Sensory-motor confidence

Michael S. Landy
NYU

Sensory and sensory-motor integration

- Sensory cue integration behavior often consistent with an ideal Bayesian observer
- Observers take into account prior information and each cue's relative uncertainty
- This is found with single modalities and multisensory stimuli
- (Near) optimality is also seen in sensory-motor tasks, combining uncertain sensory and prior information to guide motor action
- Motor behavior also optimally combines uncertainty in movement with outcome costs and benefits

Metajudgments: Sensory and motor confidence

- We can also judge the quality of our decisions and actions
- This is most often studied with perceptual decisions
- Confidence: Perceived probability that a decision was correct
- In both perceptual decisions and sensory-motor contexts, confidence involves information integration

Integration of prospective and retrospective information in sensory-motor confidence

Marissa Fassold

Shannon Locke

Fassold, Locke & Landy (under review)

What is sensorimotor confidence?

Confidence can be defined as a metacognitive judgement based on our internal feeling of success

Sensorimotor confidence is specific to the success of motor actions with a sensory directed goal.

Why do we care? Sensorimotor confidence allows us to quickly assess if an action needs to be repeated or recalibrated prior to experiencing the consequences of its success or failure.

Temporally Distinct Cues

Prospective Cues - available prior to the action

- Sensory information
- Prior experience with task
- Knowledge of motor noise

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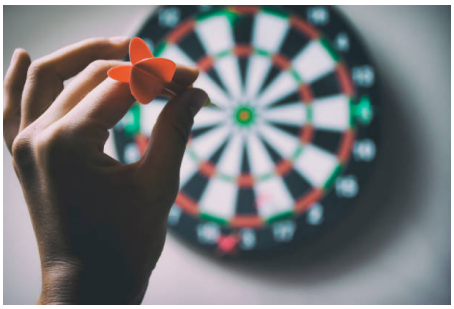
- Proprioception
- Knowledge of proprioceptive noise
- Visual feedback (when available)



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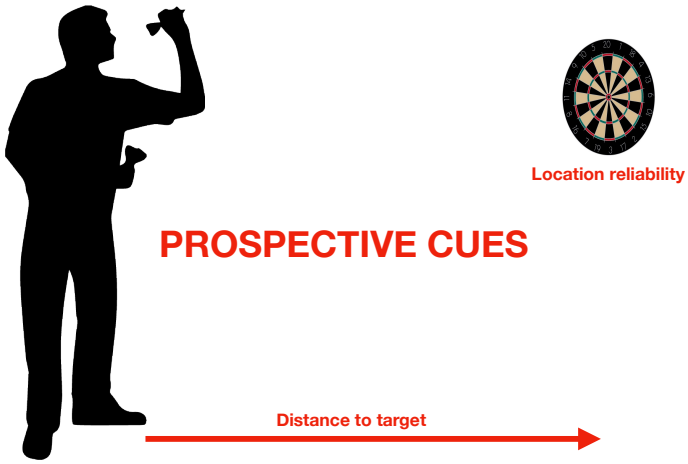
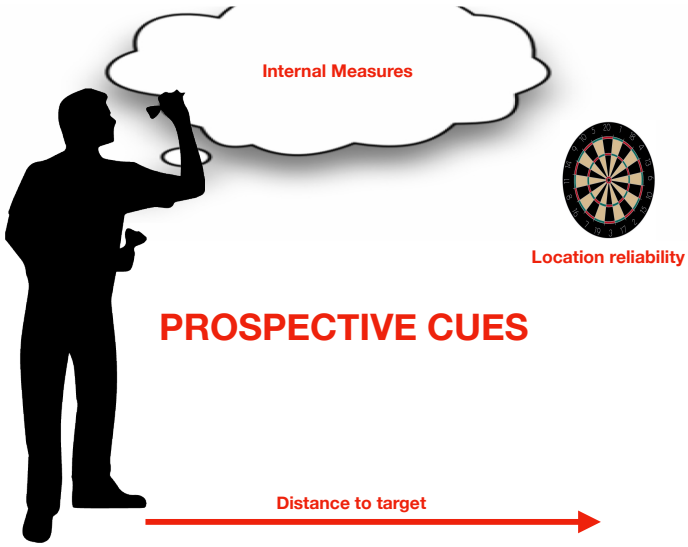
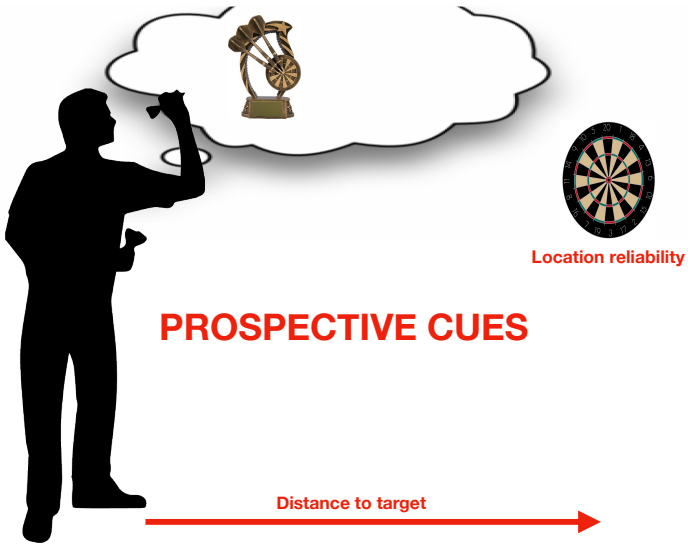



Internal Measures
Location reliability
PROSPECTIVE CUES
Distance to target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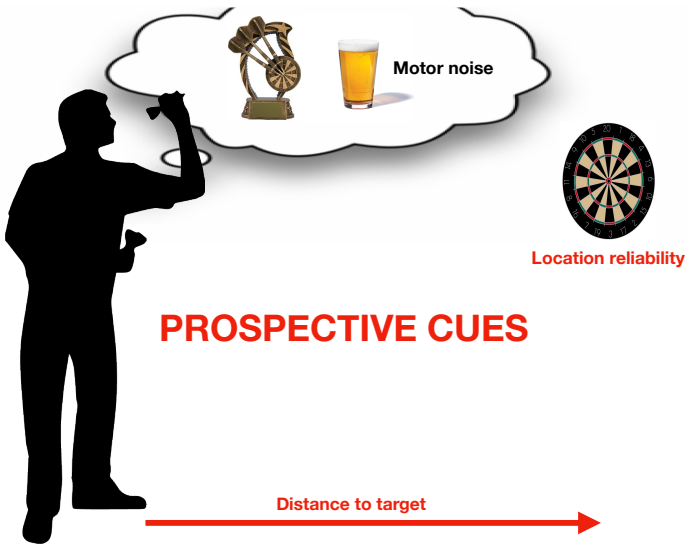
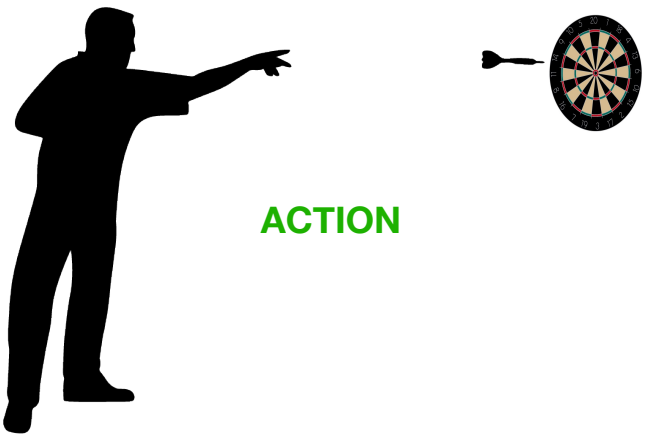
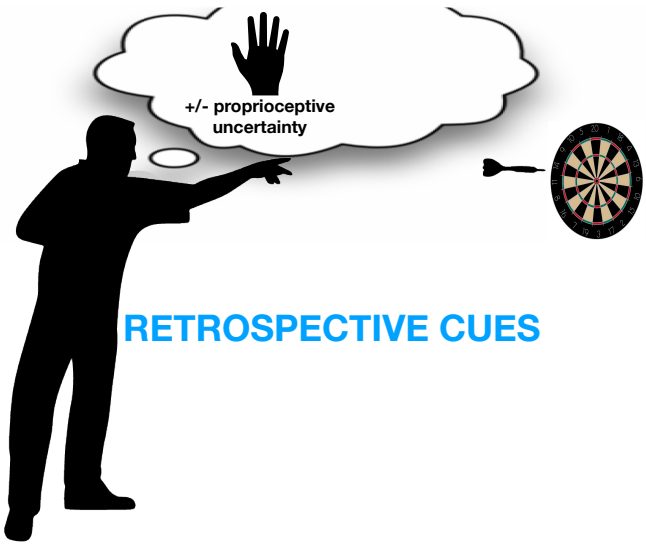
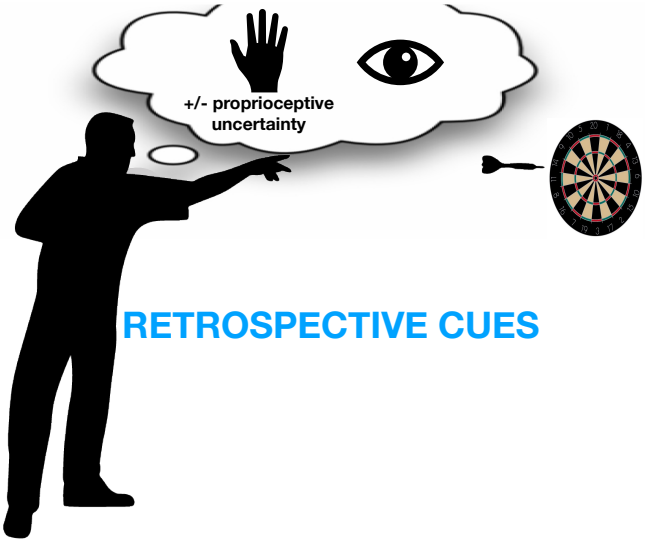

Motor noise
Location reliability
PROSPECTIVE CUES
Distance to target

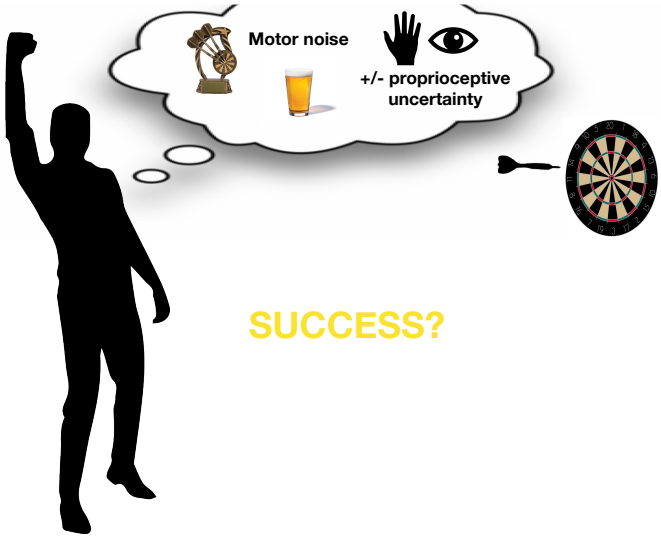

ACTION


ACTION


+/- proprioceptive uncertainty
RETROSPECTIVE CUES



RETROSPECTIVE CUES

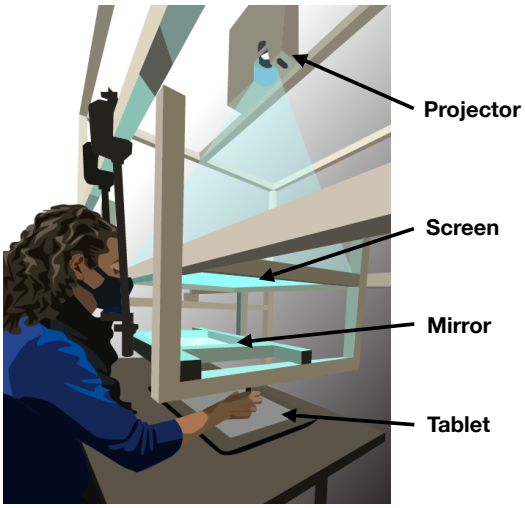


SUCCESS?

Sensory Input	Prospective Cues	PROSPECTIVE CONFIDENCE	Action	Retrospective Cues	RETROSPECTIVE CONFIDENCE
Visual target presentation	Knowledge of motor noise Past feedback Real world priors Target angle Target distance		Goal directed movment in 3D space	Proprioceptive Feedback Visual Feedback Forward Models	

time

- How do the cues at these two time points contribute to the final sensorimotor confidence judgment?
- Are they always incorporated together or do observers depend only on one or the other set of cues?

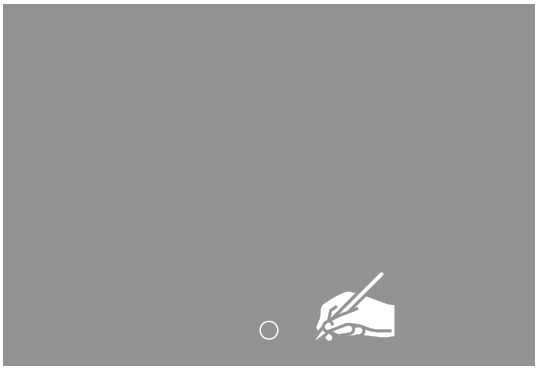


Motor Awareness Task

How well can you estimate the location of your hand in space?

Purpose: To independently measure the participant's proprioceptive noise.

Motor Awareness Task



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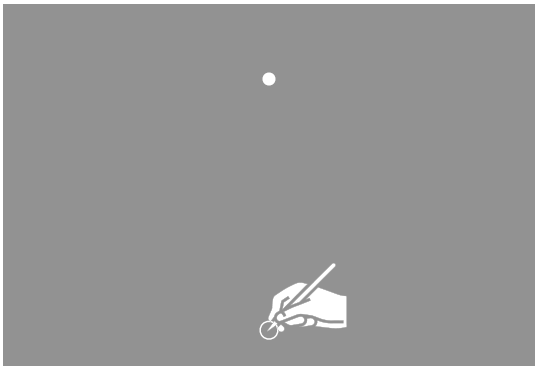

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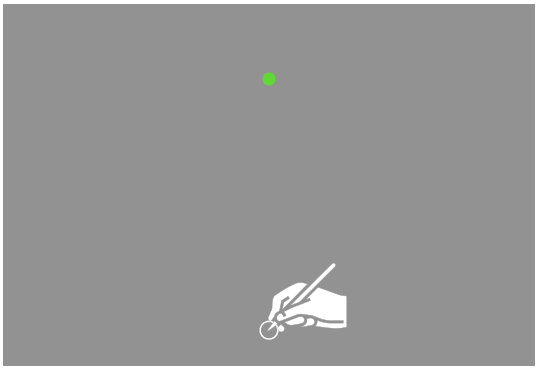
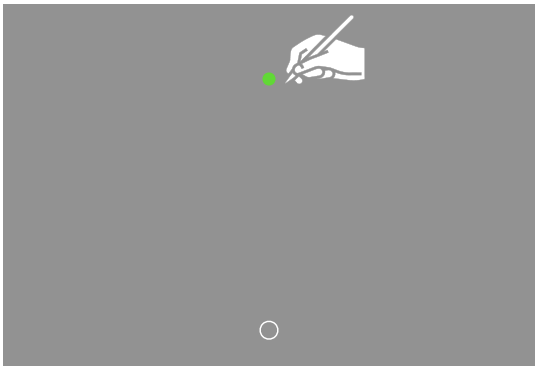


Motor Awareness Task



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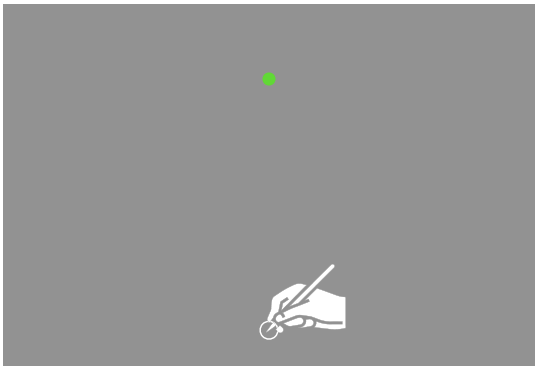

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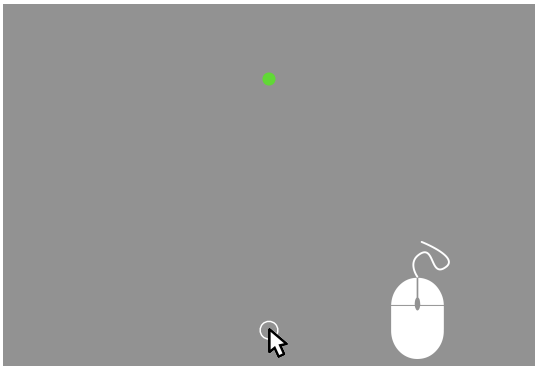

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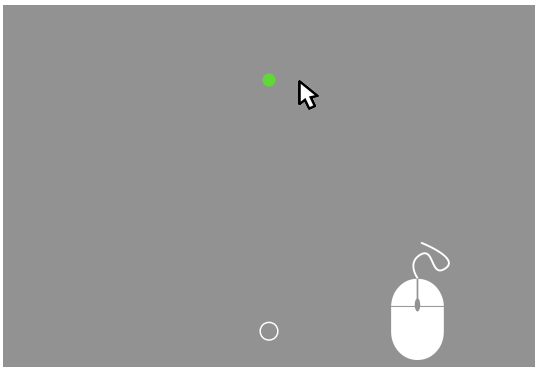

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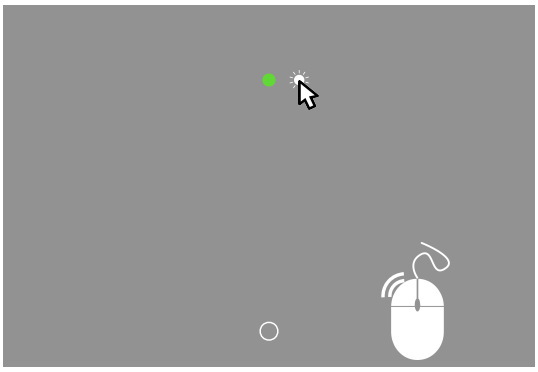

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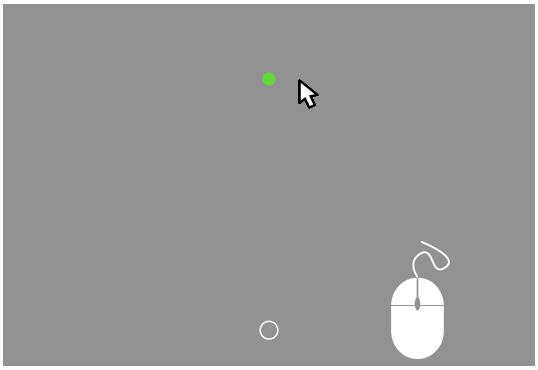
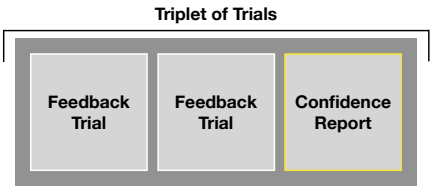


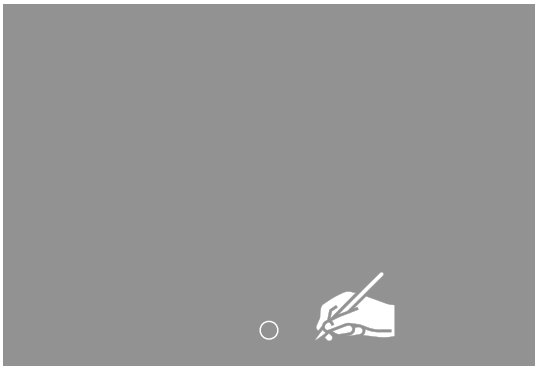
Confidence Judgment Experiment

Task: Report confidence on unseen reaches to a visually cued target location.

Endpoint Feedback: Presented only on the two trials prior to each confidence judgement.



Experimental Paradigm



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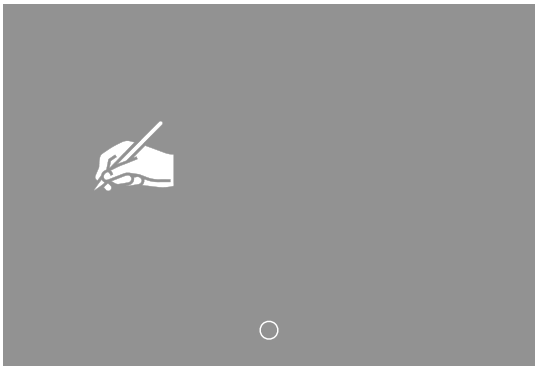

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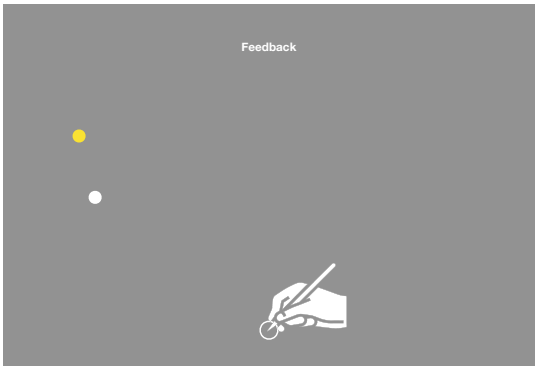

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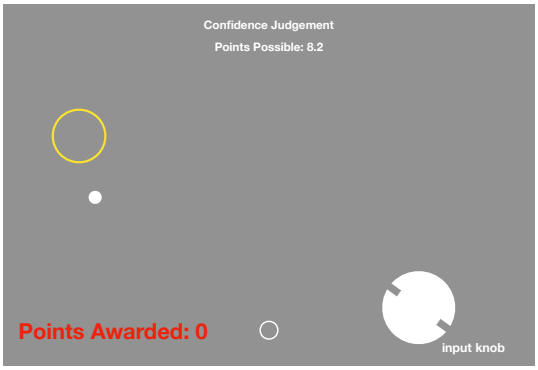

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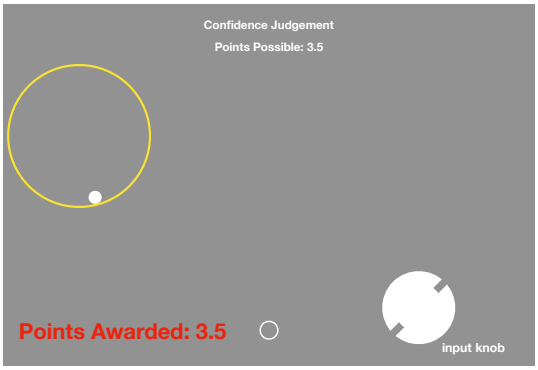
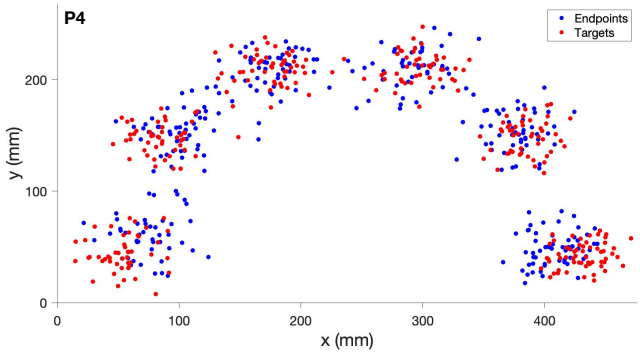
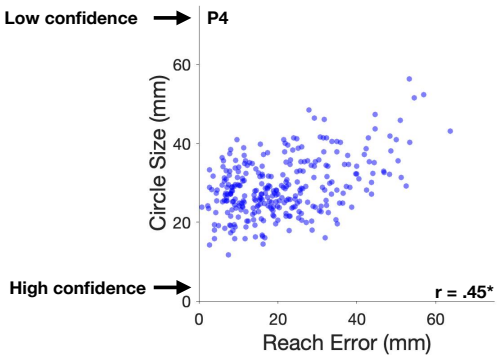


Behavioral Results

Endpoints on Tablet



Confidence Performance Correlation



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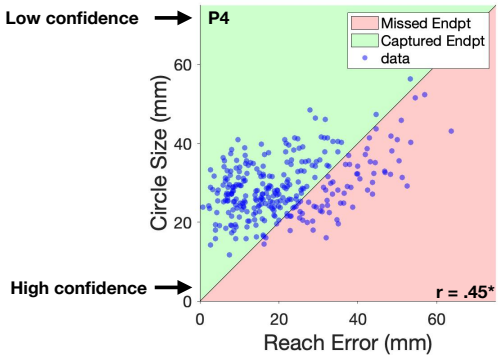

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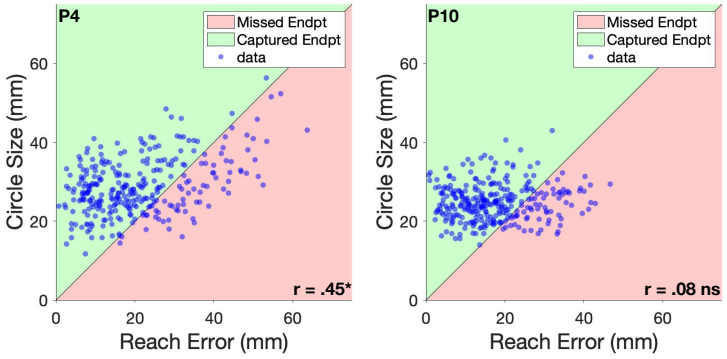
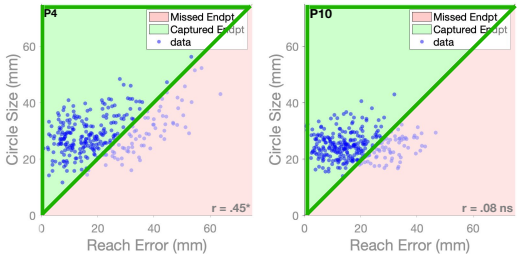


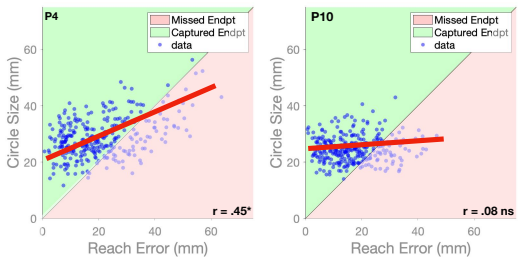
Confidence Performance Correlation

- Participants capture the majority of their endpoints to successfully earn points



Confidence Performance Correlation

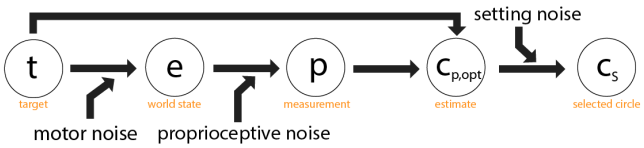
- Participants capture the majority of their endpoints to successfully earn points
- Some participants' confidence reports significantly correlated with performance, while others' are not



MODEL PARAMETERS

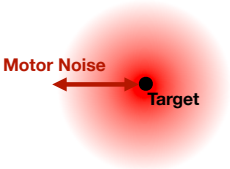
MODELS	Prospective Cues	Retrospective Cues	Setting Noise
Ideal Observer	✓	✓	✓
Retrospective Observer	✗	✓	✓
Prospective Observer	✓	✗	✓

Generative Model



Ideal Observer Model

Ideal Observer Model



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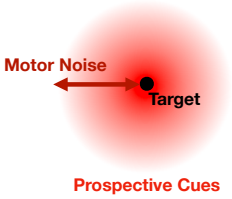

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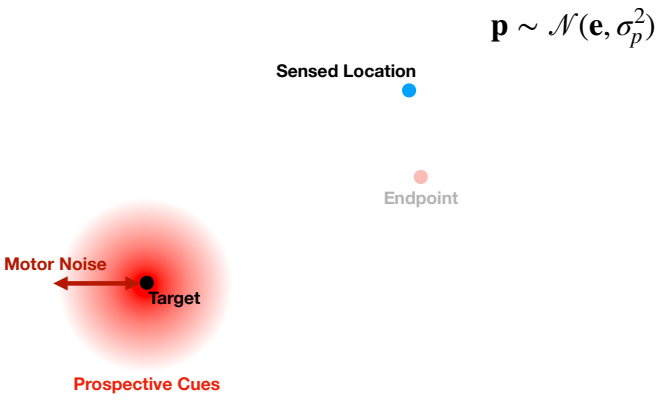

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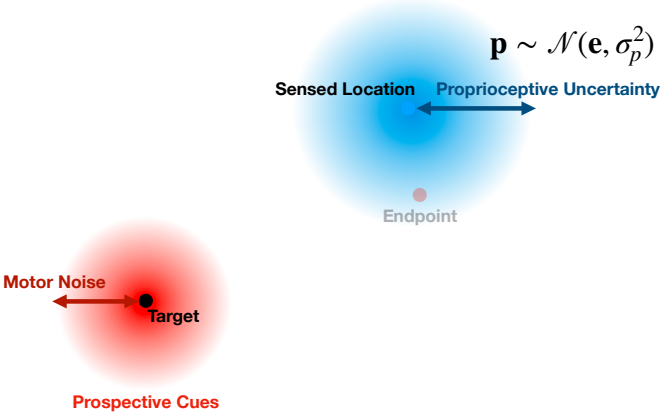

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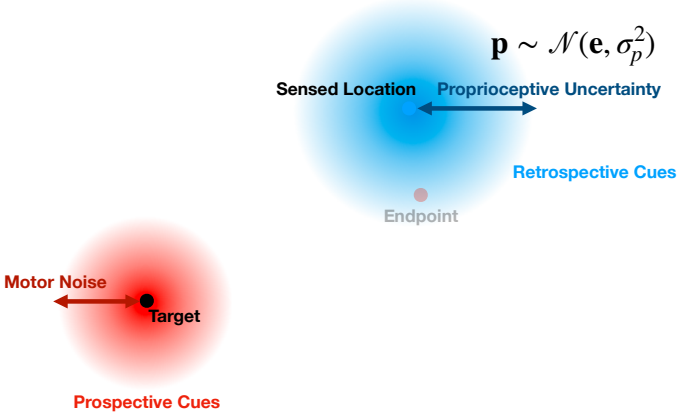

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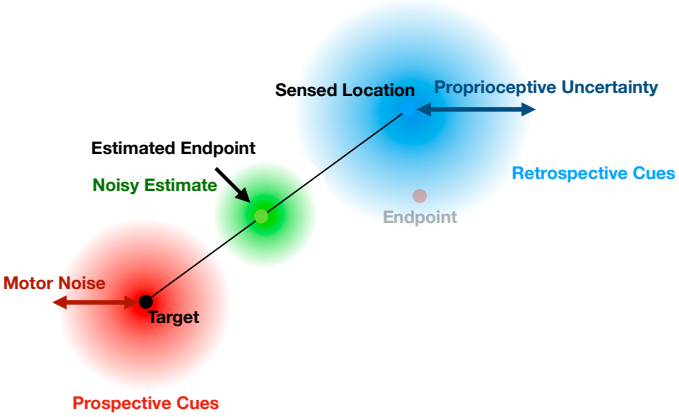

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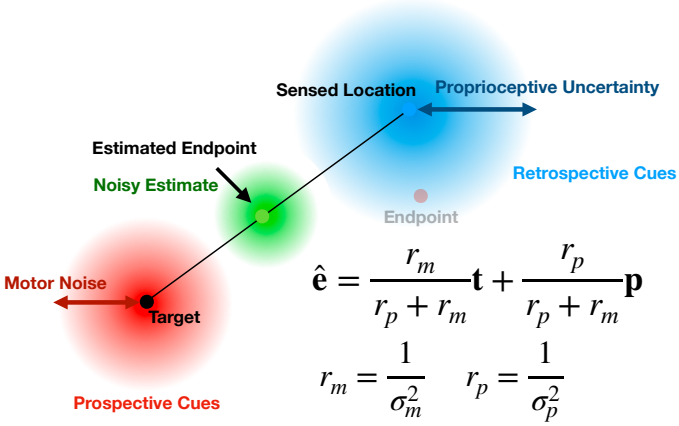

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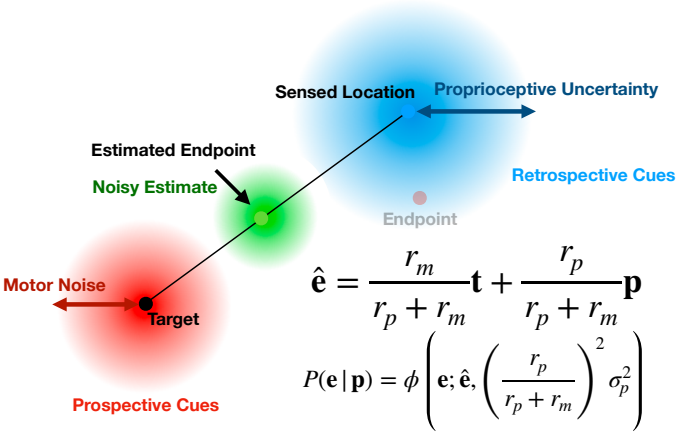

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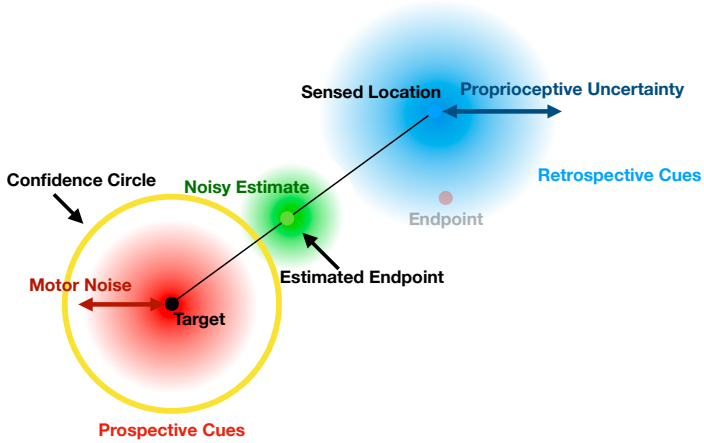


Ideal Observer Model

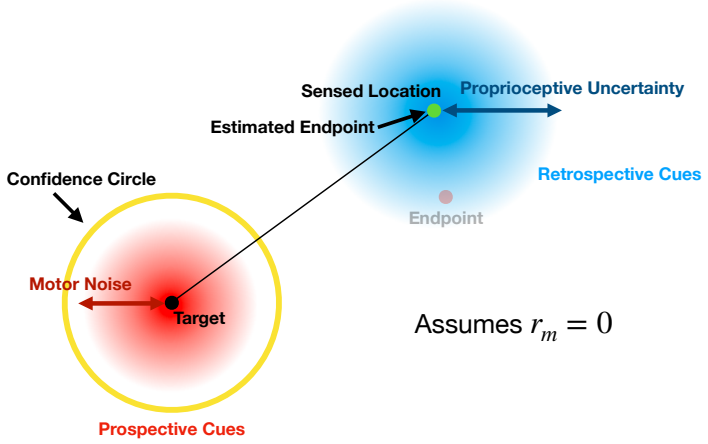
$$P(\mathbf{e}\,|\,\mathbf{p}) = \phi\left(\mathbf{e};\hat{\mathbf{e}},\left(\frac{r_p}{r_p+r_m}\right)^2\sigma_p^2\right)$$

$$EG(s_c\,|\,\mathbf{p}) = f(s_c)\iint_{C(\mathbf{t},s_c)} p(\mathbf{e}=(x,y)\,|\,\mathbf{p})dxdy$$

$$c_{s,opt} = \arg\max_{c_s} EG(s_c\,|\,\mathbf{p})$$

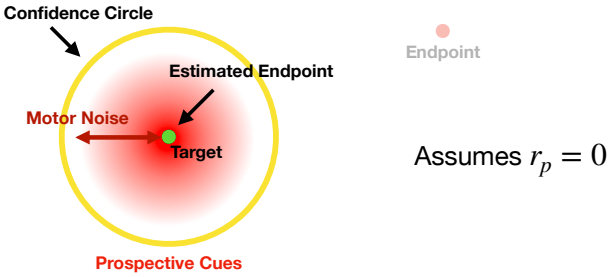
$$c_s \sim \mathcal{N}(c_{s,opt},\sigma_s^2)$$

Retrospective Observer Model



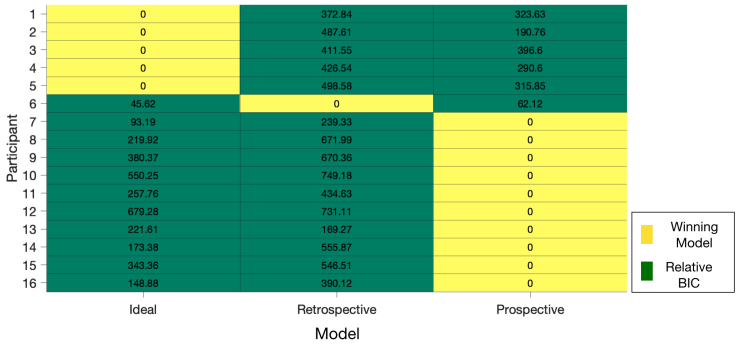
Assumes $r_m = 0$

Prospective Observer Model



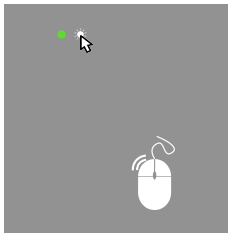
Assumes $r_p = 0$

BIC Model Comparison

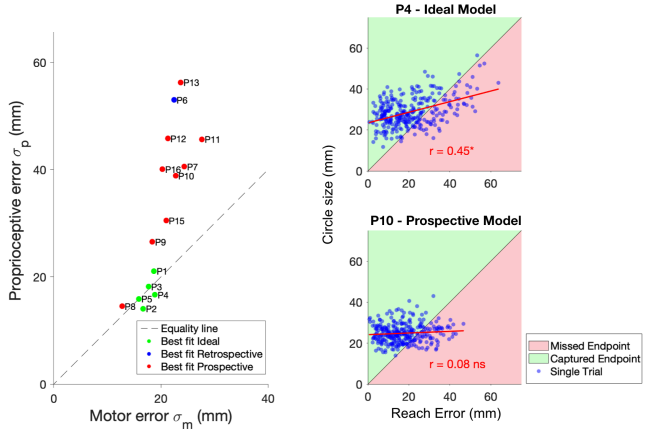


Summary of Model Fits

- Observers can use proprioception when prompted
- But, proprioceptive information is not always used when making a sensorimotor confidence judgment



Best Fit Model Parameters



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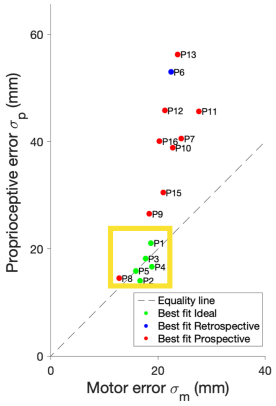
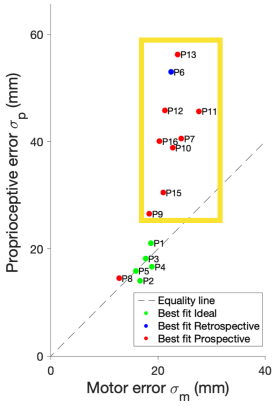


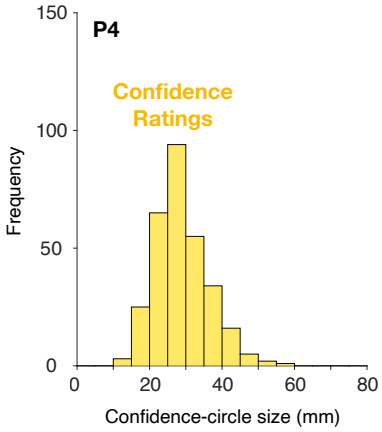
Proprioceptive information is used during confidence judgment when uncertainty is known to be low

Best Fit Model Parameters



Proprioception is not used during confidence judgment when uncertainty is high

Model Predictions of Confidence



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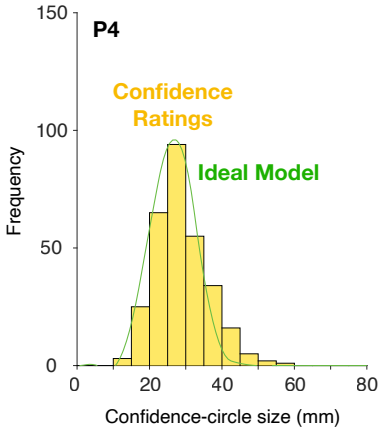

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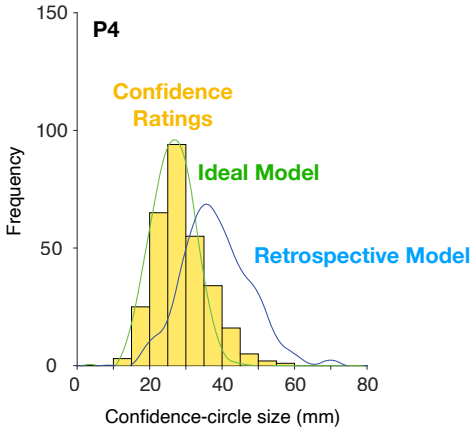
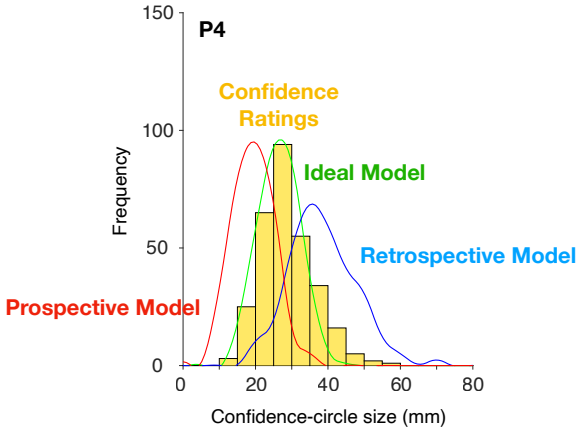
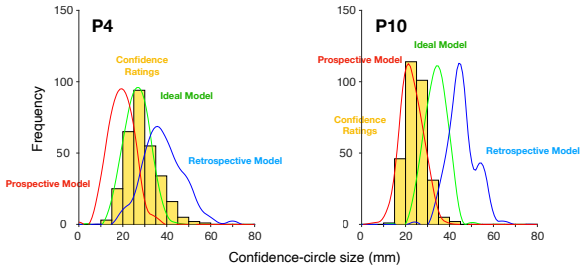


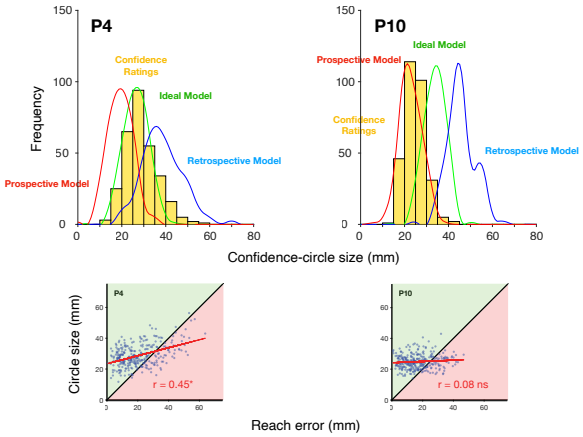
Model Predictions of Confidence

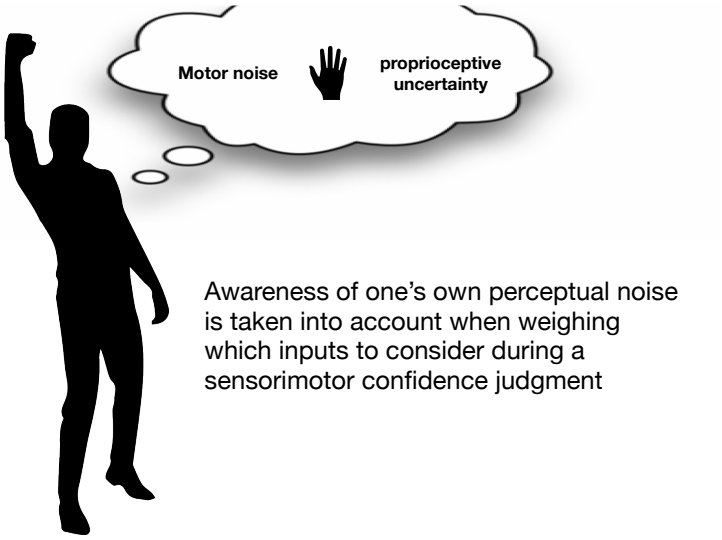


Model Predictions of Confidence



Model Predictions of Confidence





Awareness of one's own perceptual noise is taken into account when weighing which inputs to consider during a sensorimotor confidence judgment

Thank you!

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