Probability Cues Enhance Perceptual Estimations

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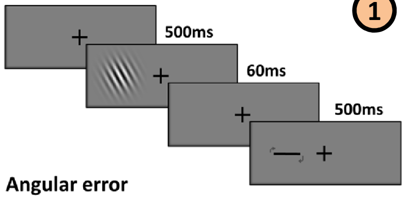
How do probability cues affect perceptual estimations?

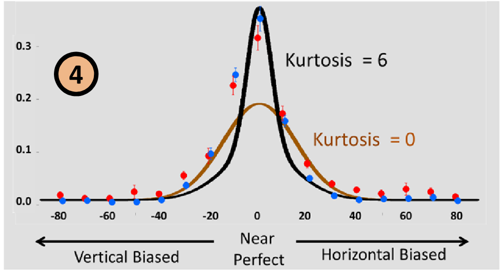
Orientation Judgment task



Angular error

- Angular deviance of estimated orientation from presented stimulus orientation

Proportion of angular errors from true stimulus orientations

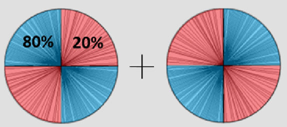


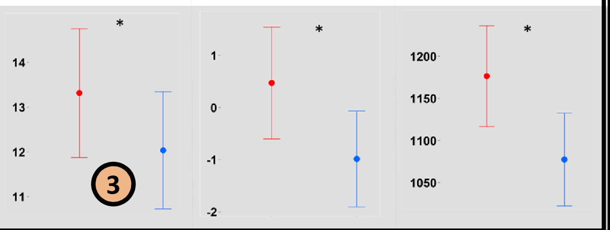
Kurtosis

- Measures of the shape of a distribution
- Higher kurtosis :
  - Greater proportion of more precise estimations
  - Less errors that are exaggerated

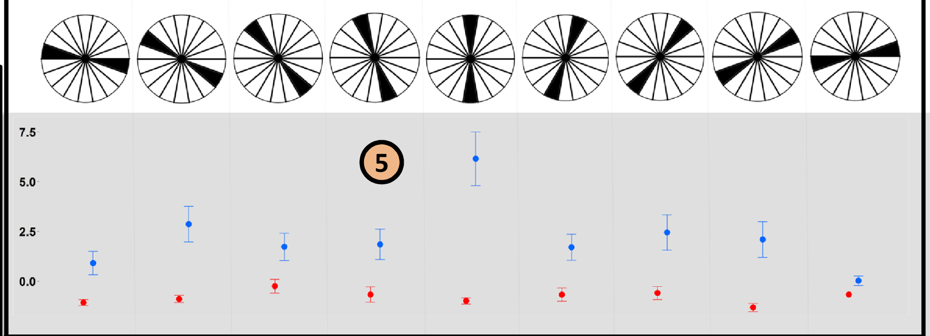
- ***Stimulus orientation*** and ***probability*** both affect the error distribution of perceptual estimates
- Vertical, high-probability orientations are estimated most precisely

Expt 1a: Probability Cuing

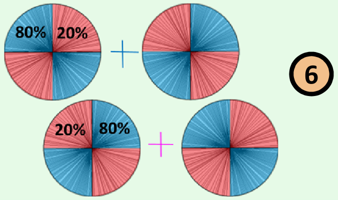


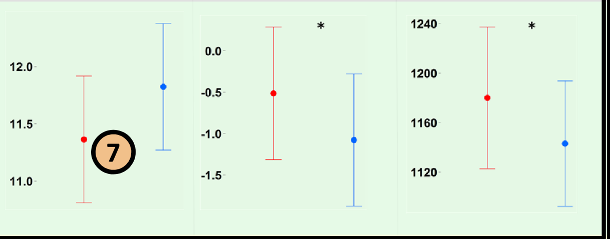


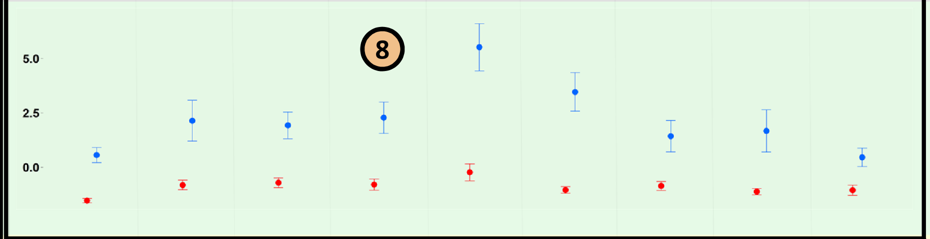
Kurtosis of angular errors across stimulus orientations^



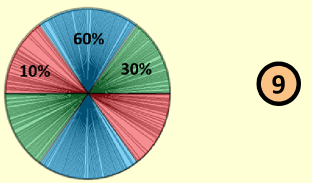
Expt 1b: Conditional Probability Cuing

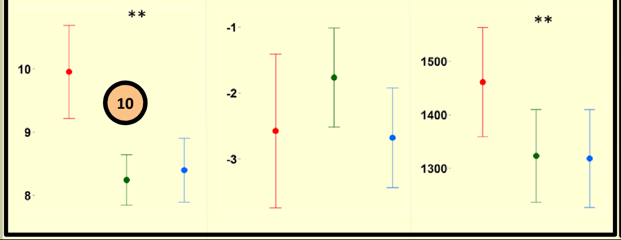


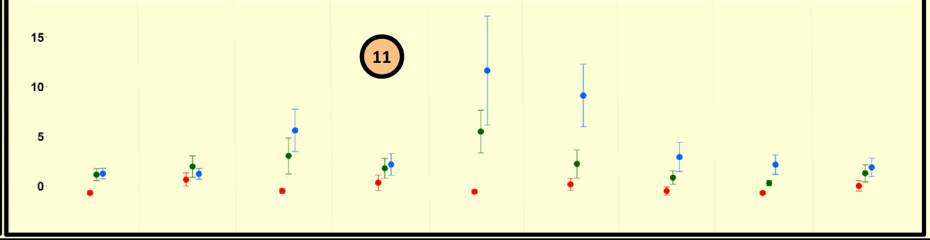




Expt 2: Graded Probability Cuing







* p <.05

** p<.05 omnibus ANOVA, pairwise comparisons suggests due to 10% vs. 30% and 10% vs. 60%

Negative bias: Errors in estimation are towards the vertical meridian. In no condition is there a significant positive (horizontal) bias.

^ Significant main effect of Probability, significant main effect of Stimulus Orientation, and significant interaction effect, for all three experiments

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1 *How do probability cues affect perceptual estimations?* To study this, we used an Orientation Judgement task, where participants are shown a gabor for 60ms, and are asked to orientate a line using keyboard buttons, to match the gabor orientation as accurately as they could. The lab has used this task in previous studies on attention and probability cueing, but we wanted to extend the research by looking at new types of analyses. Primarily, since this task allows us to get a trial-by-trial measure of precision by looking at the angular errors, we wanted to look at how probability affects the distribution of angular errors made.

2 We ran three studies using the paradigm, each differing in the probability distribution of orientations, of which participants were never explicitly told. In the first task, for example, when the gabors appeared on the left, they are more likely left tilting, but reverse on the right.

3 Although no participant could report the probability distributions, the traditional behavioural measures did show a significant effect of probability. Participants made bigger errors for the low-probability tilts. Interestingly, the high probability tilts also tended to be estimated more vertically than they should have. Participants also were faster in matching high-probability tilts. Accuracy and RT patterns here due to probability match the pattern seen in other probability manipulations.

4 We next looked at the proportion and extent of angular errors. While participants were generally making very precise estimations, there is a higher proportion of very precise responses for the high-probability tilts than for the low, and higher proportion of responses for the low-probability tilts as bigger errors were made. What is interesting is that this difference in distributions between the probabilities is well-captured by a measurement of kurtosis. Distributions with higher kurtosis, shown by the black curve, exhibits a greater peak, but lower shoulders than distributions with lower kurtosis (brown line).

5 Given the kurtosis difference between high and low probability tilts, we were interested in whether this difference is modulated by what the gabor orientation was. We grouped up trials with similar orientations and found that although there is a higher kurtosis for high than low probability orientations across the board, this difference is particularly exaggerated then the gabor was vertically-orientated.

6 *Would the behavioural effects hold up if the probability distribution were more complex?* For the second task, we made the probability distributions of the gabor tilts conditional on the colour of the fixation cross. For example, left tilts might be more likely on the left, but only if the fix cross is magenta, and reversed if cyan.

7 In terms of the traditional behavioural results, we find that the mean angular error is no longer a good measure of performance difference, although there is still a greater vertical bias for the high probability tilts. The reaction times, though, do show that participants were faster at matching high versus low, probability tilts, although they could not even report that there was a probability distribution in the first place, let alone describe what it was.

8 However, when looking at the kurtosis measure, we find the exact same trend seen in the simpler experiment: Vertical, high probability orientations were estimated most precisely, as indicated by the kurtosis measure.

9 *Is behavioural performance is sensitive to finely-tuned changes in probability?* In this experiment, we only used a centrally-located gabor, where orientations in one space occurred 60% of the time, another occurred 30% of the time, and the other occurred 10% of the time.

10 There is an probability effect on the angular errors and on RT. However, the measures do not discriminate between the 60% and 30% tilts, but only between the 10% and the other two tilt probabilities.

11 But the kurtosis measure does seem to nicely discriminate between the conditions. Particularly, we see the same trends in kurtosis that we saw in the two previous experiments, only now in a consistently graded manner.

Conclusions

The kurtosis measure is the most robust in detecting the probability and area effects, finding it consistently even when traditional measures like accuracy and RTs fail. Perhaps kurtosis measures exactly what probability cues does to estimations: Informative cues causes shifting of responses away from small errors, towards making more precise judgements. Additionally, probability and orientation effects interact, indicating that they might share a similar locus.