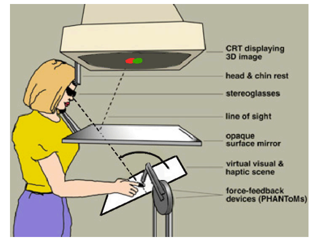
What if we change your motor variability?

Experiment: Increase “Motor Noise”

Changes in movement endpoints in response to visually-imposed changes in movement variability

Experimental set-up:



Trommershäuser, Gepshtein, Maloney, Landy, Banks (2005). *J. Neurosci.*, *25*, 7169.

Experiment: Increase “Motor Noise”

Idea:

- finger visually represented by red point
- on each trial: unpredictable perturbation of the visual feedback of the finger tip by

$$\begin{bmatrix}\Delta x\\ \Delta y\end{bmatrix} \sim \text{Gaussian}\left(0, \begin{bmatrix}\sigma^2_{pert} & 0\\ 0 & \sigma^2_{pert}\end{bmatrix}\right)$$

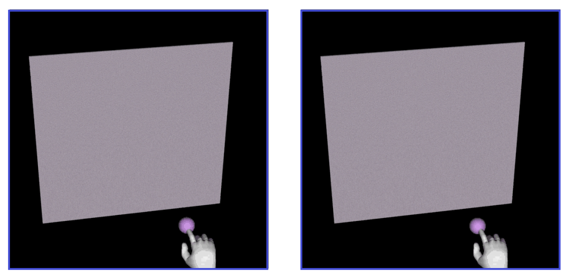
- Points are scored based on the perturbed finger position

$\Rightarrow$ Increase of subject’s **effective movement variability σ^2_{eff}**

Trommershäuser, Gepshtein, Maloney, Landy, Banks (2005). *J. Neurosci.*, *25*, 7169.

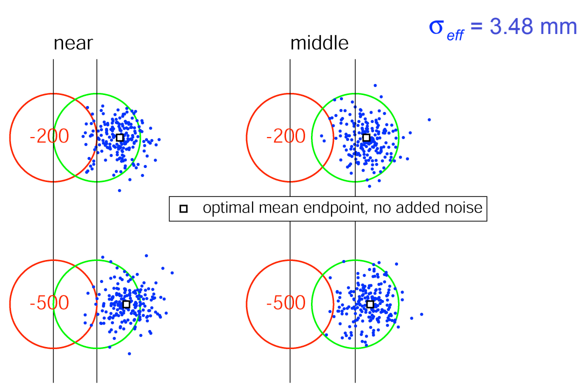
Experiment: Increase “Motor Noise”

Experimental manipulation of effective movement variability:



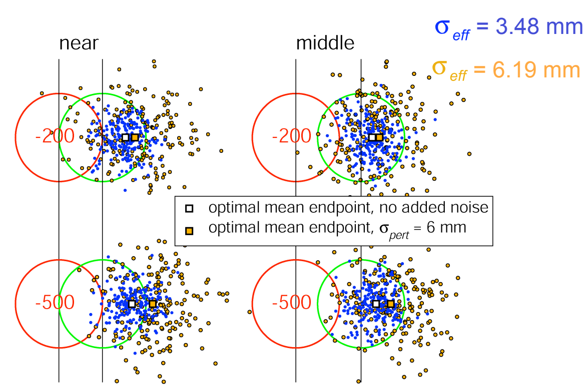
Trommershäuser, Gepshtein, Maloney, Landy, Banks (2005). *J. Neurosci.*, *25*, 7169.

Prediction



Trommershäuser, Gepshtein, Maloney, Landy, Banks (2005). *J. Neurosci.*, *25*, 7169.

Prediction

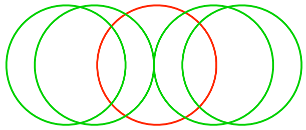


Trommershäuser, Gepshtein, Maloney, Landy, Banks (2005). *J. Neurosci.*, *25*, 7169.

Design

middle near near middle

4 Configurations



varied within blocks

3 Penalties

Reward: 100
Penalties: 0 -200 -500

varied between blocks

3 Added noise

σ_{pert} : 0 mm 4.5 mm 6 mm

varied between sessions (retraining)

Trommershäuser, Gepshtein, Maloney, Landy, Banks (2005). *J. Neurosci., 25,* 7169.

Design

Six subjects

1 practice session: 300 trials,
decreasing time limit

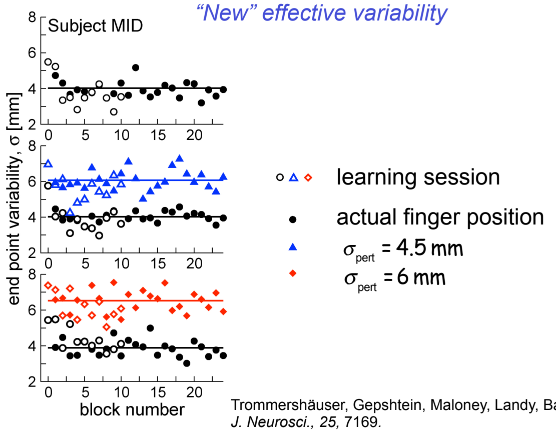
per noise condition:
1 learning session: 300 trials
2 sessions of data collection: 360 trials each

40 repetitions per condition

Trommershäuser, Gepshtein, Maloney, Landy, Banks (2005). *J. Neurosci., 25,* 7169.

Results

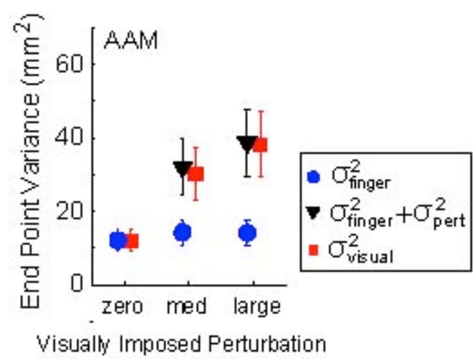
"New" effective variability



Trommershäuser, Gepshtein, Maloney, Landy, Banks (2005). *J. Neurosci., 25,* 7169.

Results

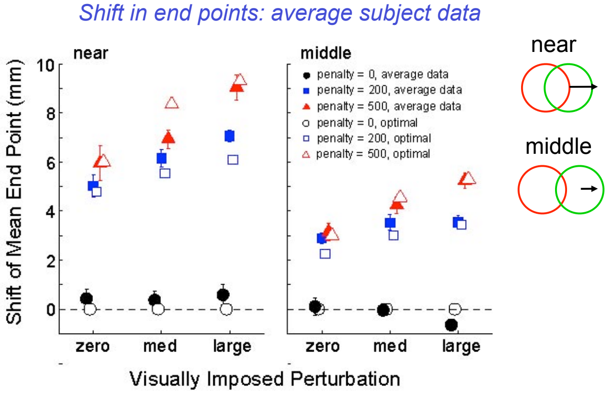
Additivity of Variances



Trommershäuser, Gepshtein, Maloney, Landy, Banks (2005). *J. Neurosci., 25,* 7169.

Results

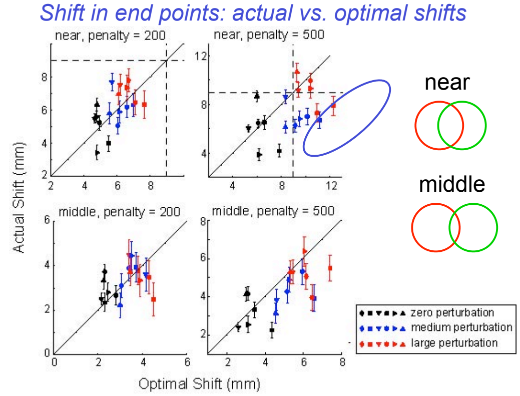
Shift in end points: average subject data



Trommershäuser, Gepshtein, Maloney, Landy, Banks (2005). *J. Neurosci., 25,* 7169.

Results

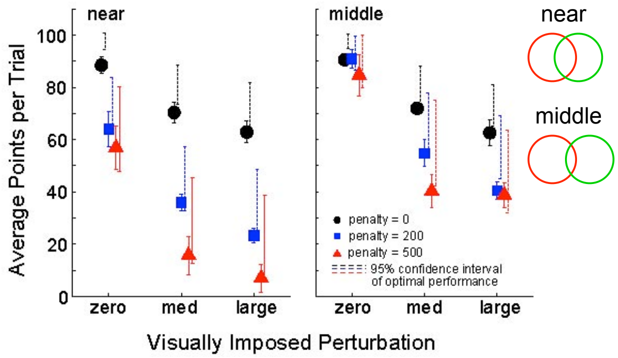
Shift in end points: actual vs. optimal shifts



Trommershäuser, Gepshtein, Maloney, Landy, Banks (2005). *J. Neurosci., 25,* 7169.

Results

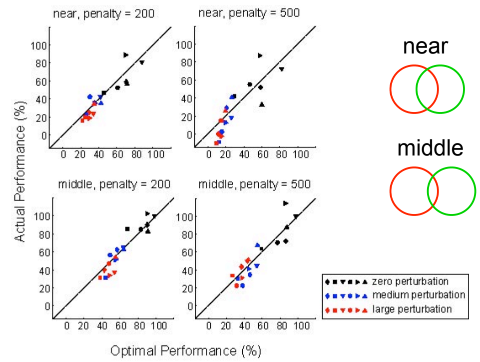
Scores: average subject data



Trommershäuser, Gepshtein, Maloney, Landy, Banks (2005). *J. Neurosci., 25,* 7169.

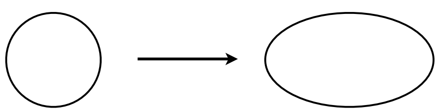
Results

Scores: actual vs. optimal performance

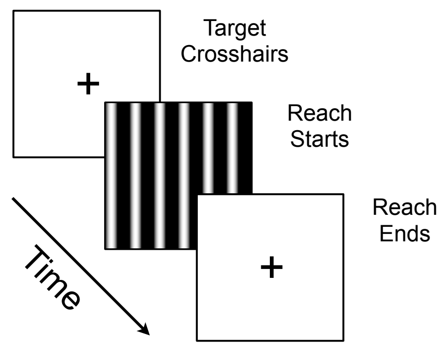


Trommershäuser, Gepshtein, Maloney, Landy, Banks (2005). *J. Neurosci., 25,* 7169.

What if we change your motor variability, making it anisotropic?

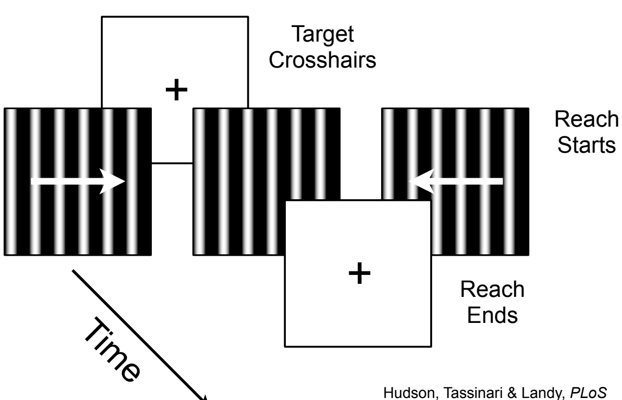


Experiment: Training: No-Drift Trials



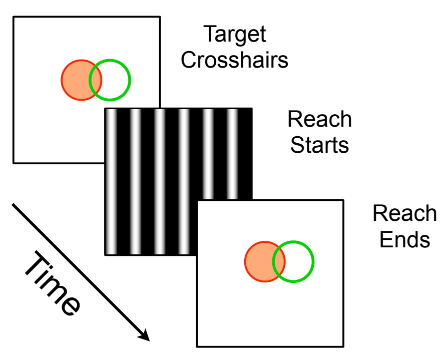
Hudson, Tassinari & Landy, *PLoS Comp. Biol.*, in press.

Experiment: Training: Drift Trials



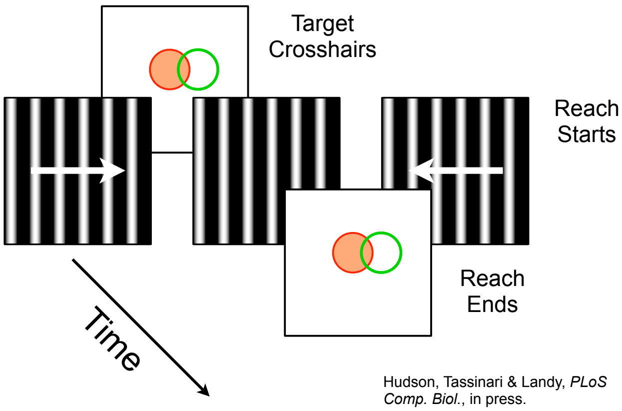
Hudson, Tassinari & Landy, *PLoS Comp. Biol.*, in press.

Experiment: Test: No-Drift Trials



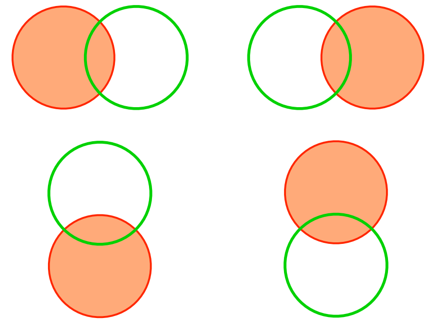
Hudson, Tassinari & Landy, *PLoS Comp. Biol.*, in press.

Experiment: Test: Drift Trials



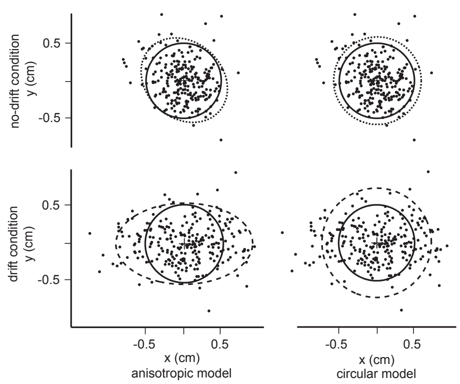
Hudson, Tassinari & Landy, *PLoS Comp. Biol.*, in press.

Payoff-Penalty Configurations



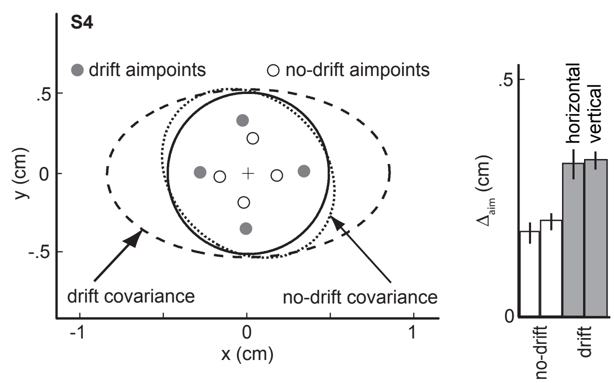
Hudson, Tassinari & Landy, *PLoS Comp. Biol.*, in press.

Results



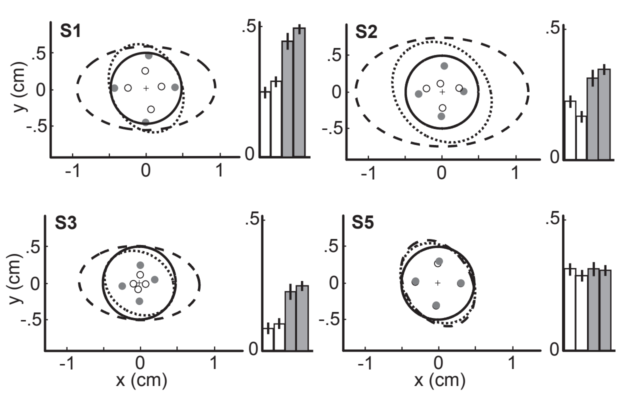
Hudson, Tassinari & Landy, *PLoS Comp. Biol.*, in press.

Results



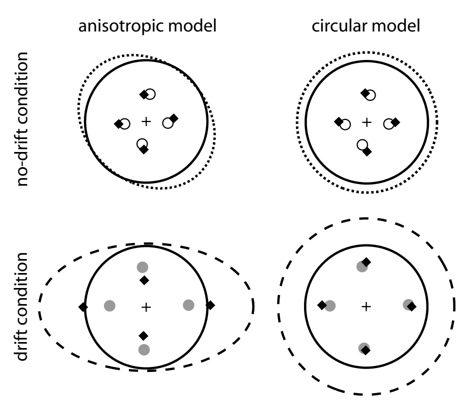
Hudson, Tassinari & Landy, *PLoS Comp. Biol.*, in press.

Results



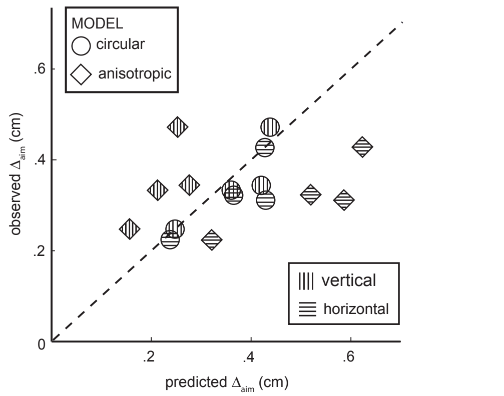
Hudson, Tassinari & Landy, *PLoS Comp. Biol.*, in press.

Results



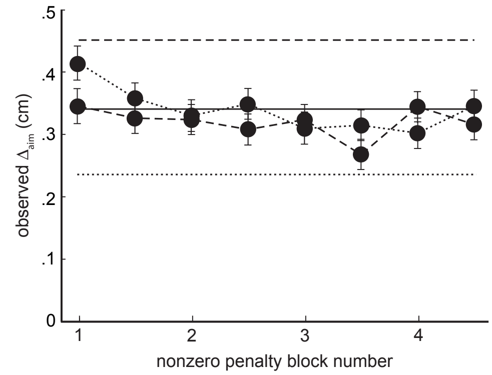
Hudson, Tassinari & Landy, *PLoS Comp. Biol.*, in press.

Results



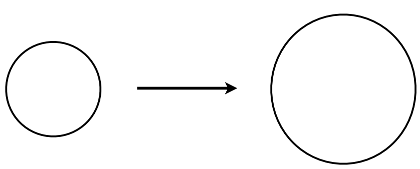
Hudson, Tassinari & Landy, *PLoS Comp. Biol.*, in press.

Results

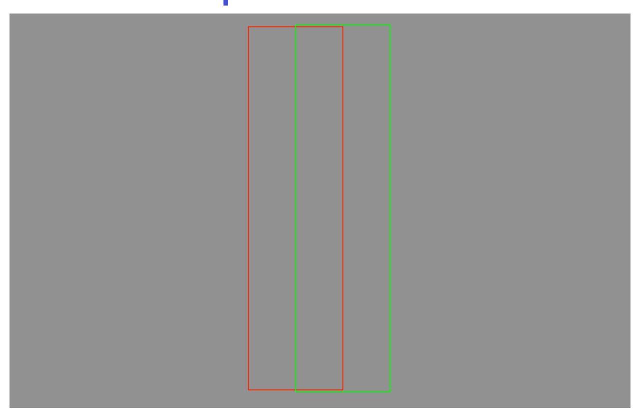


Hudson, Tassinari & Landy, *PLoS Comp. Biol.*, in press.

What if we change your outcome variability, trial-by-trial during a task? Will you learn the new variability? How?

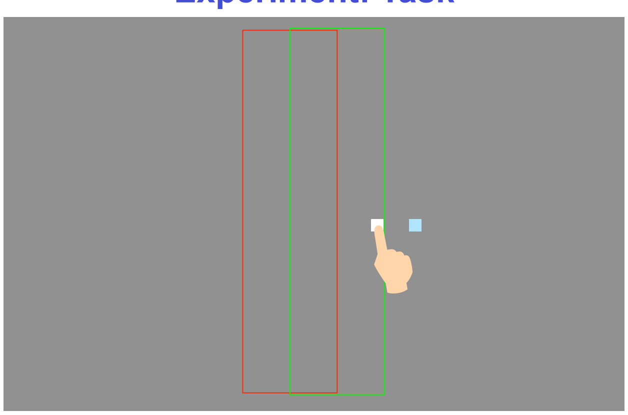


Experiment: Task



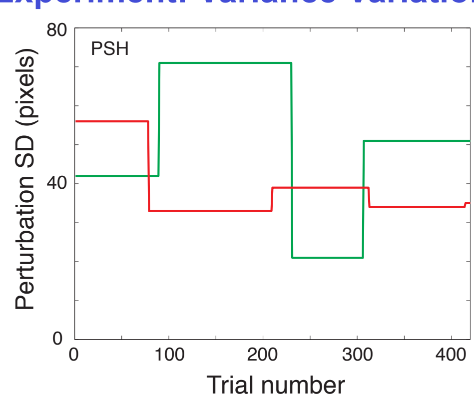
Landy, Daw & Trommershäuser, J Neurosci, in press

Experiment: Task



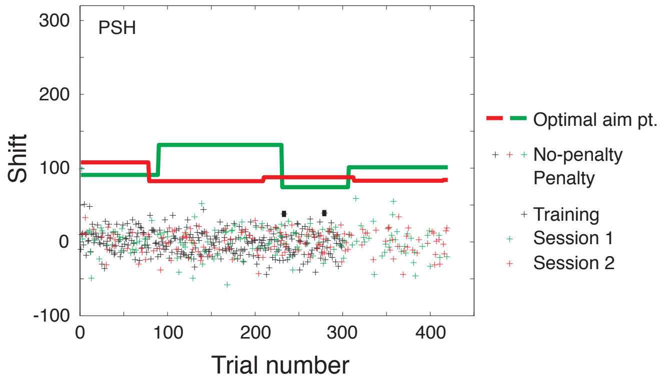
Landy, Daw & Trommershäuser, J Neurosci, in press

Experiment: Variance Variation



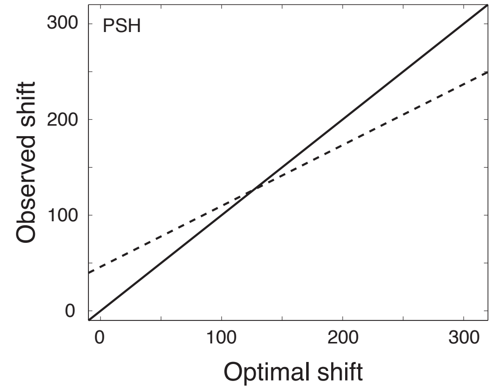
Landy, Daw & Trommershäuser, J Neurosci, in press

Experiment: Trial-by-Trial Data



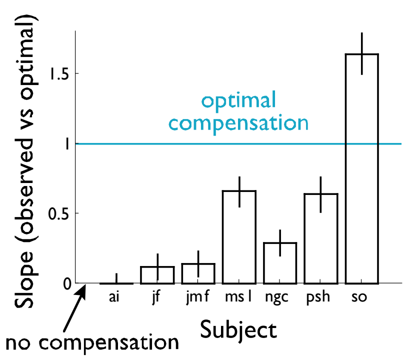
Landy, Daw & Trommershäuser, J Neurosci, in press

Experiment: Raw Data vs. Optimal



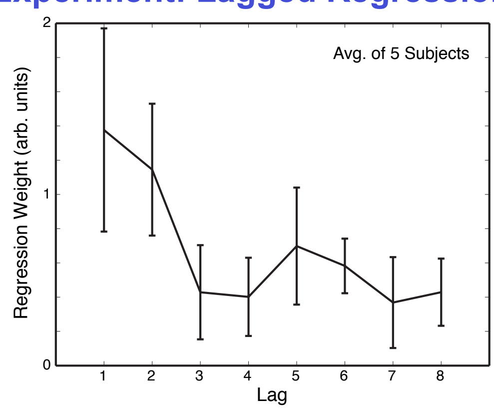
Landy, Daw & Trommershäuser, J Neurosci, in press

Experiment: Raw Data vs. Optimal



Landy, Daw & Trommershäuser, J Neurosci, in press

Experiment: Lagged Regression

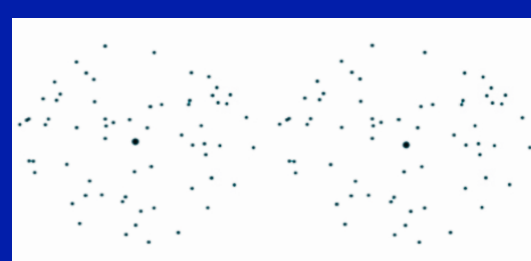


Landy, Daw & Trommershäuser, J Neurosci, in press

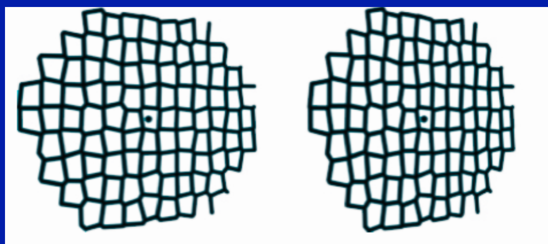
Do cue weights depend on local viewing conditions?

Hillis et al. (2004)

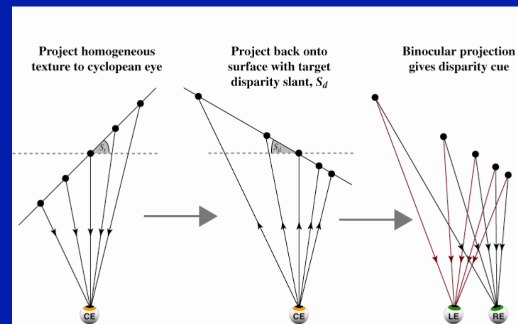
Stimuli – Disparity-only



Stimuli – Voronoi textures



Cue Conflict Stimuli



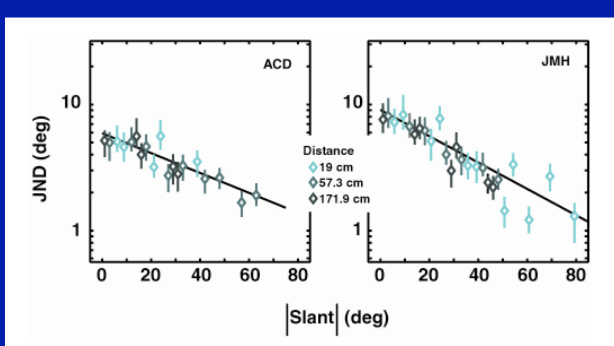
Methods

- Task: 2IFC slant discrimination
- Single-cue and two-cue blocks
- Opposite-sign slants mixed across trials in a block to avoid slant adaptation
- One stimulus fixed, other varied by staircase; several interleaved staircases
- Analysis: fit psychometric function to estimate PSE and JND

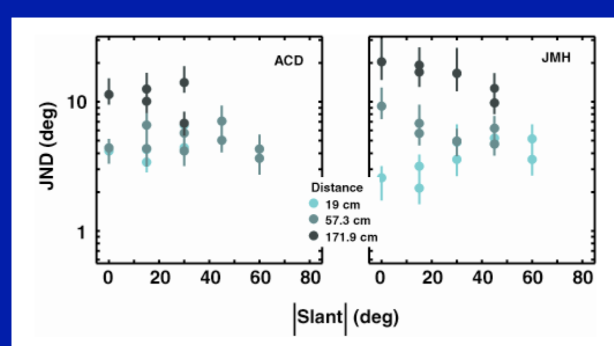
Outline

- Background: Optimal cue combination
- Methods: slant discrimination
- Single-cue results
- Two-cue results: perceived slant
- Two-cue results: JNDs
- Conclusions

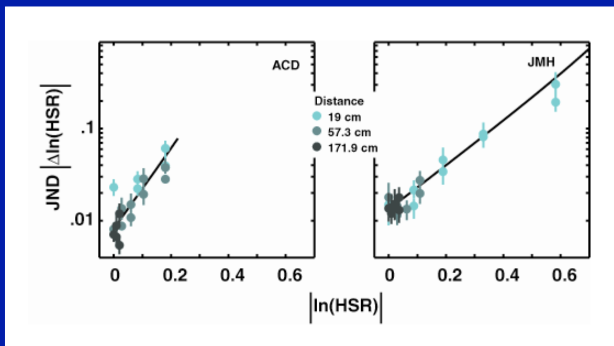
Single-cue JNDs: Texture



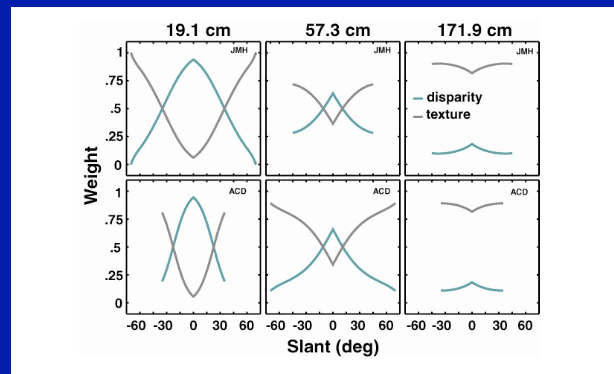
Single-cue JNDs: Disparity



Single-cue JNDs: Disparity



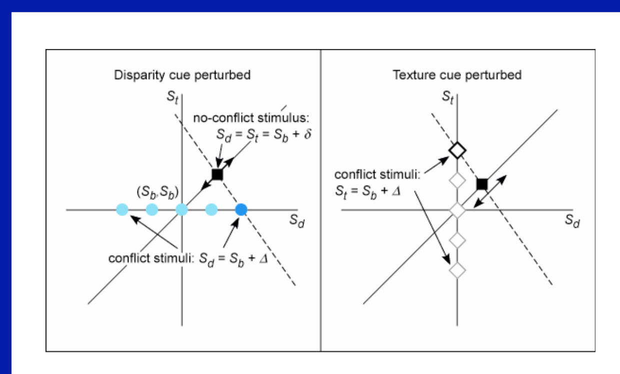
Predicted Cue Weights



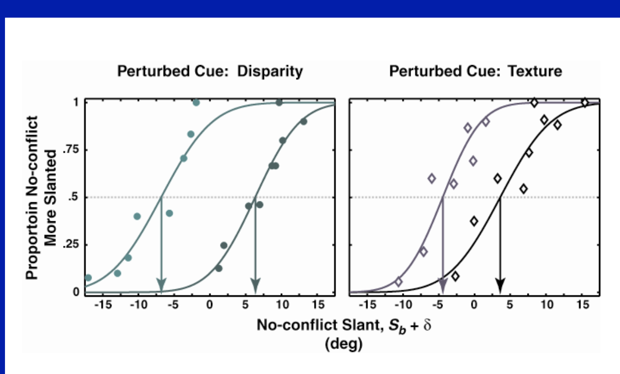
Outline

- Background: Optimal cue combination
- Methods: slant discrimination
- Single-cue results
- Two-cue results: perceived slant
- Two-cue results: JNDs
- Conclusions

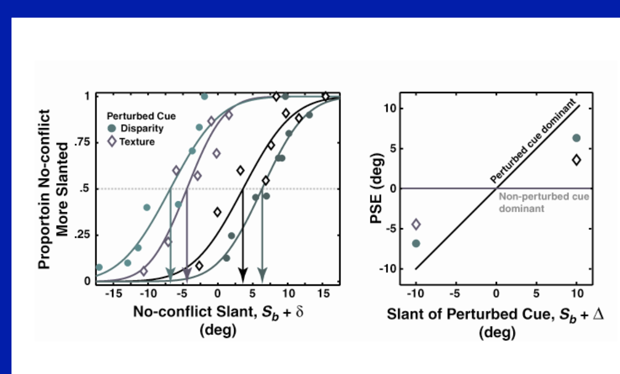
Cue Conflict Paradigm



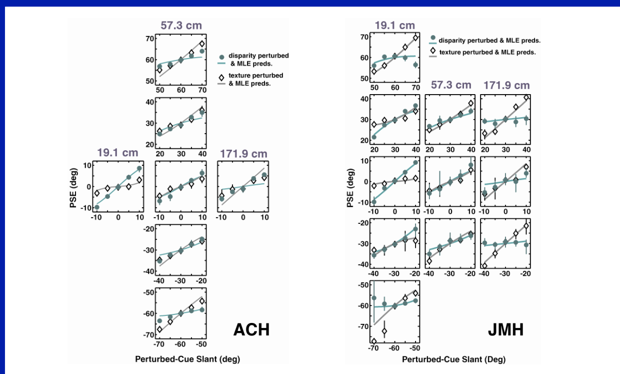
Determination of PSEs



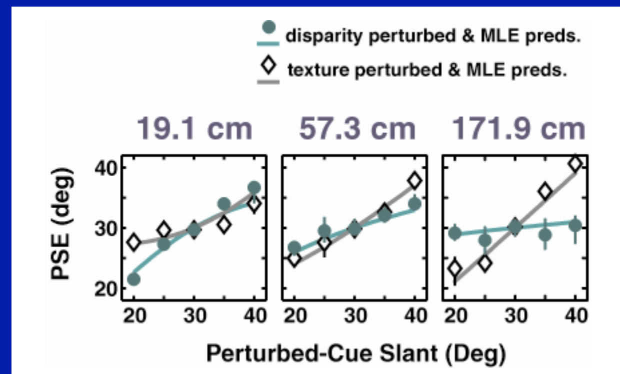
Determination of Weights



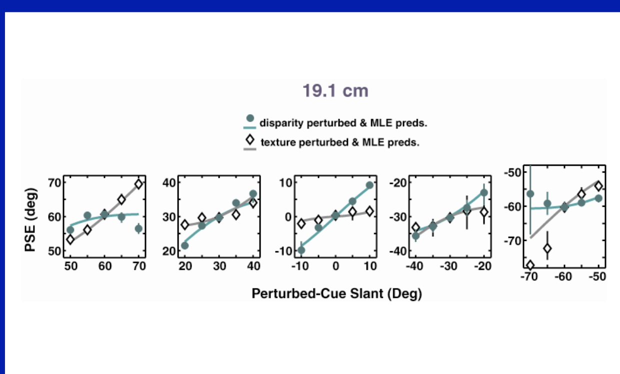
Full Two-Cue Dataset



Effect of Viewing Distance



Effect of Base Slant



Outline

- Background: Optimal cue combination
- Methods: slant discrimination
- Single-cue results
- Two-cue results: perceived slant
- Two-cue results: JNDs
- Conclusions

Improvement in Reliability with Cue Combination

If the optimal weights are used:

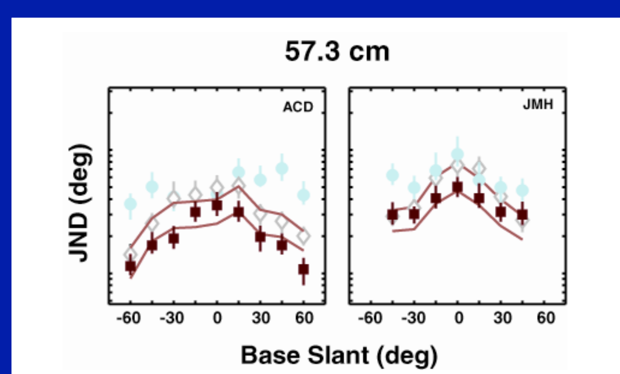
$$w_t = \frac{1/\sigma_t^2}{1/\sigma_t^2 + 1/\sigma_d^2} \quad \text{and} \quad w_d = \frac{1/\sigma_d^2}{1/\sigma_t^2 + 1/\sigma_d^2}$$

then the resulting variance

$$\frac{\sigma_t^2 \sigma_d^2}{\sigma_t^2 + \sigma_d^2}$$

is lower than that achieved by either cue alone.

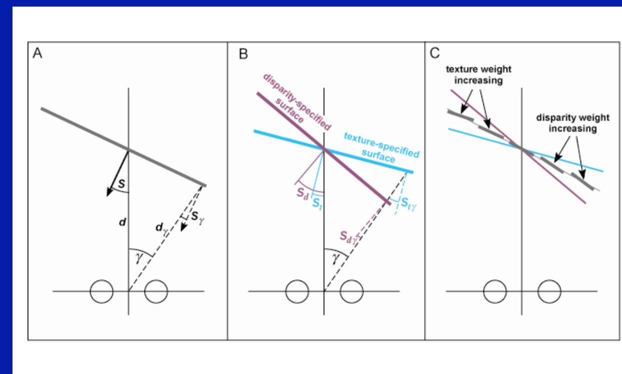
Improvement in JND with 2 Cues



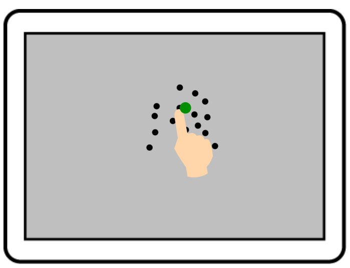
Conclusion

- The data are consistent with optimal cue combination
- Texture weight is increased with increasing distance and increasing base slant, as predicted
- Two cue JNDs are generally lower than the constituent single-cue JNDs
- Thus, weights are determined trial-by-trial, based on the current stimulus information and, in particular, the two single-cue slant estimates

Are Cue Weights Chosen Locally?



Experiment: Priors and Likelihoods



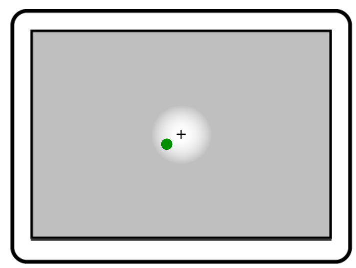
Training:

- Subject shown 'splash'
- Task is touch where coin landed
- Feedback provided
- 150 Trials

Tassinari, Hudson & Landy (2006). *J. Neurosci.*, *26*, 10154-10163.

See also: Körding & Wolpert (2004). *Nature*, *427*, 244-247.

Teaching Subjects the Prior



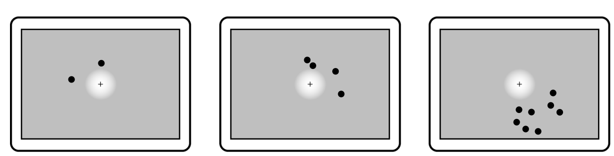
Tassinari, Hudson & Landy (2006). *J. Neurosci.*, *26*, 10154-10163.

Experimental Trials

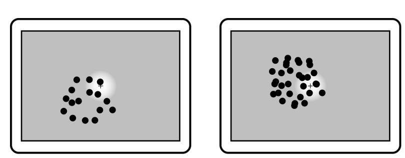
- 900 Trials
- Task is touch where coin landed
- Only hit/miss feedback is given
- Hits worth $0.05

Tassinari, Hudson & Landy (2006). *J. Neurosci.*, *26*, 10154-10163.

Experimental Stimuli



2 dots   4 dots   8 dots



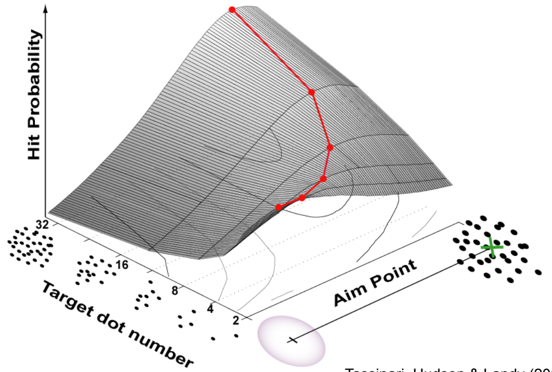
16 dots   32 dots

Splash σ = 4 cm
Prior σ = 2 cm

Where should one aim to maximize number of hits?

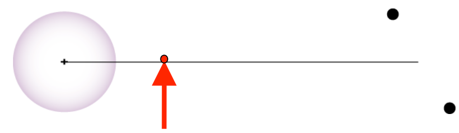
Tassinari, Hudson & Landy (2006). *J. Neurosci.*, *26*, 10154-10163.

Gain Landscape



Tassinari, Hudson & Landy (2006).
J. Neurosci., *26*, 10154-10163.

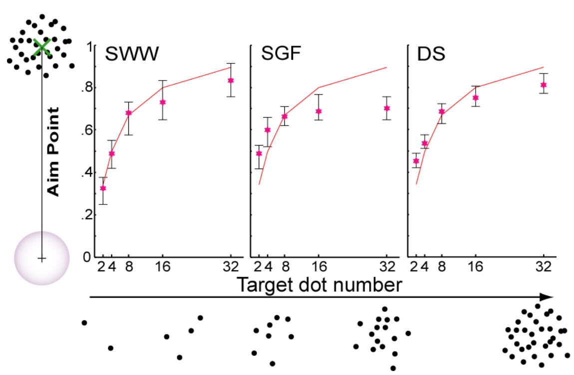
2 Dot condition:



32 Dots:

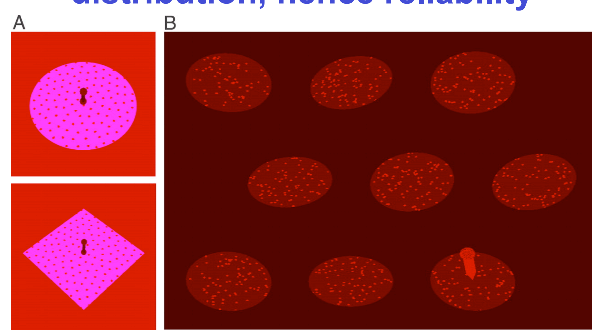
Tassinari, Hudson & Landy (2006).
J. Neurosci., *26*, 10154-10163.

Results

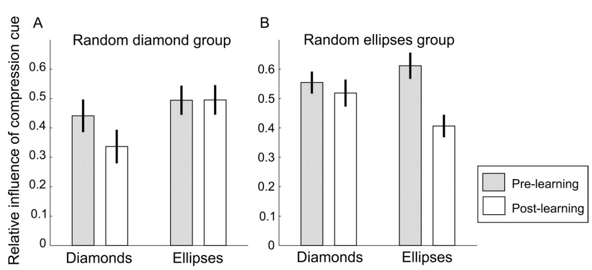


Tassinari, Hudson & Landy (2006).
J. Neurosci., *26*, 10154-10163.

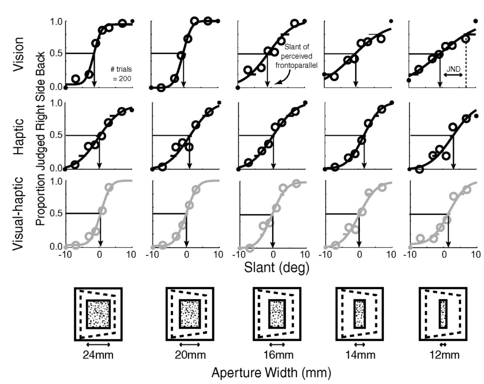
Learning a prior on stimulus distribution, hence reliability



Seydell et al. J Vis 2010

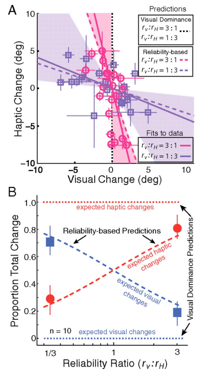


Cue-combination data from one representative subject.

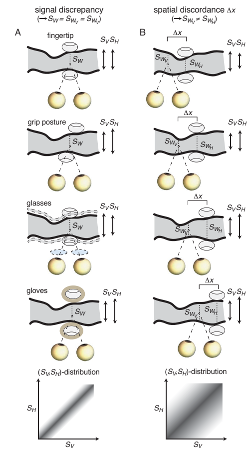


Burge J et al. J. Neurosci. 2010

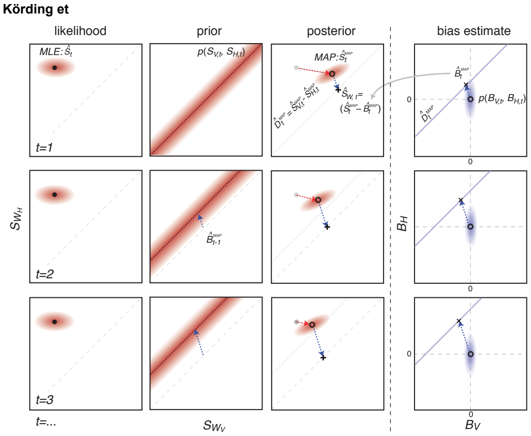
Adaptation predictions and data.



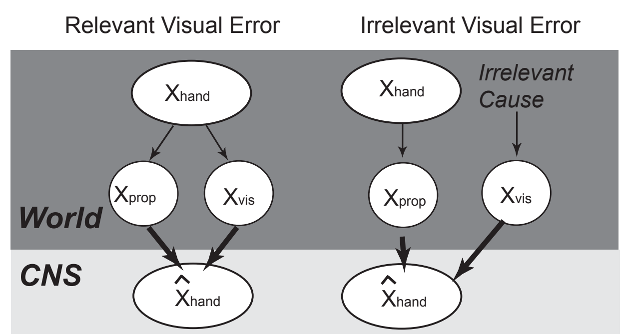
Ernst & Di Luca (2011). In Körding et al.

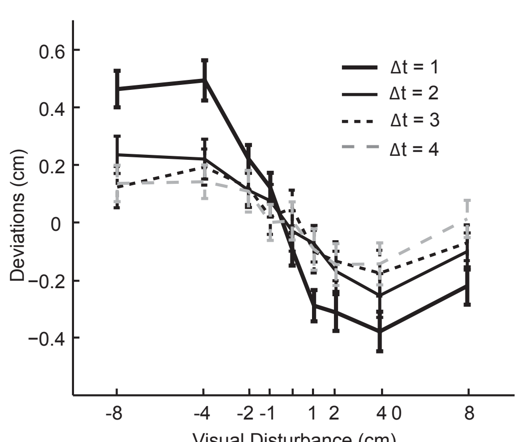


Ernst & Di Luca (2011). In Körding et al.

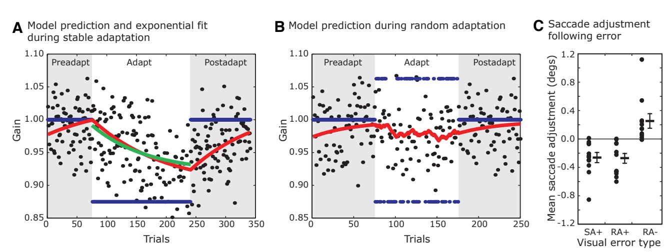


Wei & Körding (2009). J Neurophys





Wei & Körding (2009). J Neurophys



Srimal et al. (2008). J Neurophys