Influence of natural statistics on depth perception

Yseult Héjja-Brichard[1,2], Silvia E.P. Bruzzone[2,3], Emilie Rapha[1,2], Jean-Baptiste Durand[1,2], Benoit R. Cottereau[1,2]

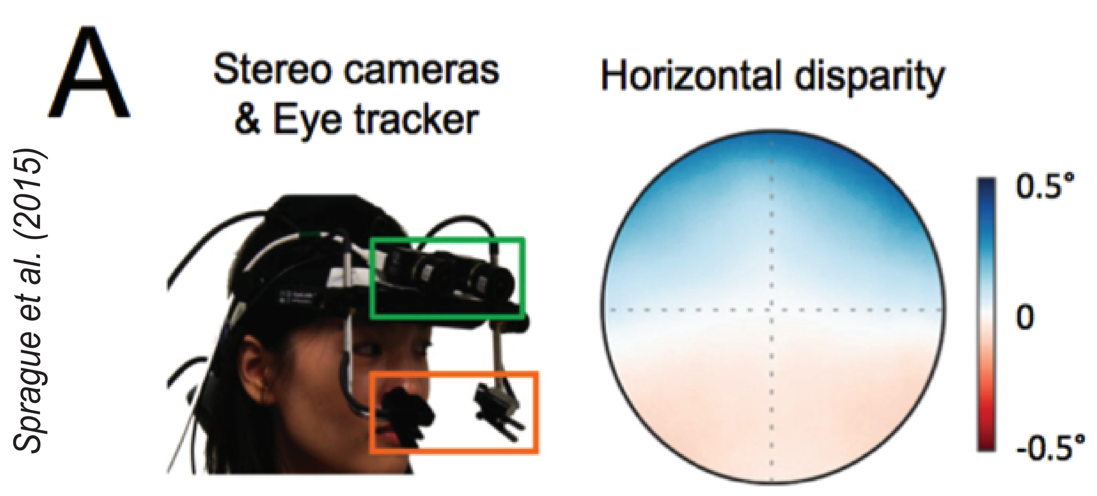
[1] Université de Toulouse, Centre de Recherche Cerveau et Cognition, Toulouse, France
[2] Centre National de la Recherche Scientifique, Toulouse, France
[3] Università degli studi di Trieste , Trieste, Italy

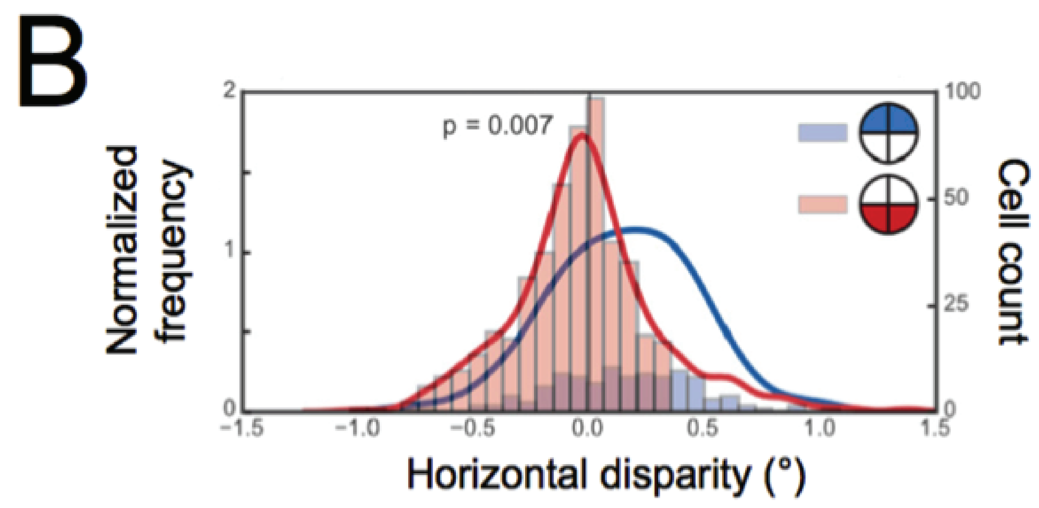
Contact: yseult.hejja@cnrs.fr

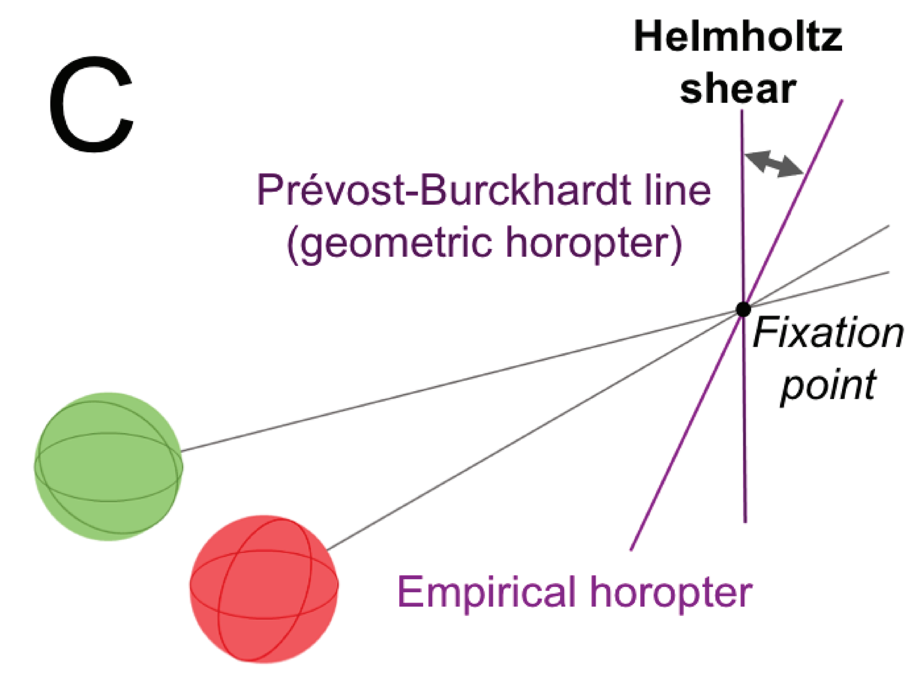
Overview

To perceive depth, the visual system uses binocular disparities, the small differences between the two retinal projections of a visual scene, by matching corresponding points. Although there is no unique solution to this correspondence problem, some retinal points have a special physiological relationship that facilitates it. The space area that projects on those corresponding points forms the horopter, where stereoacuity is the finest. The vertical component of this horopter is not a vertical line, as one would expect if the corresponding points had identical anatomical locations in both retinae. Instead, it is tilted in a top-back manner relative to the fixation plane. This deviation, known as the Helmholtz's shear, has been suggested to reflect the distribution of binocular disparities in visual scenes (A) and could reflect the tuning properties of binocular neurons (B) in the early visual cortex (Sprague et al., 2015; Nasr and Tootell, 2016).

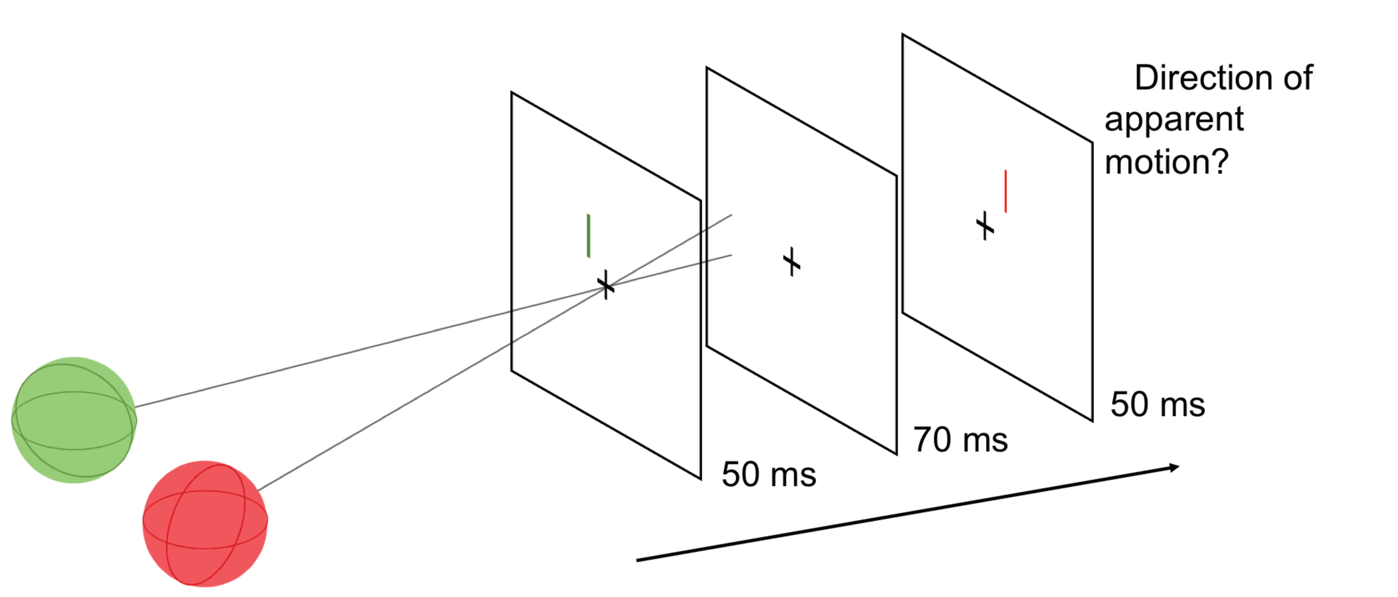
We measured the horopter in a macaque subject to determine whether such a perceptual bias also exist in another species, and if so, whether it is in agreement with natural statistics.







Experimental paradigm



Localisation of the corresponding points on the vertical meridian at six eccentricities (±1°; ±3°; ±7°)
Bar separation: Constant stimuli for the macaque subject
vs. adaptive staircase for human observers

Observers' characteristics

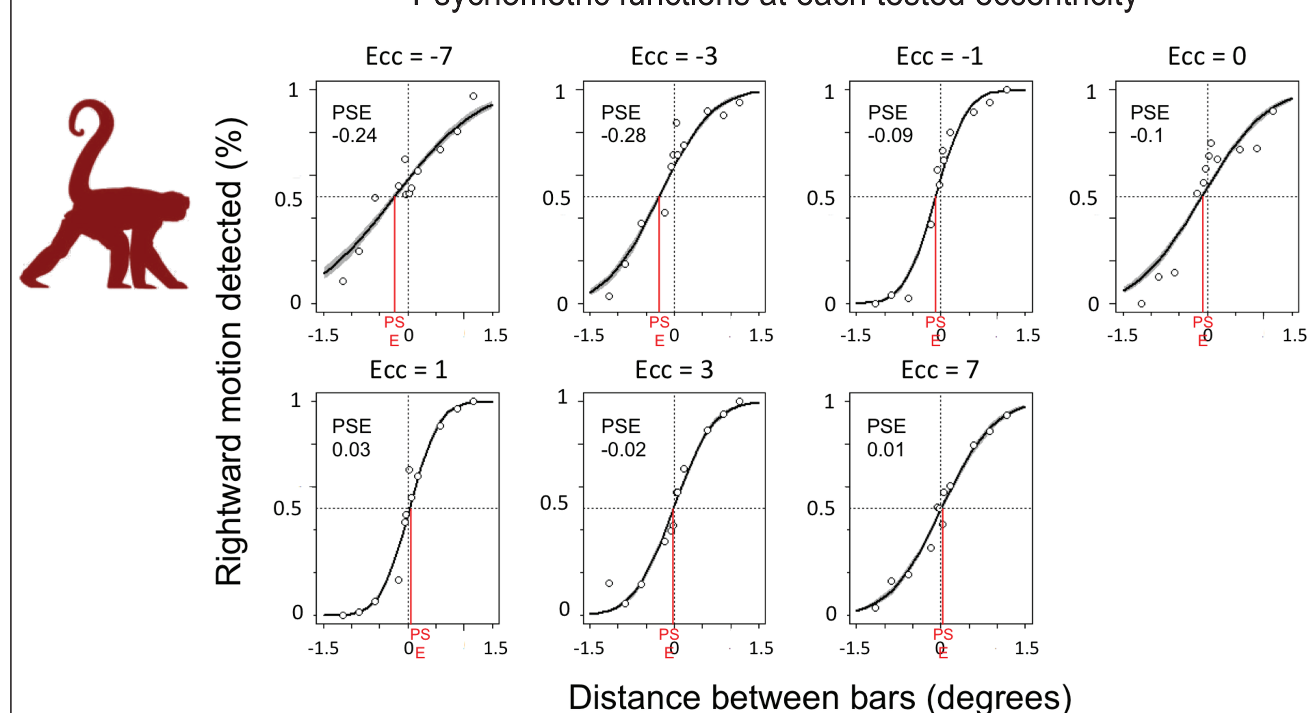
Optimal shear angle

$$\theta = 2\tan^{-1}\frac{I}{2h}$$

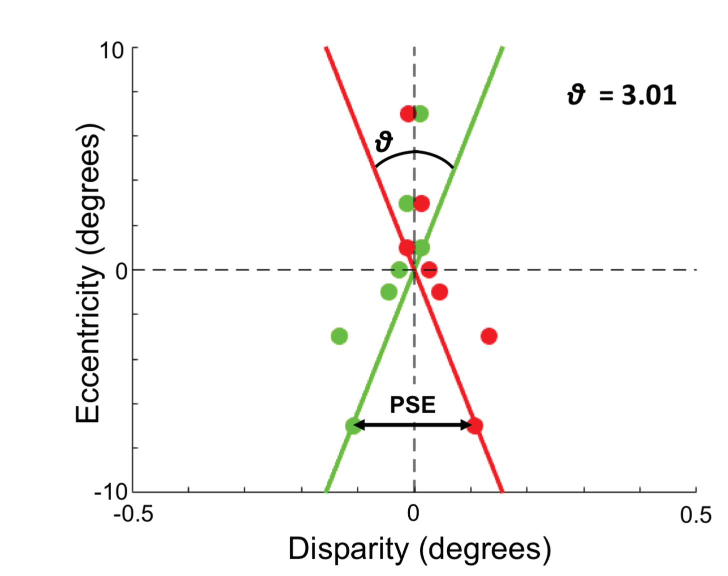
Subjects	IOD (cm)	Eyes' height (cm)	Optimal shear angle (degrees)	Shear angle (degrees)
S1	6.15	153	2.3028	4.1141
S2	6.55	166.5	2.2537	7.3516
S3	6.30	171.5	2.1045	3.1262
S4	6.90	163.5	2.4176	4.4498
S5	6.15	157.5	2.2370	5.712
S6	6.70	169.5	2.2645	4.0147
S7	6.30	156	2.2144	2.7108
S8	6.30	169	2.1356	5.2106
M1	3.14	38	4.8973	3.01

Results

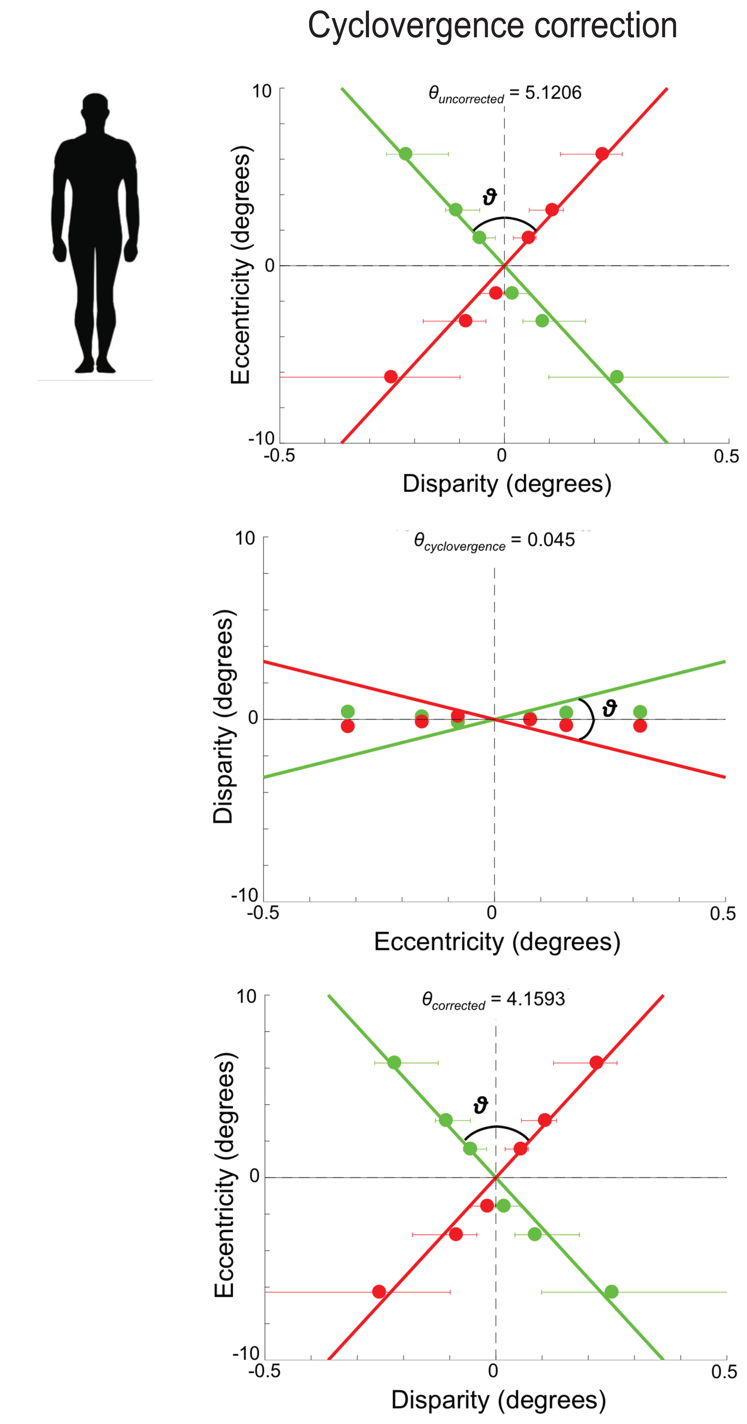
Psychometric functions at each tested eccentricity



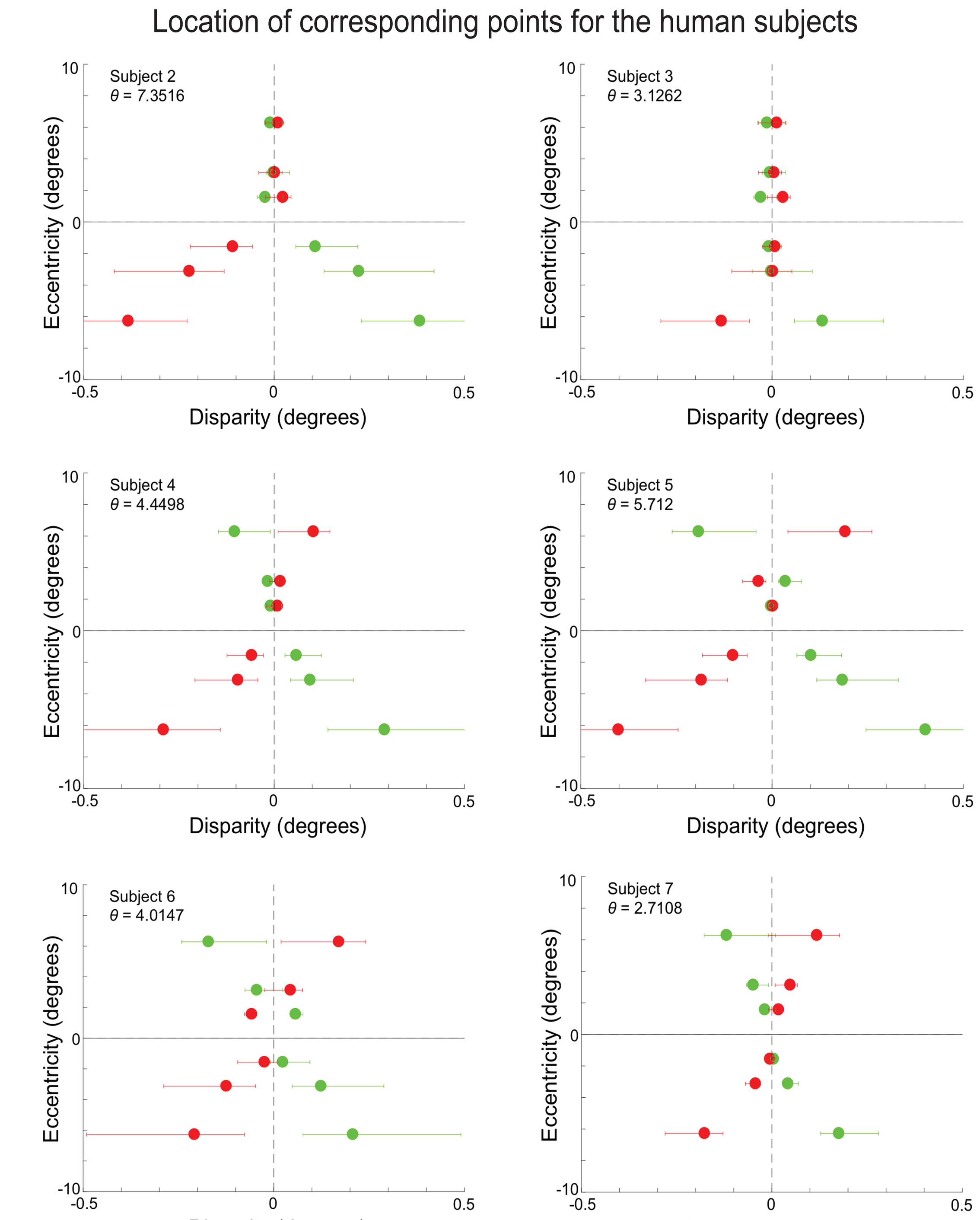
Location of corresponding points for the macaque subject



Cyclovergence correction



Location of corresponding points for the human subjects



Conclusions

- We showed for the first time that the empirical horopter of a macaque subject deviates from the geometrical horopter and might also reflect natural statistics

- The measured values do not correspond to the optimal shear angle predictions, challenging the view that the horopter is aligned with the ground

- Interspecies comparisons reveal a similar tilted pattern between both species, potentially questionning the role that visual experience, and thus spatial regularities, might play at the individual level

Bibliography

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