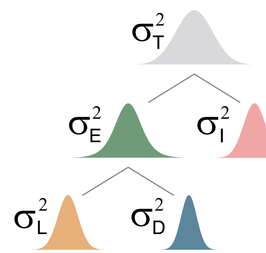
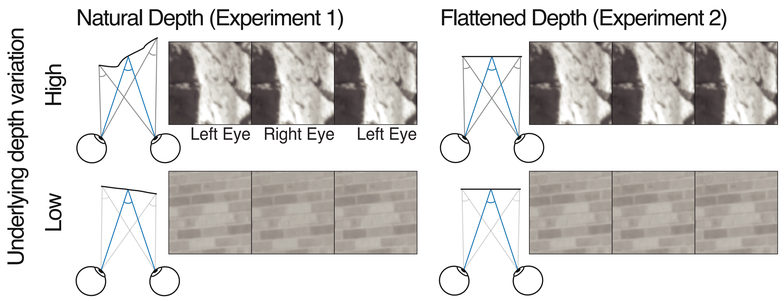
How distinct sources of nuisance variability in natural images and scenes limit human stereopsis

David N. White & Johannes Burge
Departments of Psychology and Neuroscience, University of Pennsylvania

Background

Binocular disparity is an important cue in depth estimation in natural viewing.
Natural scenes are marked by variation in luminance patterns and local depth structure.
How does this natural variation limit stereo-depth discrimination?



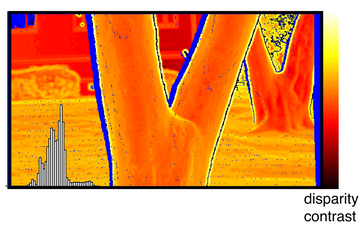


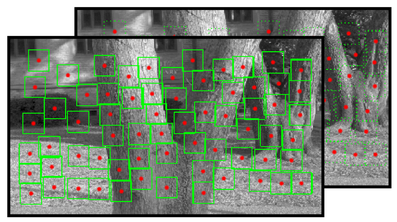
Stimulus Generation

20,000 unique stereo-patches sampled from 98 natural stereo images with coregistered range data.

Patches selected based on disparity contrast, given presentation display geometry

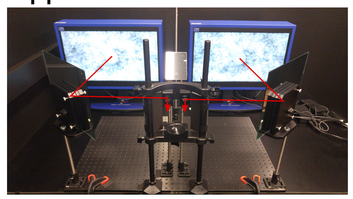
Patches were fixed in luminance contrast and mean luminance.





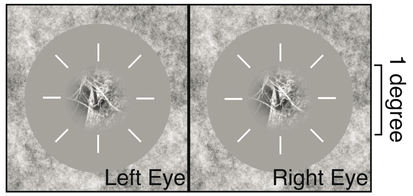
Methods

Apparatus

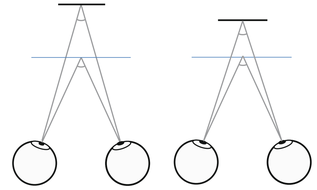


Haploscope rig

Stimuli

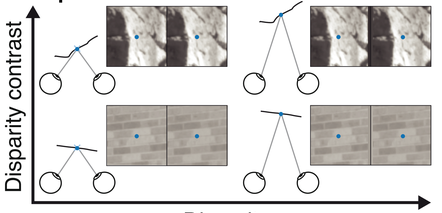


Task and Procedure

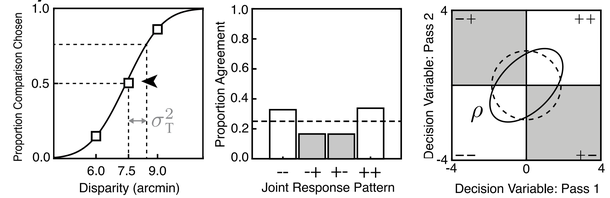


2IFC. Which is further?

Independent Variables



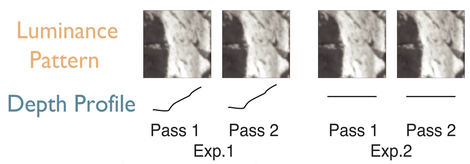
Analysis



Observers respond by choosing the comparison + or standard -
One pass allows the estimation of thresholds σ_T^2
Two passes allows calculation of between-pass response agreeement
From patterns of agreement—estimation of decision variable correlation ρ

$$\rho = \frac{\sigma_E^2}{\sigma_T^2} \qquad \sigma_T^2 = \sigma_E^2 + \sigma_I^2$$

Correlation reflects relative importance of internal σ_I^2 and external factors σ_E^2
Correlation and threshold allows factor variance to be determined.



Observers completed two double pass experiments
Trials between experiments only differ by lack of depth profile in Exp. 2

$$\rho_1 = \frac{\sigma_{E1}^2}{\sigma_{T1}^2} = \frac{\sigma_L^2 + \sigma_D^2 + 2\,\mathrm{cov(L,D)}}{\sigma_{T1}^2}$$

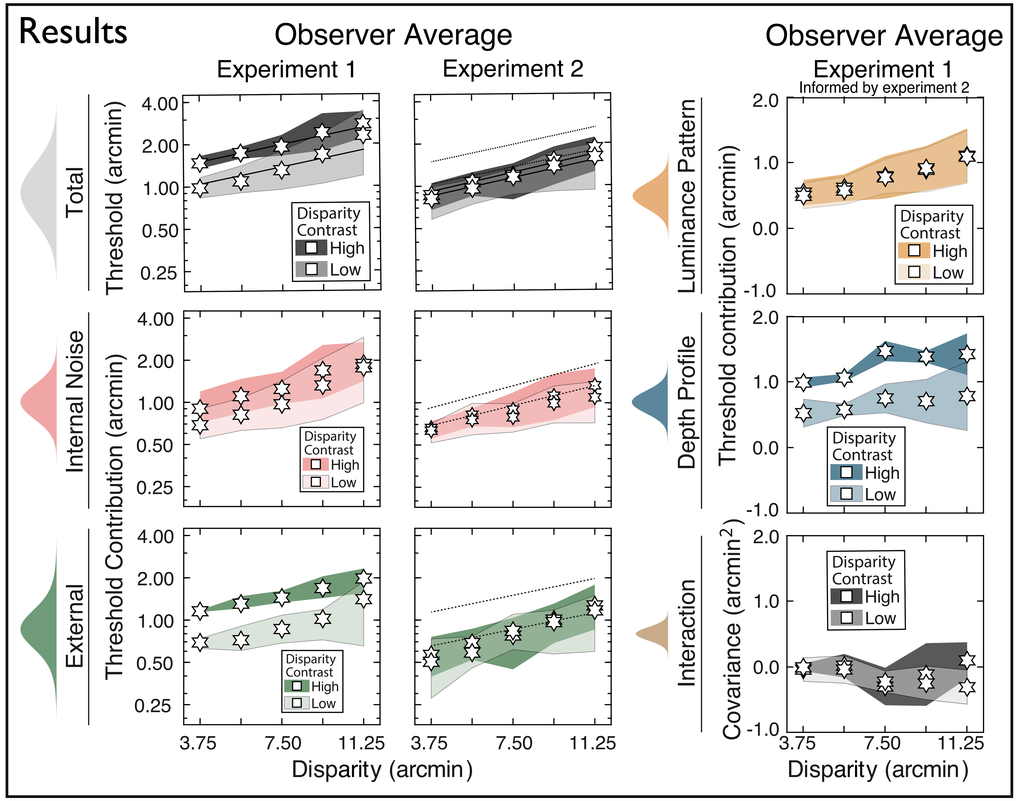
$$\rho_2 = \frac{\sigma_{E2}^2}{\sigma_{T2}^2} = \frac{\sigma_L^2}{\sigma_{T2}^2}$$

$$\rho_{1,2} = \frac{\sigma_L^2 + \mathrm{cov(L,D)}}{\sigma_{T1}\sigma_{T2}}$$

$$\begin{array}{cc|cccc} & \text{Pass} & 1 & 2 & 1 & 2 \\ & \text{Exp.} & 1 & 1 & 2 & 2 \\ \hline 1 & 1 & 1 & \rho_1 & & \boxed{\rho_{1,2}} \\ 2 & 1 & & 1 & & \\ 1 & 2 & & & 1 & \rho_2 \\ 2 & 2 & \ddots & & & 1 \end{array}$$

Decision variable correlation and threshold specify system of equations
Solving system of equations allows partition of distinct external components

Results



Conclusion

Internal and external factors equally limit performance when mean luminance and luminance contrast is fixed.
Quasi-quadruple pass analysis allows impact of distinct external components to be partitioned.
Luminance-pattern-driven and depth-profile-driven factors are almost completely separable.
For low disparity-contrast conditions, luminance-profile and depth-profile impacts performance nearly equally.
The majority of between-observer differences are due to internal noise.