Prior expectations in line orientation perception

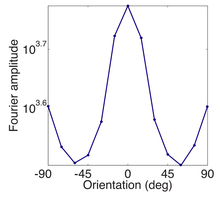
Ahna R. Girshick, Eero P. Simoncelli, Michael S. Landy

Dept. of Psychology & Center for Neural Science, New York University, NY

Main ideas

Does line orientation perception reflect natural image statistics?

Preponderence of cardinal orientations (horizontal & vertical) in natural images:[1,2,3]



In the Bayesian framework, we can ask:

Do observers use a prior in line orientation perception?

If so, is it consistent with natural image statistics?

Experiment

Stimuli

Collection of Gabors, orientations drawn from a wrapped Gaussian N(θ,σ)

Low noise (L), σ = 0°

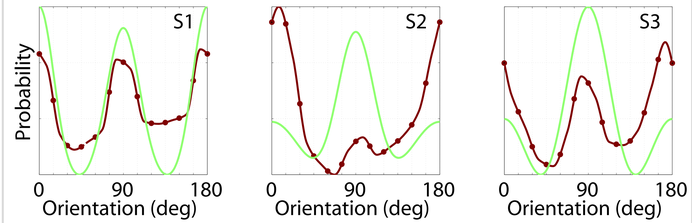
High noise (H), σ ≈ 20°
(determined separately per observer)

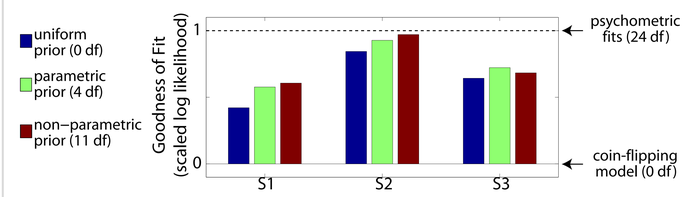
2AFC Task : On which side was the mean orientation more clockwise?
12 orientations, 7200 trials per observer

3 Conditions

LvL: to estimate low-noise likelihood
HvH: to estimate high-noise likelihood
HvL: to estimate prior

Estimated priors





Conclusions

The Bayesian framework provides a good description of line orientation perception.

(1) Observers use non-uniform priors.

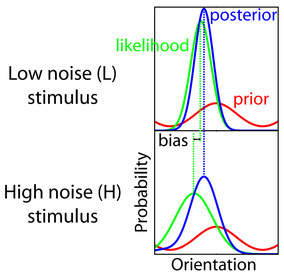
(2) The estimated priors reflect natural image statistics, peaking at horizontal & vertical.

The details

Experimental logic using Bayes' rule

$P(\theta|\text{Image}) \propto P(\text{Image}|\theta) \times P(\theta)$

Posterior (*percept*) ∝ Likelihood (*measurement*) × Orientation prior

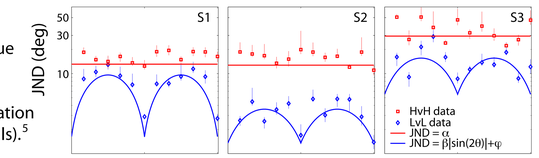


- A non-uniform prior causes a shift in the posterior relative to the likelihood.
- The more reliable the likelihood the smaller the shift (top panel).
- As experimenters, we do not have direct access to the posterior. We infer the shift from LvH matches.
- We use the pattern of relative shifts, or *bias*, to estimate the shape of the prior. [4]

Psychometric results

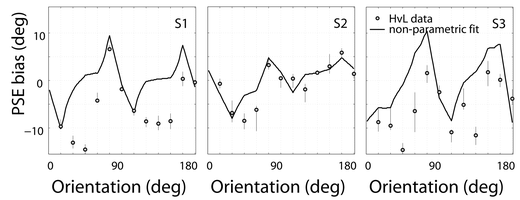
JNDs

LvL oblique effect (better discrimination at cardinals).[5]



PSEs

Bimodal bias suggests bimodal prior.



Bayesian model

Likelihood model:
Gaussian wrapped over 180°, σ from JND data

Non-parametric prior model:
Piecewise linear in log probability over 15° bins, with 11 local slope parameters
12th slope constrained such that prior wraps around 180°

Parametric prior model:
Mixture of 2 Gaussians with df=4 ($\mu_H, \mu_V, \sigma_H, \sigma_V$)

Posterior computation & decision rule:
Standard & comparison posteriors estimated as product of likelihood & prior
MAP decision rule (stimulus with the more clockwise posterior peak was chosen)

Fitting:
Maximized log likelihood of model psychometric predictions given psychometric data, separately per observer
HvH & LvL data fit separately

Control experiment

Did visible horizontal & verticals (e.g. monitor frame) bias observers?

- Experiment was repeated through aperture in 2IFC task.
- Same behavior was observed.

References

1. Switkes, E, Mayer, MJ, Sloan, JA (1978). *Vision Res.*
2. van der Schaaf, A, van Hateren, JH (1996). *Vision Res.*
3. Coppola, DM, Purves, HR, McCoy, AN, Purves, D (1998). *Proc Natl Acad Sci USA.*
4. Stocker, AA, Simoncelli, EP (2006). *Nat Neurosci.*
5. Appelle, S (1972). *Psychol Bulletin.*

Acknowledgements

Landy & Simoncelli labs, NIH grants EY16165 & EY08266

ahna@cns.nyu.edu