Visual discrimination is a two-stage process

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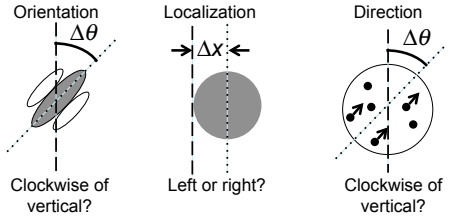
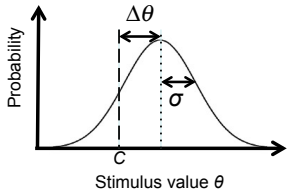
What process underlies discrimination?

Three discrimination tasks



Signal detection theory

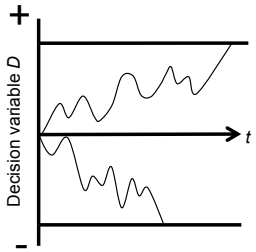


Decision variable: $E = \log \frac{P(\theta > C)}{P(\theta < C)}$

If $E > 0$, say "Clockwise"
If $E < 0$, say "Counter Clockwise"

Accuracy depends on the magnitude of E, which depends on signal-to-noise ratio (SNR): $d' = \frac{\Delta\theta}{\sigma}$

Drift-diffusion model (DDM)



Momentary evidence $E(t)$

Decision variable accumulates evidence

$$D(t) = \sum_{i=1}^{t} E(t)$$

Evidence accumulates until
- $D(t)$ reaches a decision boundary
  or
- task forces process to terminate

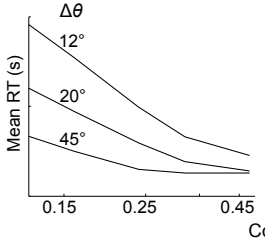
Accuracy and RT depend on D and hence on SNR

Prediction of DDM for RT: Δ and σ interact

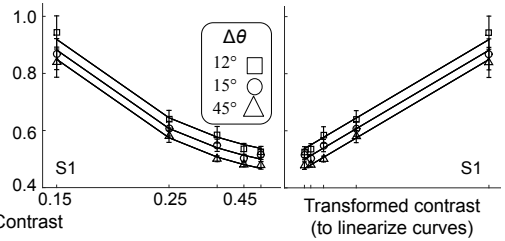
Model (Drift-diffusion + Population code)
- 36 orientation-selective neurons
- Poisson firing rates
- Decoded via Bayesian inference[1]
- Decode every 50 ms

Experiment 1:
- Orientation, location and direction discrimination;
- 5 contrast/coherence levels (σ)
  3 $\Delta\theta/\Delta x$ levels, all interleaved
- Instructions: Respond quickly but maintain 95% accuracy

Simulation (DDM prediction)



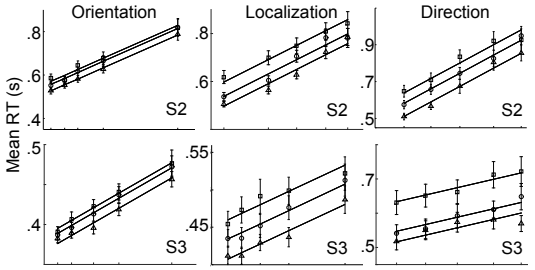
Expt. 1: Example Data – Orientation discrimination



DDM prediction fails:

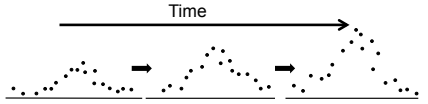
No interaction of Δ and σ (parallel fits)

Expt. 1: Three discrimination tasks

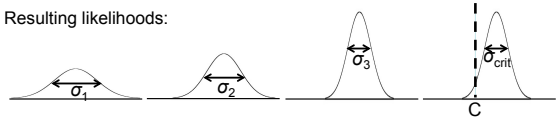


Alternative model: Estimate-Then-Decide

Accumulated neural responses:



Resulting likelihoods:



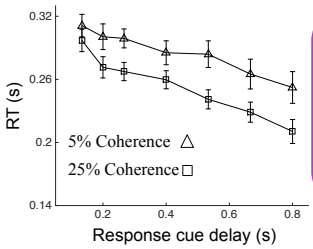
Stage 1: Estimation until σ reduced to σ_{crit}, duration depends only on contrast / coherence

Stage 2: Decision, duration depends on SNR, e.g., only on $\Delta\theta$

Predictions:
- Effects of $\Delta\theta/\Delta x$ and σ additive
- Early accumulation termination: RT depends on SNR at time of cue

Experiment 2:
- Direction discrimination
- Respond upon hearing a cue

Expt. 2: Results



Conclusion

Discrimination is a two-stage process: (1) Estimate, then (2) Decide

1. Ma, W. J., Beck, J. M., Latham, P. E. & Pouget, A. (2006). *Nat Neurosci 9:* 1432-1438

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