A Bayesian model of distance perception from ocular convergence

Peter Scarfe[1] and Paul Hibbard[2]

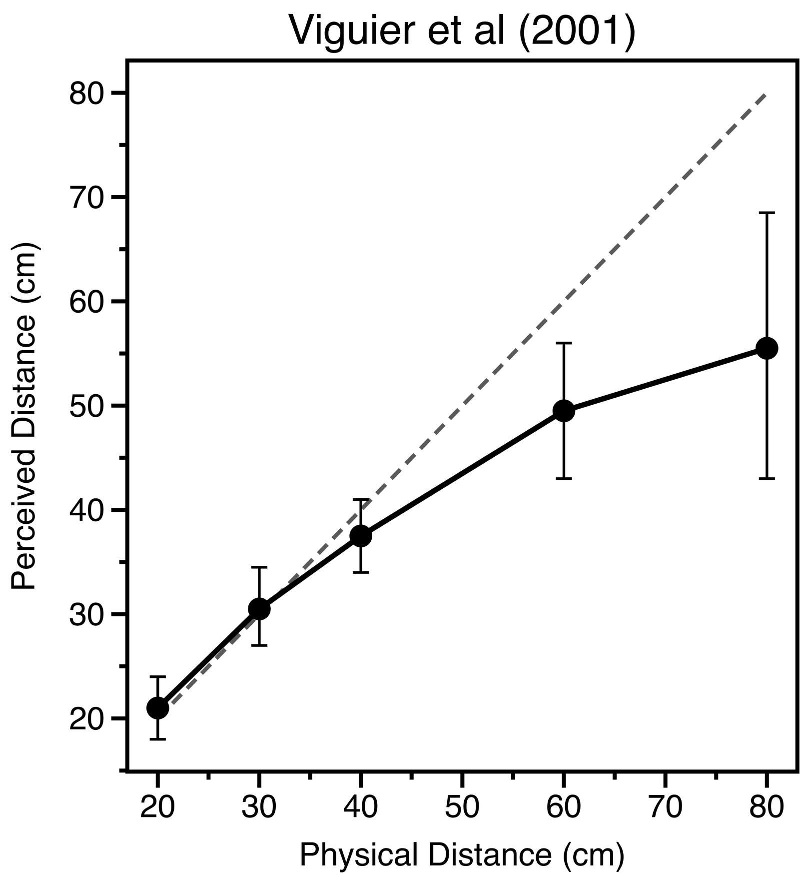
[1] School of Psychology and Clinical Language Sciences, University of Reading. [2] Department of Psychology, University of Essex.

University of Essex

University of Reading

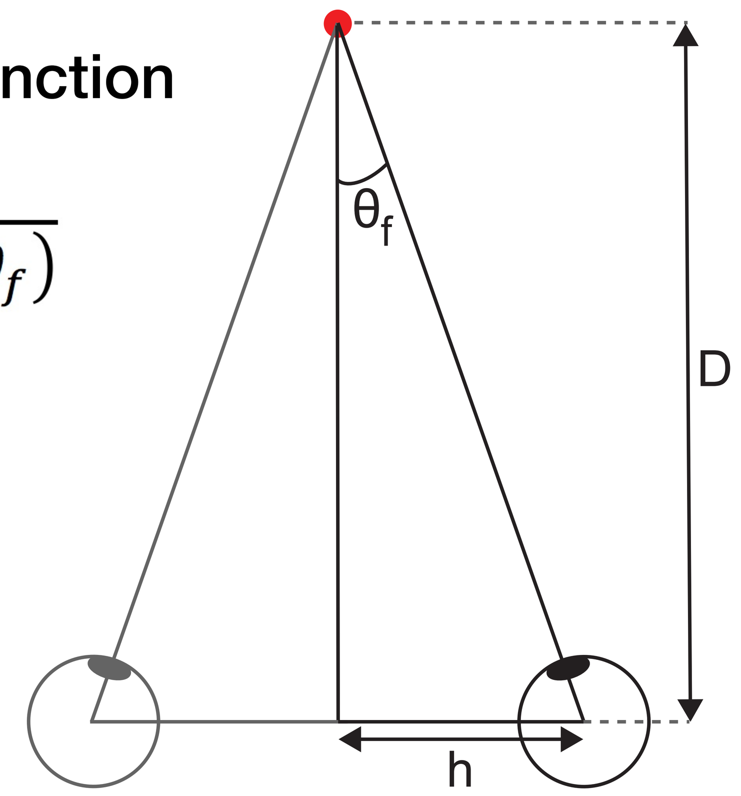
Introduction

It has been recognized since the time of Descartes that the convergence state of the eyes could provide valuable information about distance in the world. This is because there is a geometric one-to-one mapping between ocular convergence and distance. However, despite correct fixation, observers make progressive underestimates of object distance as it increases (Viguier et al. 2001). **Why is distance mis-estimated? Can these mis-estimates in some senses be considered optimal?**

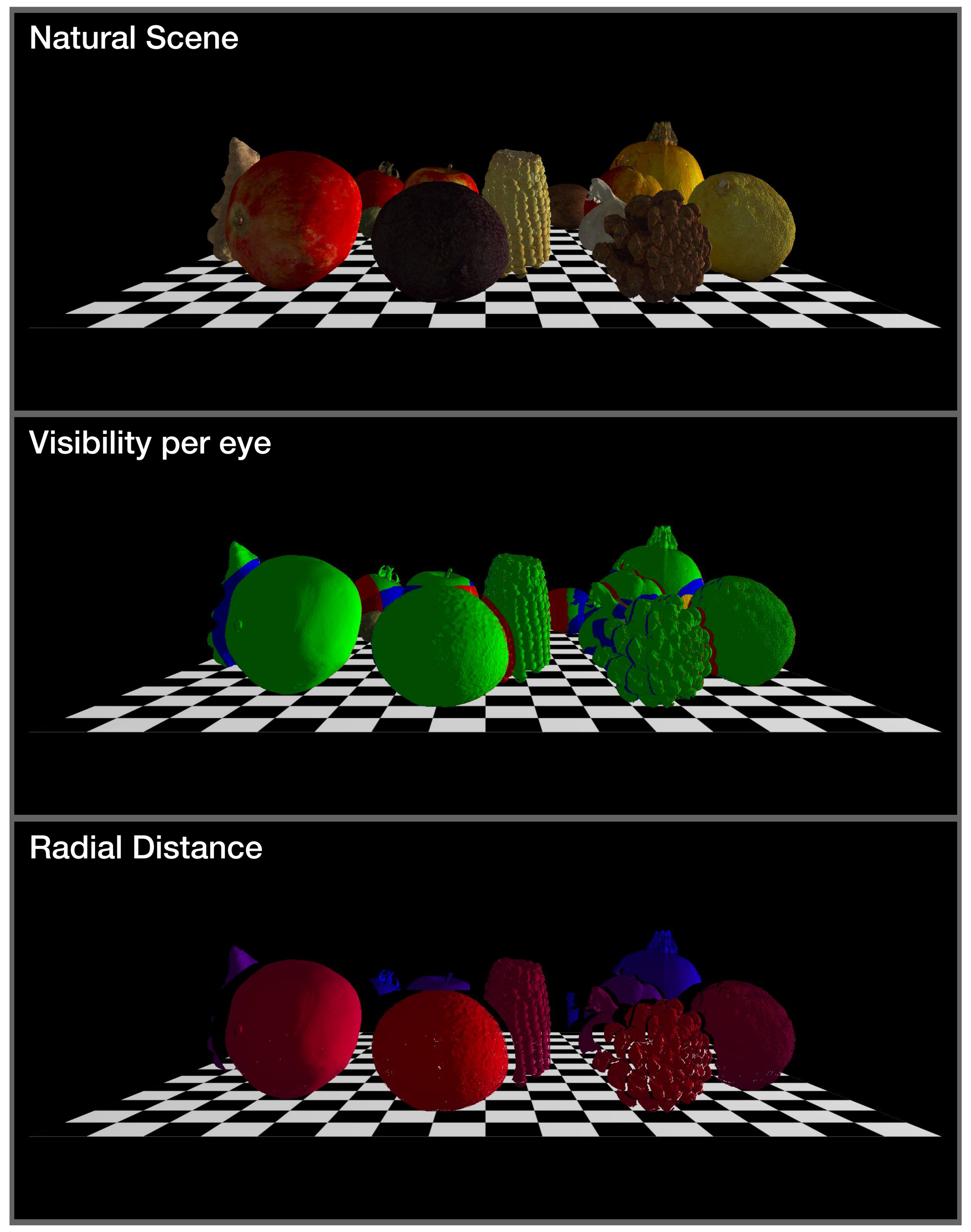


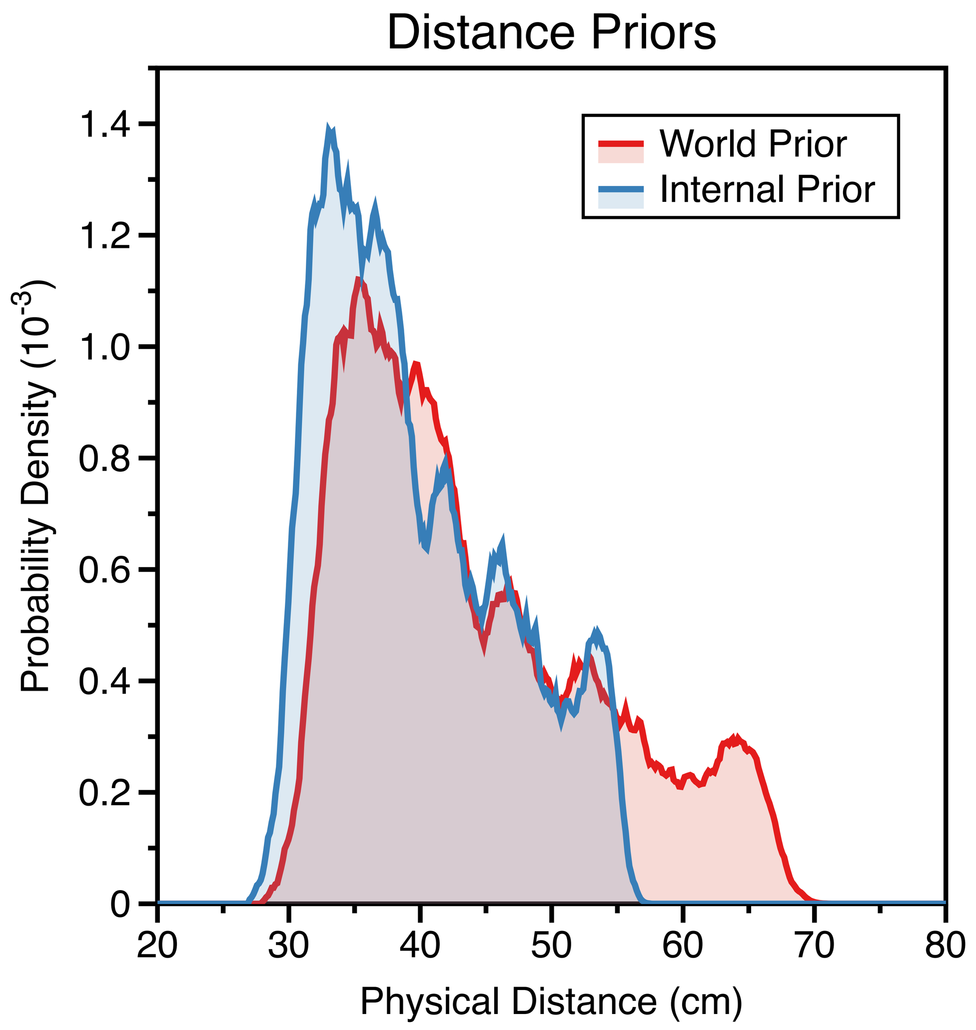
Transfer function

$$D = \frac{h}{\tan(\theta_f)}$$



Environmental Priors





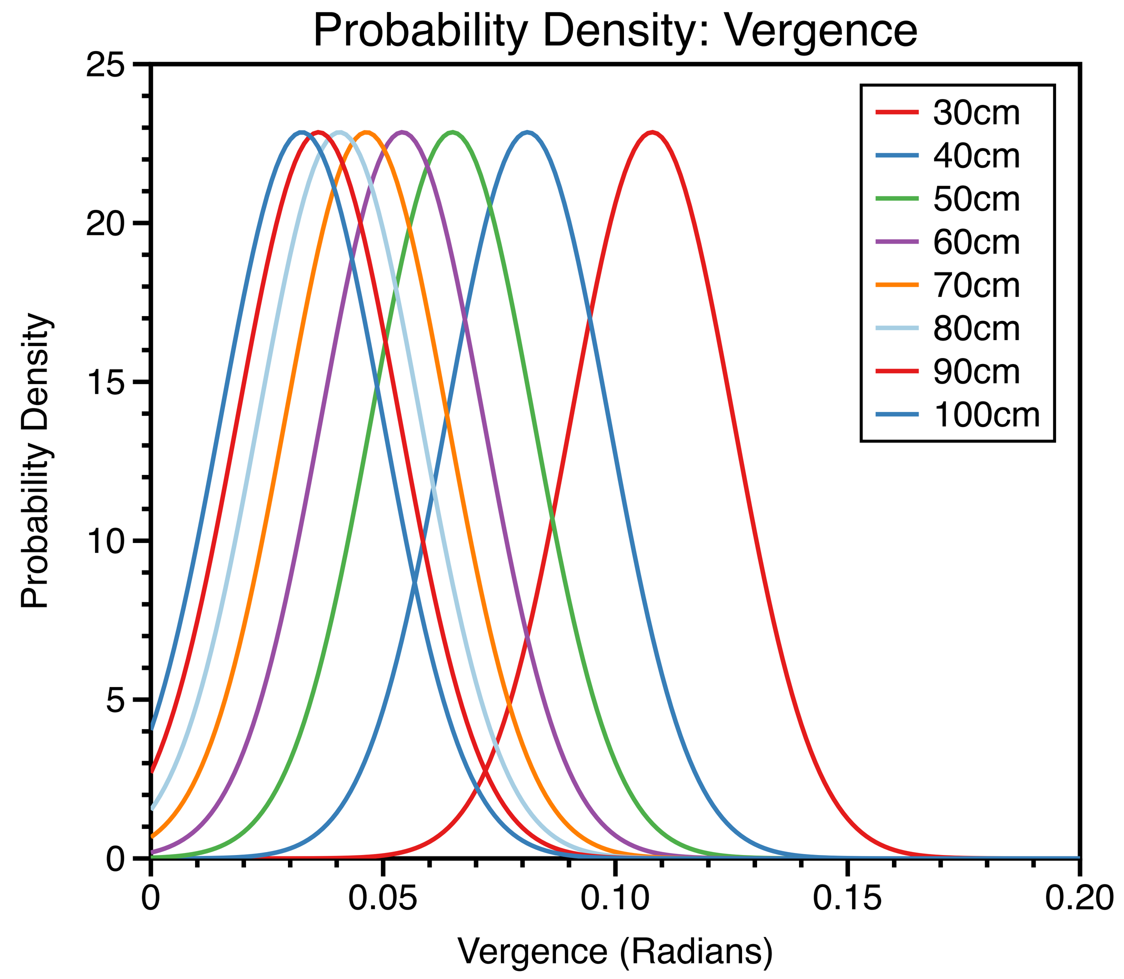
Natural scene statistics are typically evoked to explain perceptual bias. However, this assumes that these statistics are accurately sampled and internalized.

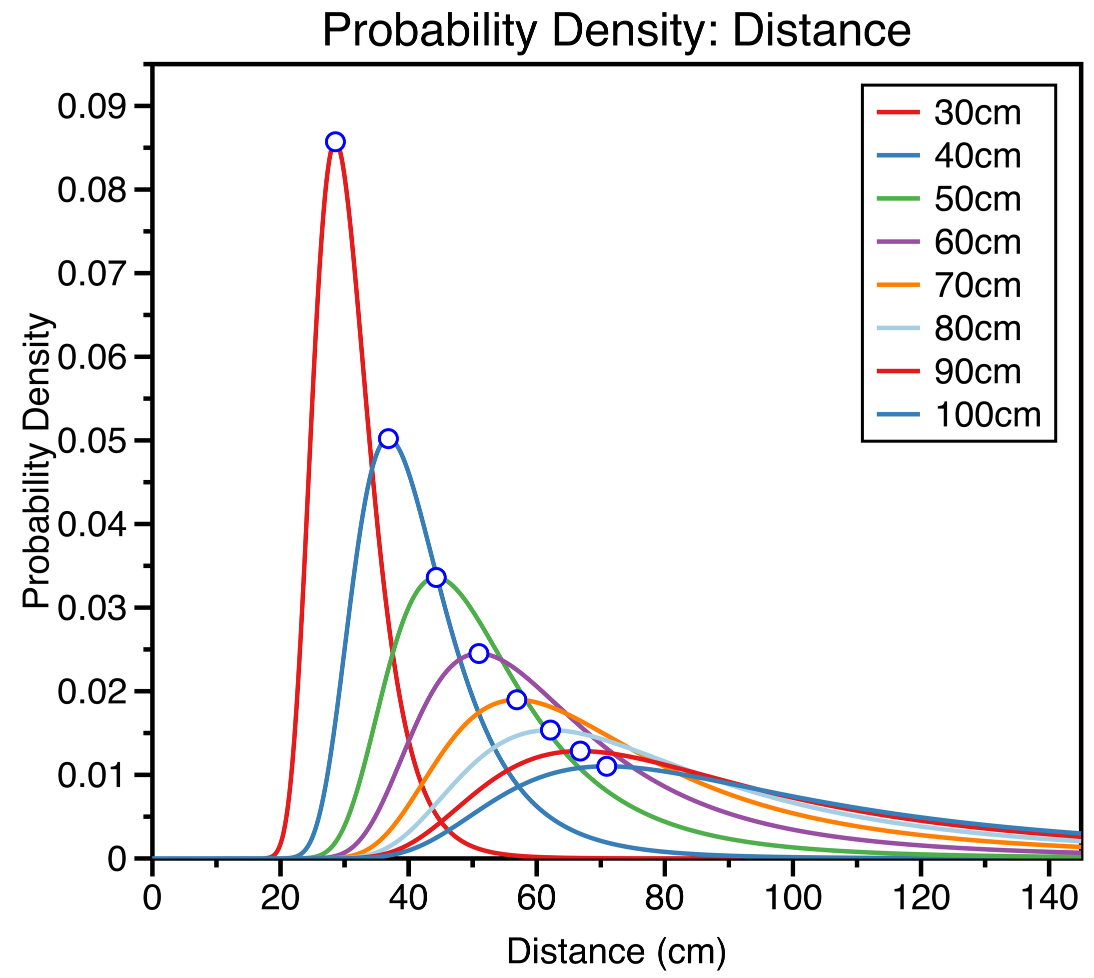
We generated 200 scenes composed of randomly placed laser scans of natural objects and generated the priors for distance.

Our optimal observer sampling this scene will internalize a biased model of the statistics of the world.

Bayesian Model

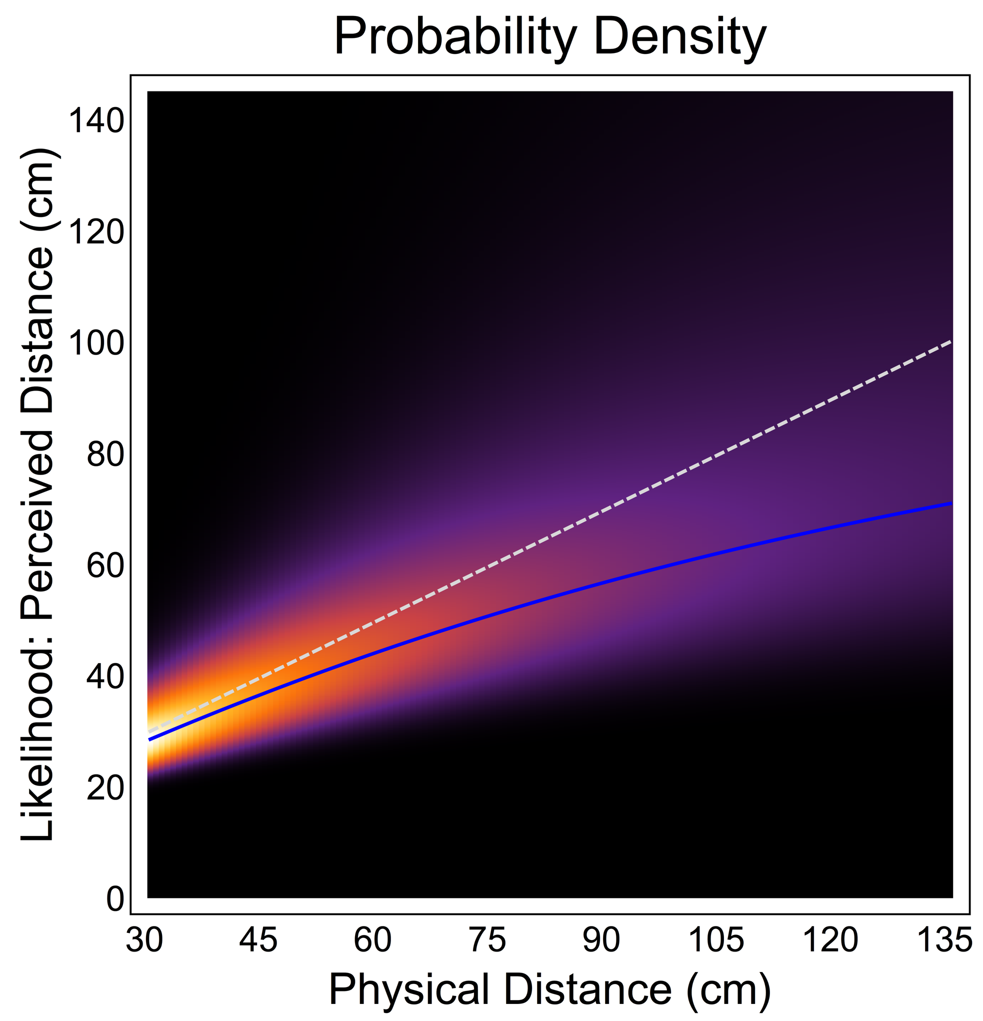
We assume that the vergence signal is corrupted by zero-mean Gaussian noise. Using the change of variable technique we calculate the probability density functions for distance. For a given fixation distance, an observer's distance estimate is the peak of this function i.e. the most likely distance to have produced the measured, noisy, vergence signal.



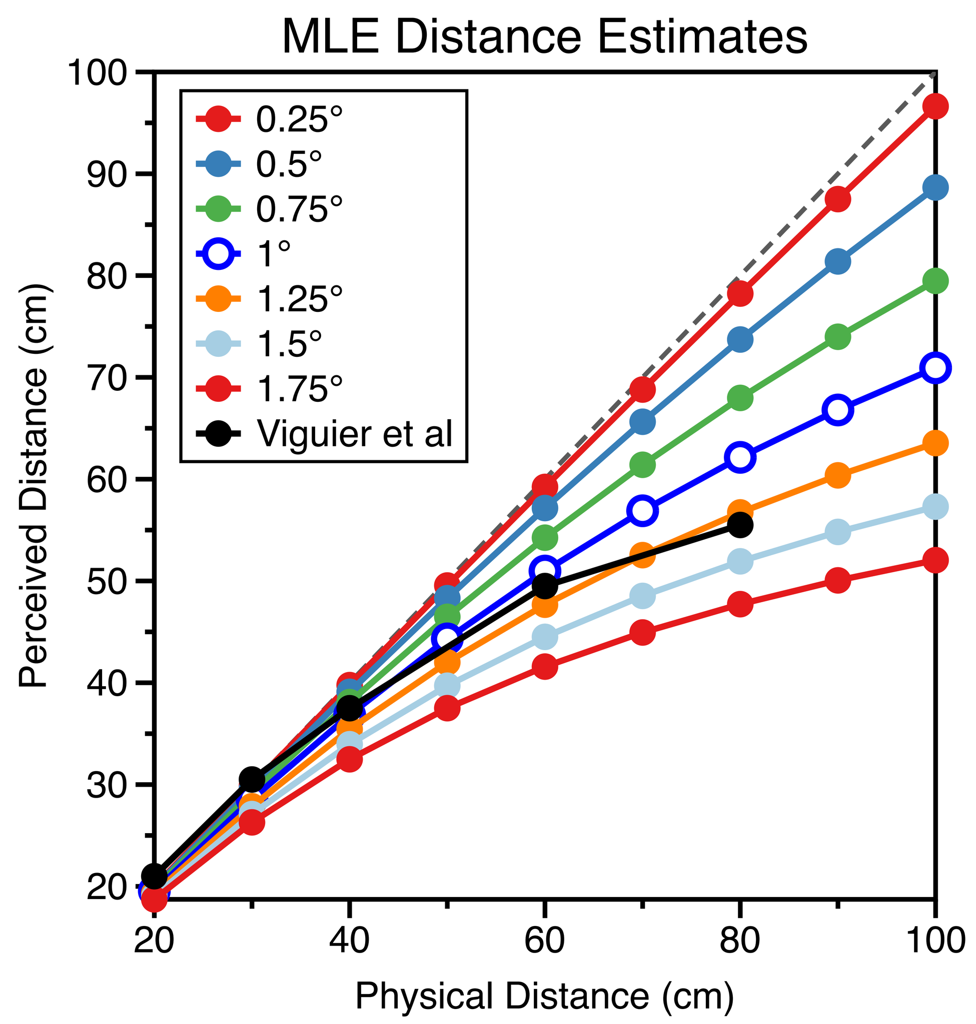


$$p(\hat{\theta}|\theta_f) = \frac{1}{\sigma\sqrt{2\pi}} e^{-\frac{(\theta-\theta_f)^2}{2\sigma^2}}$$

$$p(\hat{D}|\theta_f) = \frac{h}{\sqrt{2\pi}(h^2+D^2)\sigma} e^{-\frac{\left(\theta_f - \cot^{-1}\left(\frac{D}{h}\right)\right)^2}{2\sigma^2}}$$



For a given level of vergence noise (here σ = 1°): likelihood functions for distance become broader and their peak shifts toward a progressive underestimation of distance. Blue Curve: Maximum Likelihood estimates. White Dashed Line: Veridical estimates.



Maximum Likelihood estimates for distance progressively underestimate physical distance. As the vergence signal becomes more noisy (increase in σ), bias in perceived distance increases. The data of Viguier et al (2001) are consistent with a vergence noise level of σ≈ 1.25°.

Conclusion

Bias in the perception of distance from ocular convergence can be explained by observers trying to estimate the most likely distance in the world to have caused the measured (noisy) vergence signal.

gptoolbox libigl

References

Jacobson, A. gptoolbox: MATLAB Toolbox for Geometry Processing. URL: https://github.com/alecjacobson/gptoolbox

Jacobson, A., Panozzo, D. and others. libigl: A simple C++ geometry processing library. Eurographics/ACM SIGGRAPH Symposium on Geometry Processing 2014 Graduate School. URL: https://github.com/libigl/libigl

Viguier, A., Clement, G. and Trotter, Yves. (2001). Distance perception within near visual space. Perception, 30, 115-124.