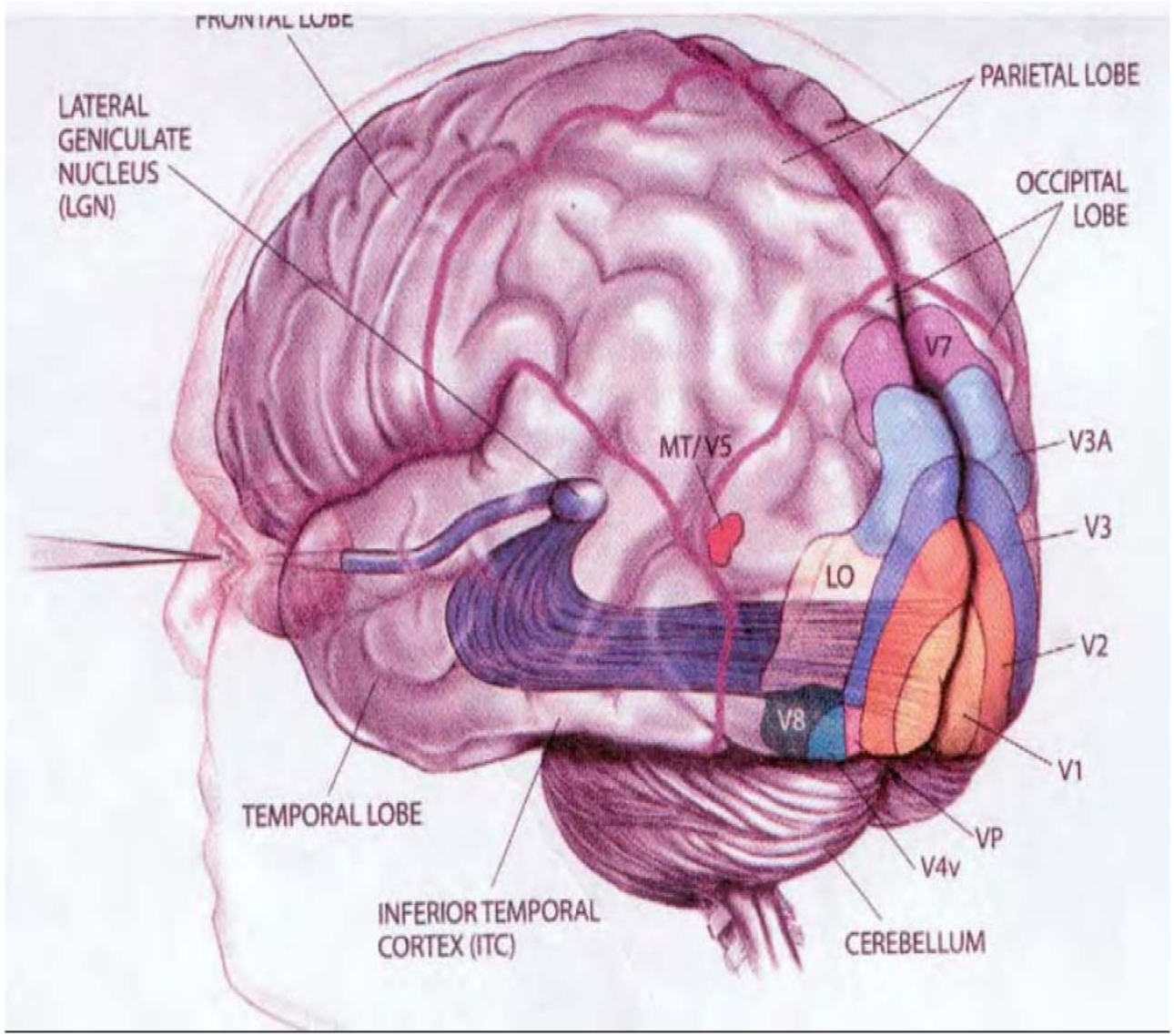
2 different paths for visual processing in extra striate cortex

ventral

Goldstein, E. Bruce: Wahrnehmungspsychologie. Berlin:Spektrum, Akad. Ver. 2002)

http://education.umn.edu/kls/research/motorlab/hsc-project4.htm

Introduction: Retinotopy, higher visual areas



Introduction: Depth Perception

Oculo motoric information: eye vergence

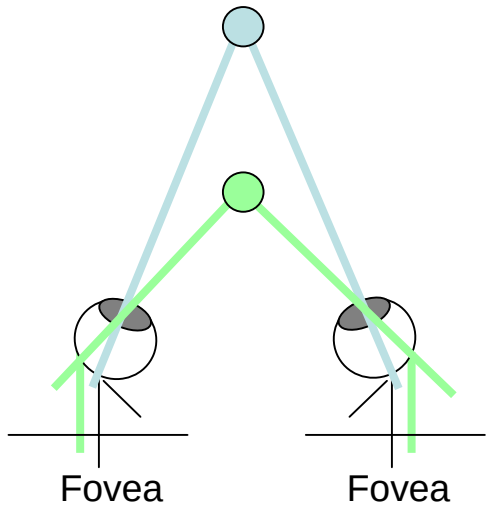
Monocular information: shade, texture gradients, perspective, occlusion,..

Depth from motion

Two 2D retinal images

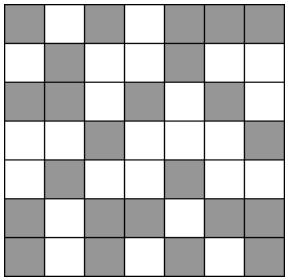
disparity

3 D perception

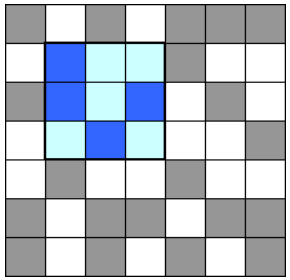


Introduction: Random Dot Stereograms (RDS, Julesz 1971)

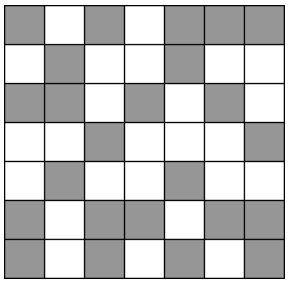
isolated depth cue: disparity

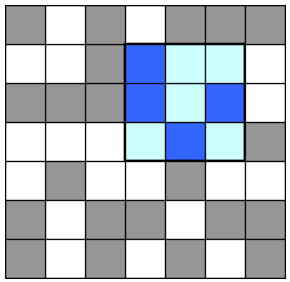


left image

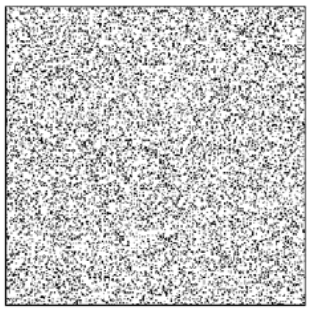


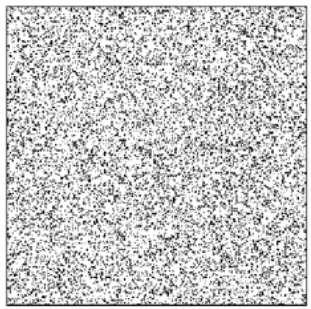
right image



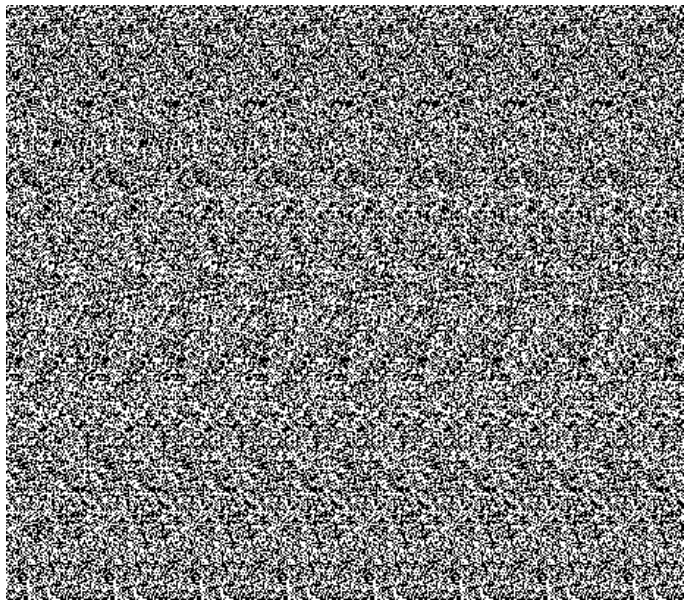


2 identical random dot patterns
with shifted subpattern





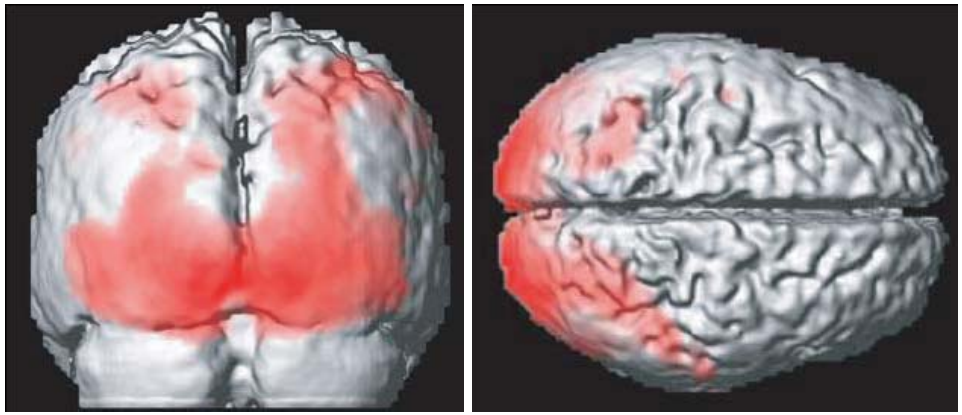
autostereogram



http://www.fraktalwelt.de/index.html

Motivation

- Activated areas for visual paradigms in functional magnetic resonance imaging (BOLD fMRI) are rather large



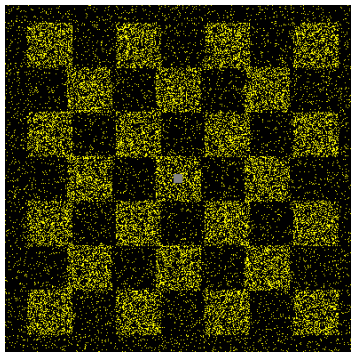
Rutschmann RM and Greenlee MW. BOLD response in dorsal areas varies with relative disparity level. *NeuroReport* Vol 15 No 4, 615–619 (2003))

- Subpopulations of neurons for depth perception may be detected with parametric design (varying the disparity level)
- Only neuronal areas significant, that show an increase with increasing disparity level

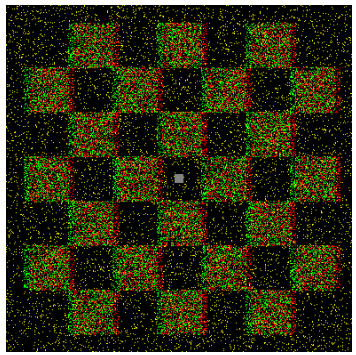
Methods

Stimuli

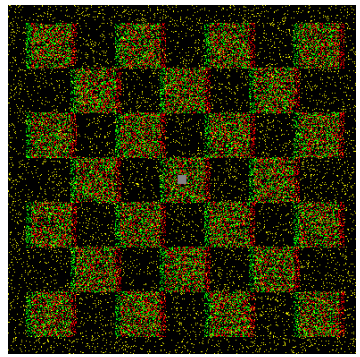
- RDS checkerboard, flicker frequency 8 Hz,
- Red/green anaglyph technique
- Disparity level: 0 (flat), 2, 4, 6, 8 pixel
- Pseudo-randomized presentation, 2 runs, different order
- Block design: 20 s on, 20 s off (gray background)



Disp 0 (flat)



Disp 6 forward



Disp 6 backward

MRI protocol

- 17 volunteers with stereo perception, 3T Magnetom Trio
- fMRI: EPI 3.4x3.4x4 mm^3, 64^2 matrix, TR 2s, 40 axial slices
- Anatomy: MPRAGE, $1mm^3$

Methods

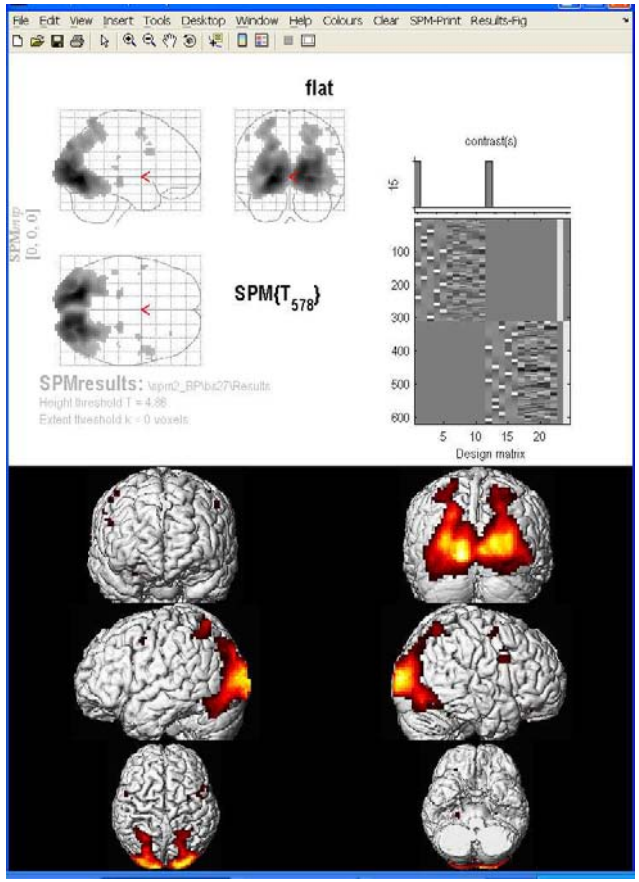
Data postprocessing

- SPM2
- realignment
- normalizing to 3x3x3 mm,
- smoothing with Gaussian filter (9mm FWHM)

Statistics protocol

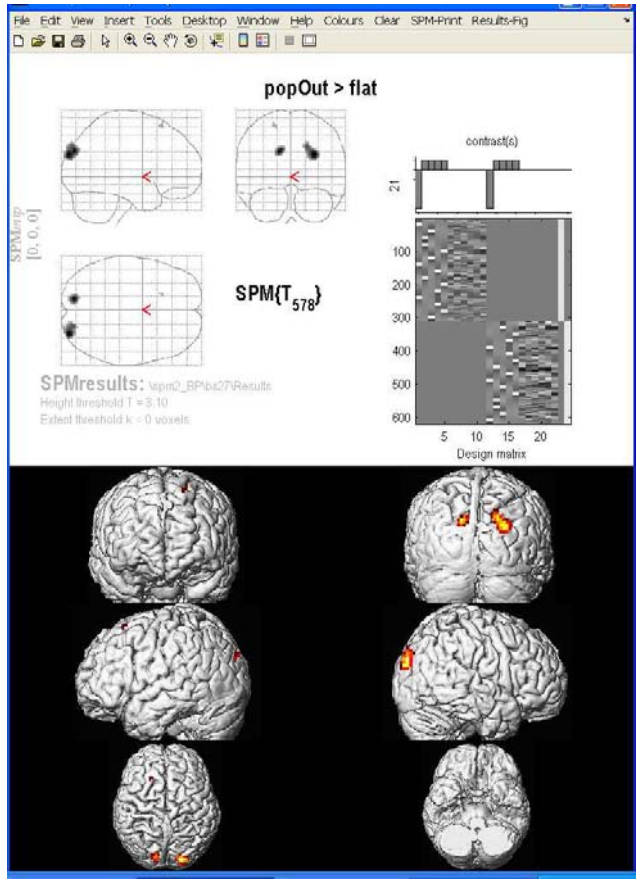
- Flat vs. disparity: 0 tested against all disparity conditions
- Parametric: linear increase of activation with increasing disparity leve
- Random effects analysis for both conditions

Results: representative volunteer



Visual stimulation (p=0.05, FWE corrected for multiple comp.):

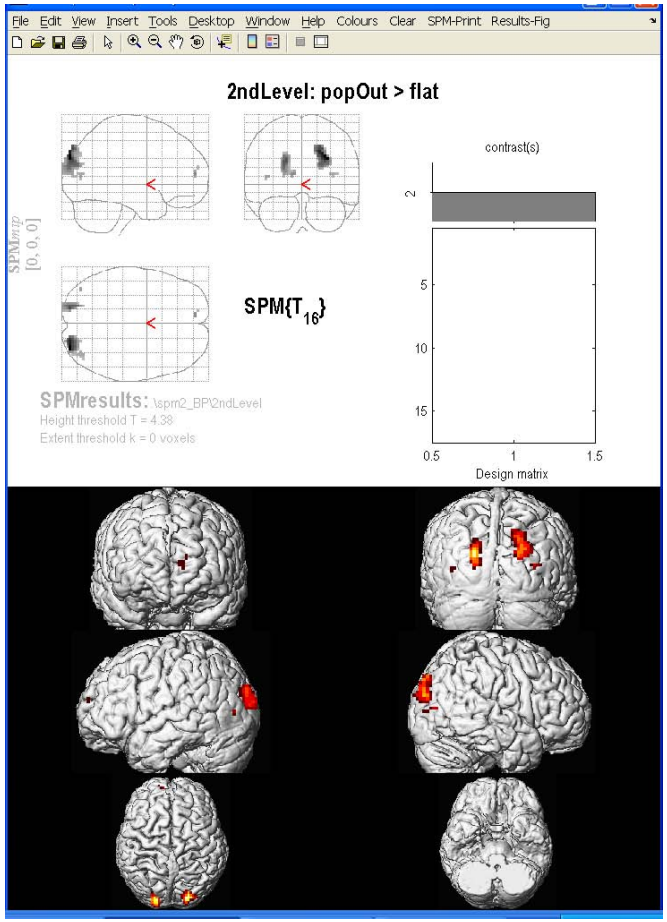
➡ Activation of striate and extrastriate areas



Differential activation flat vs. disparity (p=0.001 uncorr.):

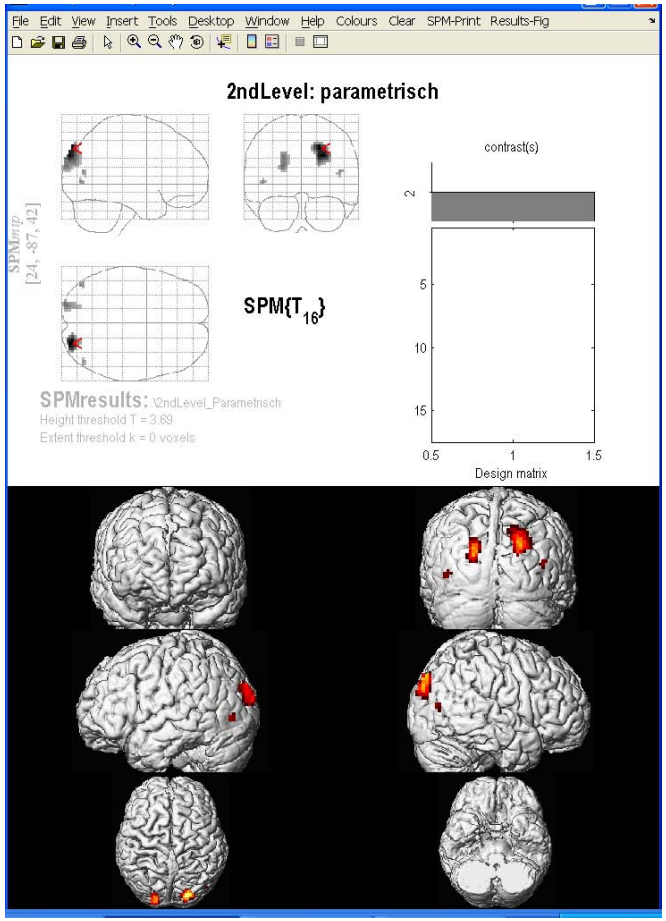
➡ Activation of extrastriate areas

Results: random effects analysis



Differential activation flat vs. disparity (p=0.05, FDR corrected):

Activation of extrastriate areas



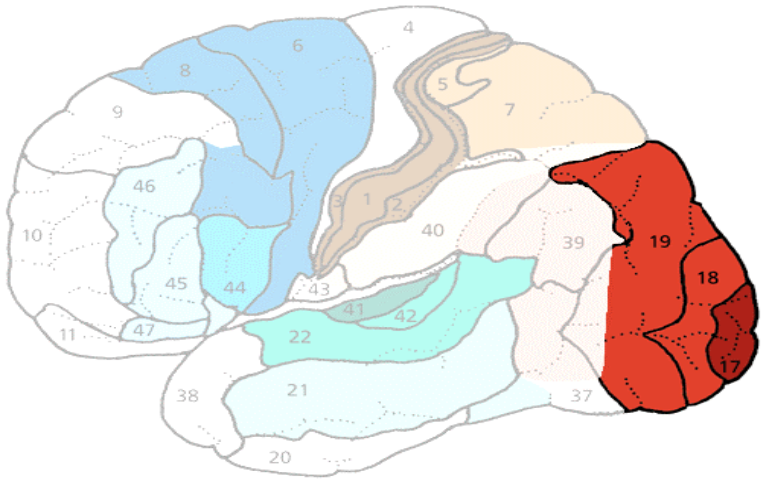
Parametric analysis (p=0.001 uncorr.): Extrastriate areas

Results: random effects analysis

Cluster		Voxel		Talairach coordinates			location
	size/ voxel	p (FDR-cor)	T	x	y	z	
1	137	0.010	8.01	30	-86	32	Right Occipital Lobe, Cuneus, BA19
2	122	0.015	6.41	-18	-86	29	Left Occipital Lobe, Cuneus, BA19
3	3	0.028	4.95	-39	-75	12	Left Middle Temporal Gyrus, BA39
4	9	0.079	4.84	36	-78	14	Right Middle Occipital Gyrus, BA 19

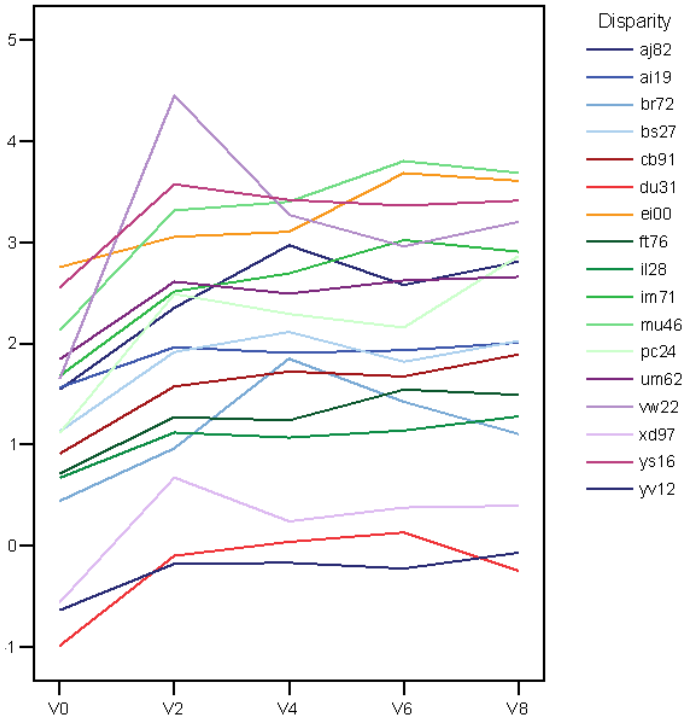
Differential activation flat vs. disparity (p=0.05, FDR corrected):

Activation of extrastriate areas, presumably V3A and junction of lateral occipital and temporal regions (MT+)

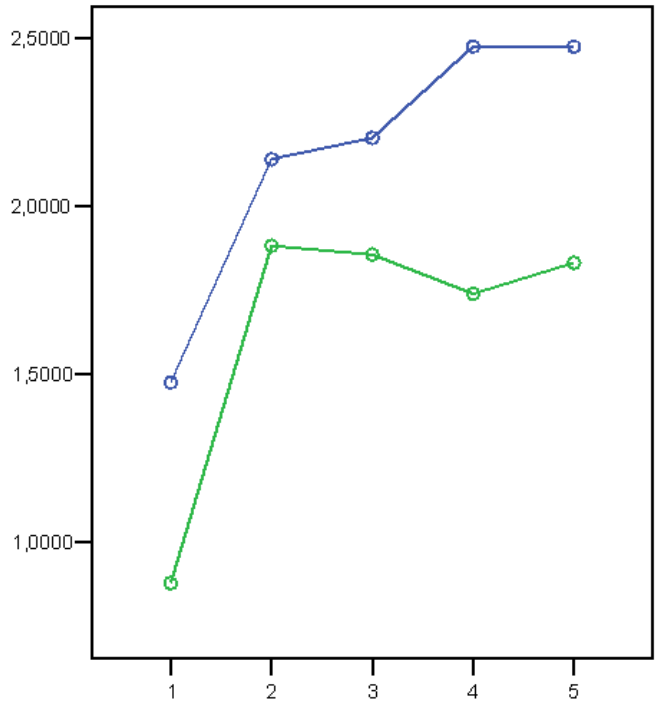


Results: parametric analysis of disparity

Mean activation



all volunteers

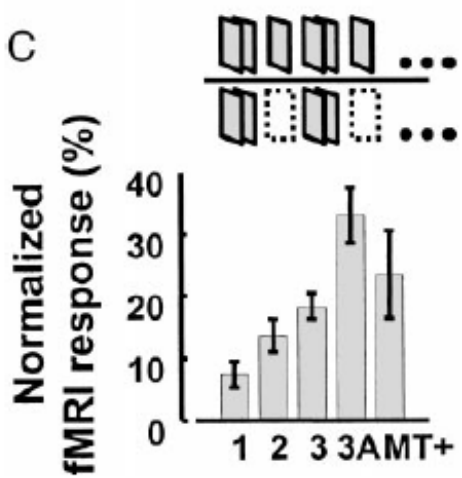


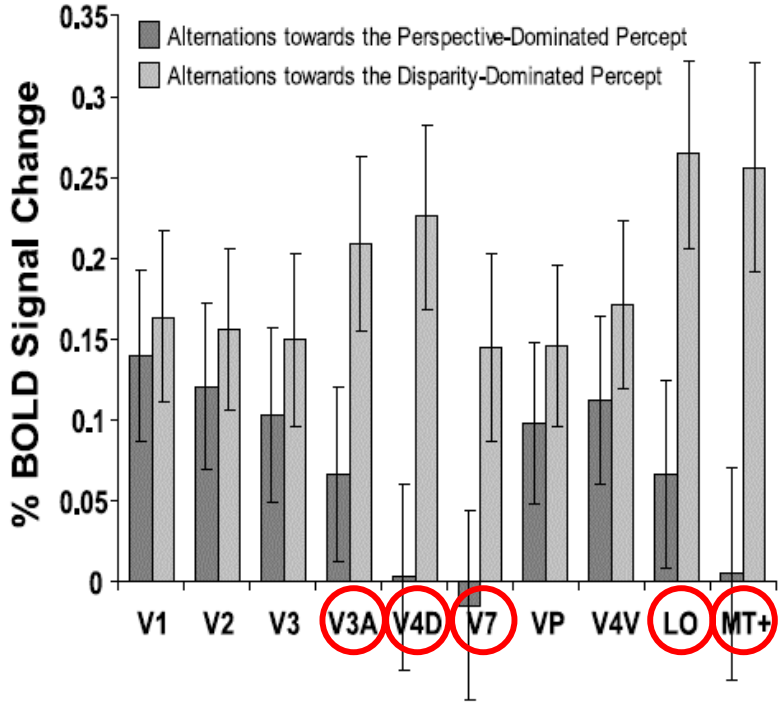
Blue: 6 volunteers with linear increase for disparity

green: remaining volunteers

Discussion: disparity vs. non-disparity

Backus et al, *J Neurophysiol* 86: 2054-68, 2001.



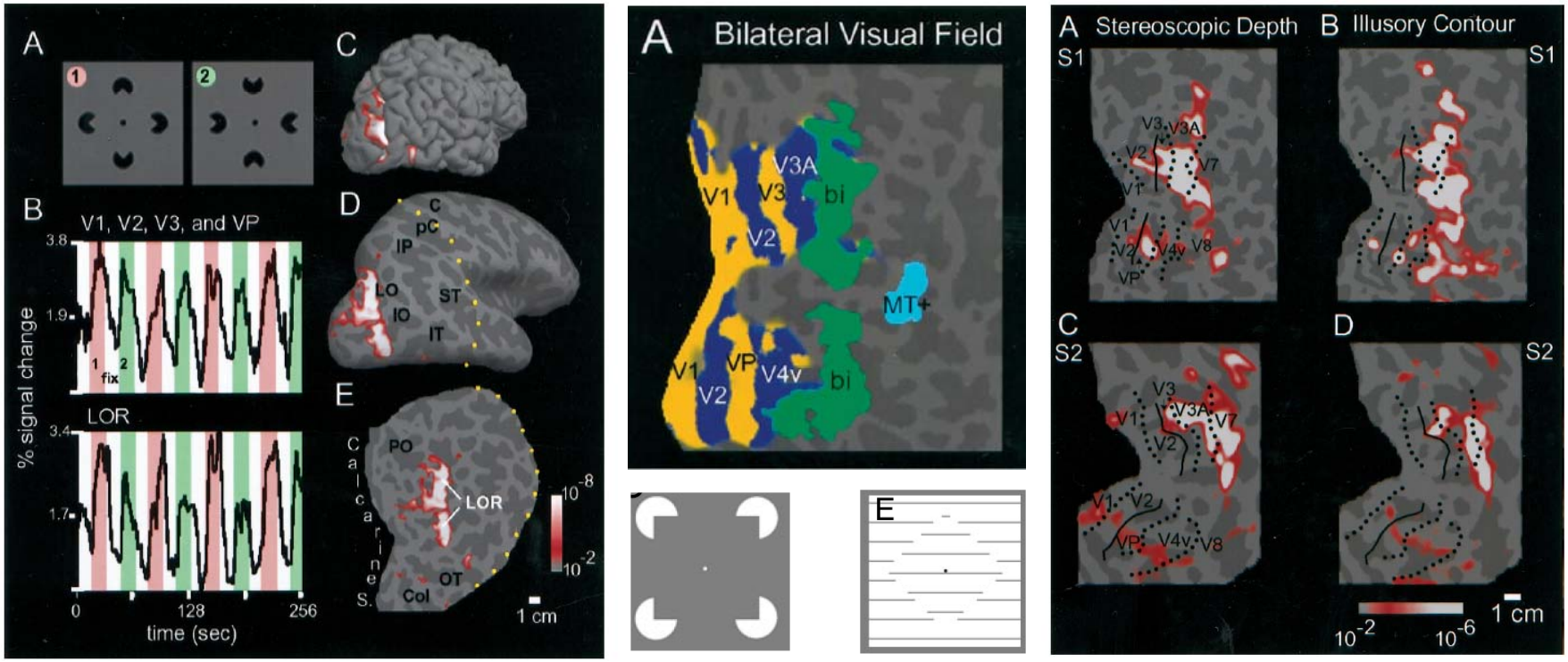


- Visual areas activated for disparity
  - V3A
  - V7
  - V4d-topo
  - MT+ und
  - LOC

Brouwer GJ et al. *J. Neurosci*, 25:10403–13 (2005)

Discussion: disparity vs. non-disparity

Mendola et al, J Neuroscience, 1999, *19*: 8560–72

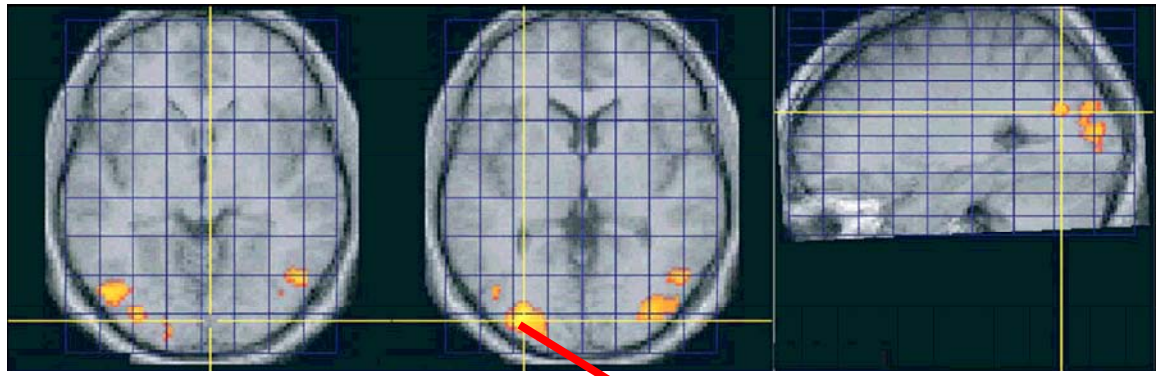


illusory contour-defined shape and stereopsis-defined shape had a significant overlap in V3A and V7,

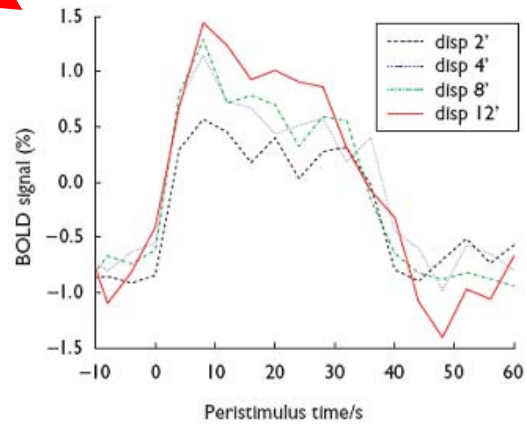
less overlap was seen inferiorly (e.g., anterior to V4v), where the illusory contour stimuli produced more activity than the stereo stimuli.

Discussion

Rutschmann RM and Greenlee MW. BOLD response in dorsal areas varies with relative disparity level. *NeuroReport* Vol 15 No 4, 615–619 (2003))



Similar design, 5 volunteers,
2 with parametric analysis



Backus et al., J Neurophys 86 (2001), 2054-2068):

Disparity related effect in V3A, small parametric dependence

Conclusion

- Study with a large group of volunteers allowing a random effects analysis
- All volunteers exhibited clear activation of the striate and extra striate visual cortex
- Primary visual areas were not involved into depth perception (relative disparity)
- V3A and lateral occipital regions were sensitive for disparity in good agreement with other groups
- Most significant changes were between no-disparity and all disparity conditions
- Only a small subgroup exhibited activation increase with increasing disparity (parametric analysis)

Acknowledgement

Dr. C. Tempelmann and Dr. M. Kanowski (Klinik für Neurologie II, director Prof. Dr. HJ Heinze) for providing help with the MRI facilities