Adaptation to the 3D properties of the environment in non-human primates

Yseult Héjja-Brichard[1,2], Samy Rima[1,2], Yves Trotter[1,2], Marty Banks[3], Jean-Baptiste Durand[1,2] & Benoit R. Cottereau[1,2]

1 Université de Toulouse, Centre de Recherche Cerveau et Cognition, Toulouse, France
2 Centre National de la Recherche Scientifique, Toulouse Cedex, France
3 Department of Psychology, University of Berkeley

Overview

Binocular disparity is a main cue for depth perception. Sprague et al. (2015) recently suggested that stereopsis might be adaptive to our visual environment, reporting a preference for gradients of disparities that are aligned with the ground in the neurons of macaque V1.

The aim of the present study is to determine whether higher visual areas also show biased responses for 3D orientation aligned with the ground surface.

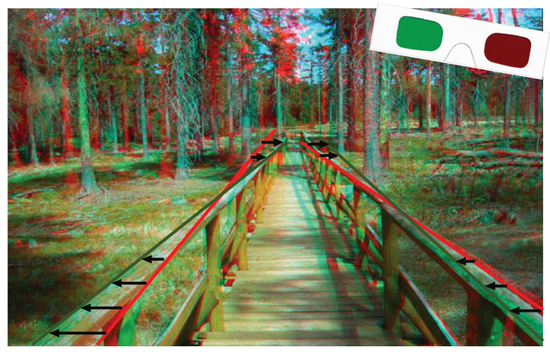
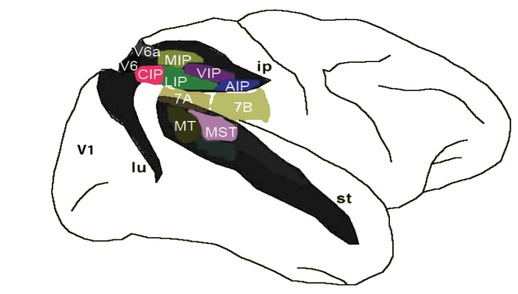
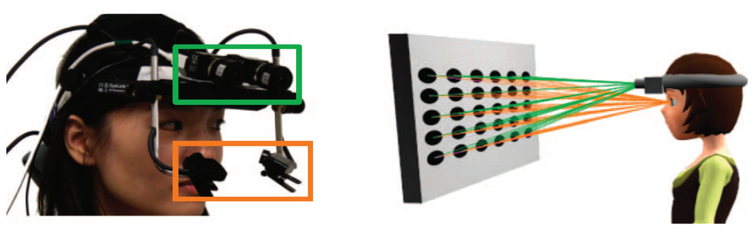


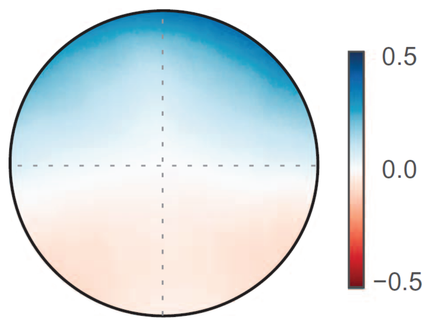
Illustration of the prevalence of disparity gradients that are aligned with the ground.



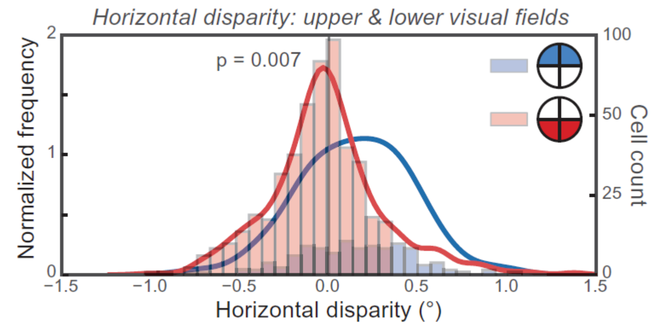
Macaque monkey brain



Stereo-camera and eye-tracker head-mounted system, see Sprague et al., 2015



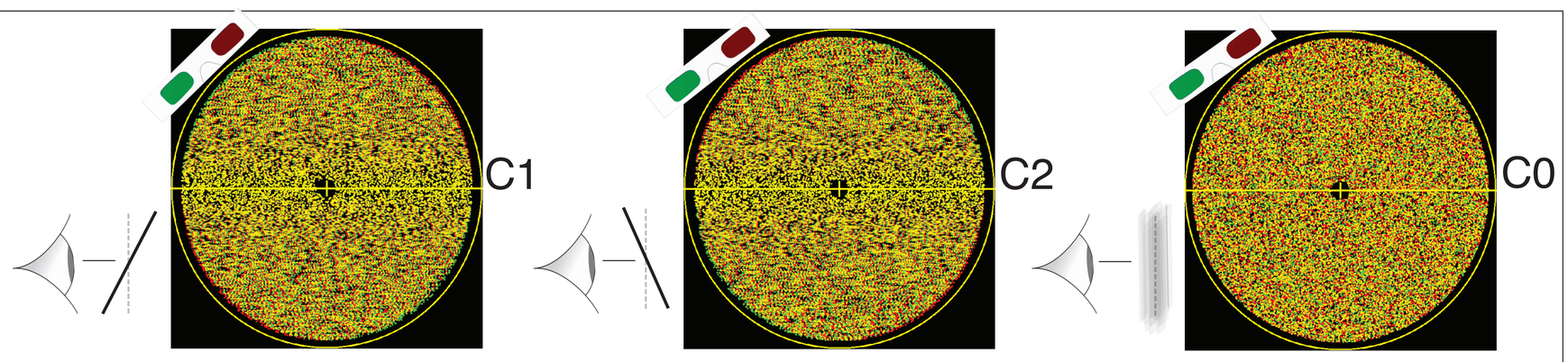
Median horizontal disparities in different parts of the visual field



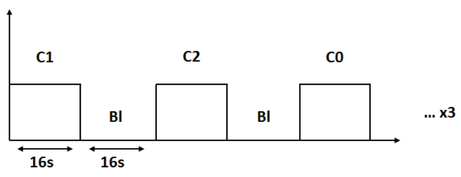
Distribution of preferred horizontal disparities grouped by upper (blue) and lower (red) fields. The histograms represent the number of cells observed with each preferred disparity, see Sprague et al., 2015.

Stimuli

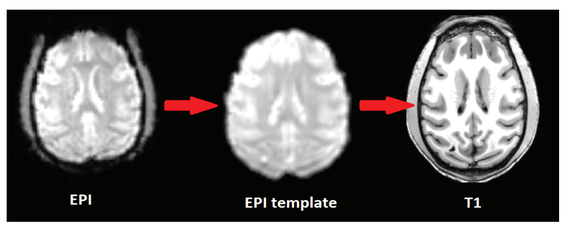
Disk defined with random dot stereograms (RDS).
3 monocularly identical conditions :
- 'aligned with the ground' (C1)
- 'not aligned with the ground' (C2)
- 'uncorrelated', as a control conditiion (C0)



Experimental Setup



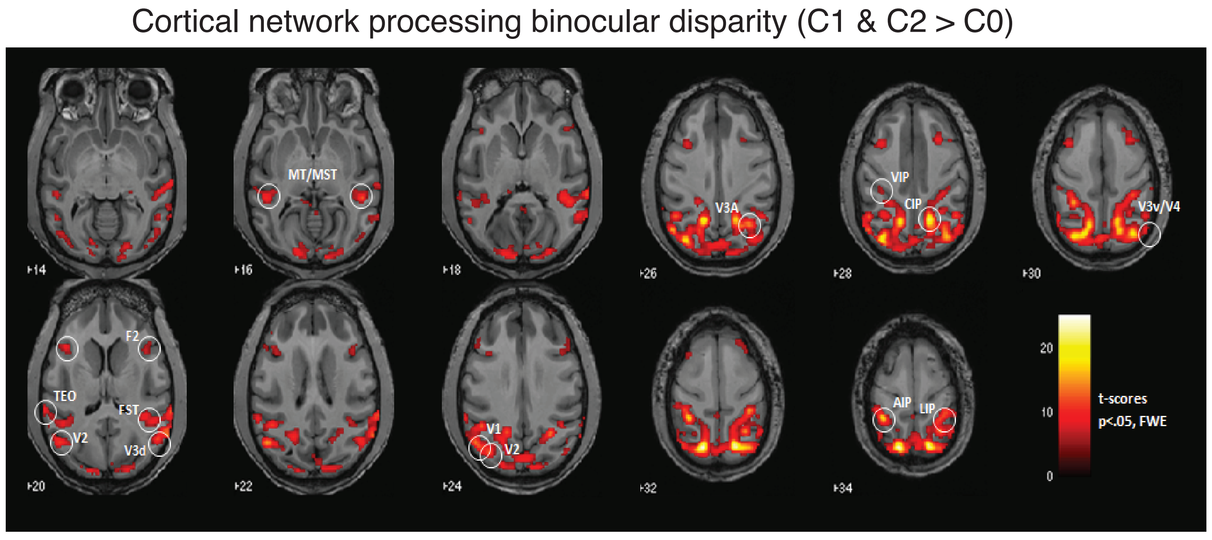
- Block design paradigm
- fMRI recordings (3T), voxel resolution: 1.25x1.25x1.5mm, TR = 2s.
- 1 awake behaving monkey with red/green anaglyphs
- Specific 8-channel coil - BOLD signal
- Eye-tracker: only runs with a fixation above 85% were kept
- Pre-processing (slice-timing correction, motion correction, smoothing), normalisations:



- GLM (motion correction parameters as regressors)
- HRF estimated on each animal using independent data

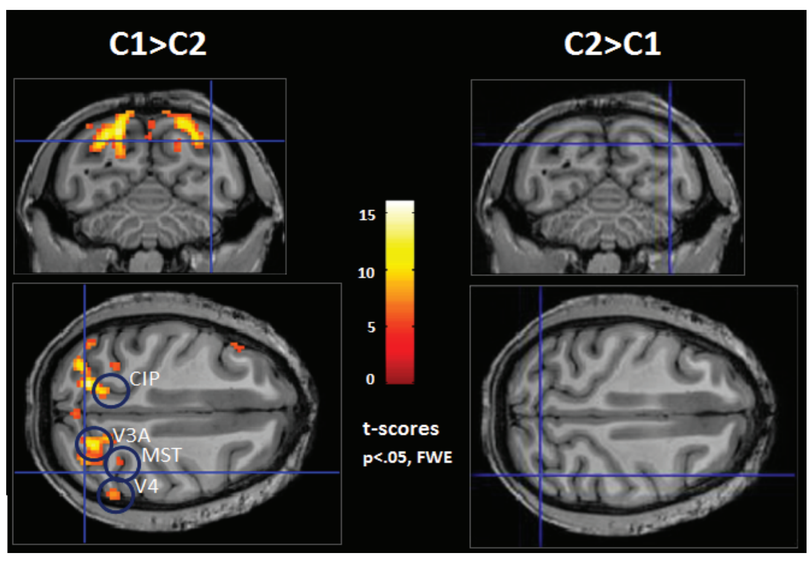
Results

Cortical network processing binocular disparity (C1 & C2 > C0)

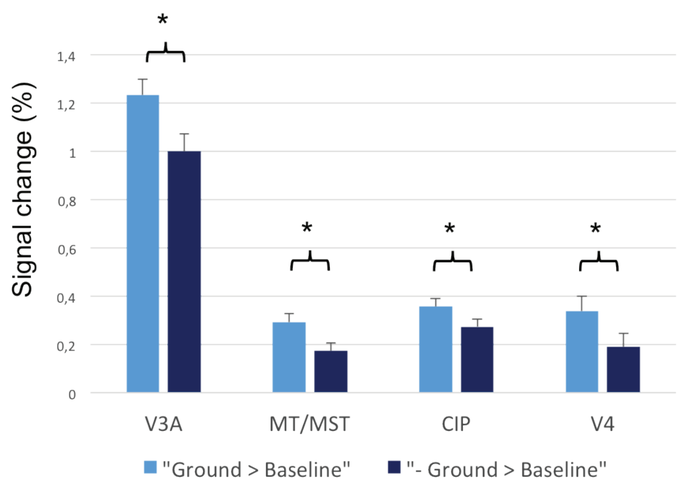


Bias in the responses to different disparity gradients

Whole-brain using (C1 & C2 > C0) as a mask



ROI-based analysis



Signal change between C1 and the baseline and between C2 and the baseline

Conclusion

We found a large cortical network involved in disparity processing and whose areas are known to respond to disparity-defined stimuli, such as slants (e.g., CIP, in Taira et al., 2000). More importantly, we were able to show for the first time that within this network, some areas respond more strongly to slants that are aligned with the ground in contrast with slant aligned in the opposite direction : V3A, CIP, MT/MST, and V4. These results suggest that, not only V1 neurons, but also higher areas are sensitive to the 3D regularities of the environment.

Bibliography

Sprague WW, et al. (2015). Stereopsis is Adaptive for the Natural Environment. Science Advances, 1(4), e1400254.

Taira M et al. (2000) Parietal neurons represent surface orientation from the gradient of binocular disparity. Journal of Neurophysiology, 83, 3140- 3146.

Perspectives

- Performing recordings in more animals and also in human subjects to determine whether these biases are identical or different between both species (NB: human and macaque have different interocular distances, heights, environments, ...)
- Generalising this study to biases in the cortical responses to various 3D properties within natural environments.

Acknowledgements: This work was supported by a grant from the Institut des sciences du cerveau de Toulouse (ISCT), 2 grants from the 'Agence Nationale de Recherche' (ANR-13-JSV4-0007-01 and ANR-12-BSV4-0005) and a 'France-Berkeley' funding. The authors declare no competing financial interests.

Contact: hejja-brichard@cerco.ups-tlse.fr