

Background

Metacognition

The ability to monitor and evaluate one's own mental states¹.

- In perception; manifest in confidence placed in internal representations of the world
- Can mediate the effects of perception on behaviour²

Metacognition in autism

- Metacognitive deficits could contribute to alterations (e.g., social reasoning, perceptual processing).
- Previous research relies on accuracy of confidence report³—also reflecting task performance; confounded by first-order performance level.

Atypical perception in autism

- Research mostly ignored higher-order levels of perception (i.e., metacognition)
- Could be caused by atypical sensory functioning (sensitivity; s); perceptual biases (decision criterion; c_d); perceptual metacognitive ability (σ_m).

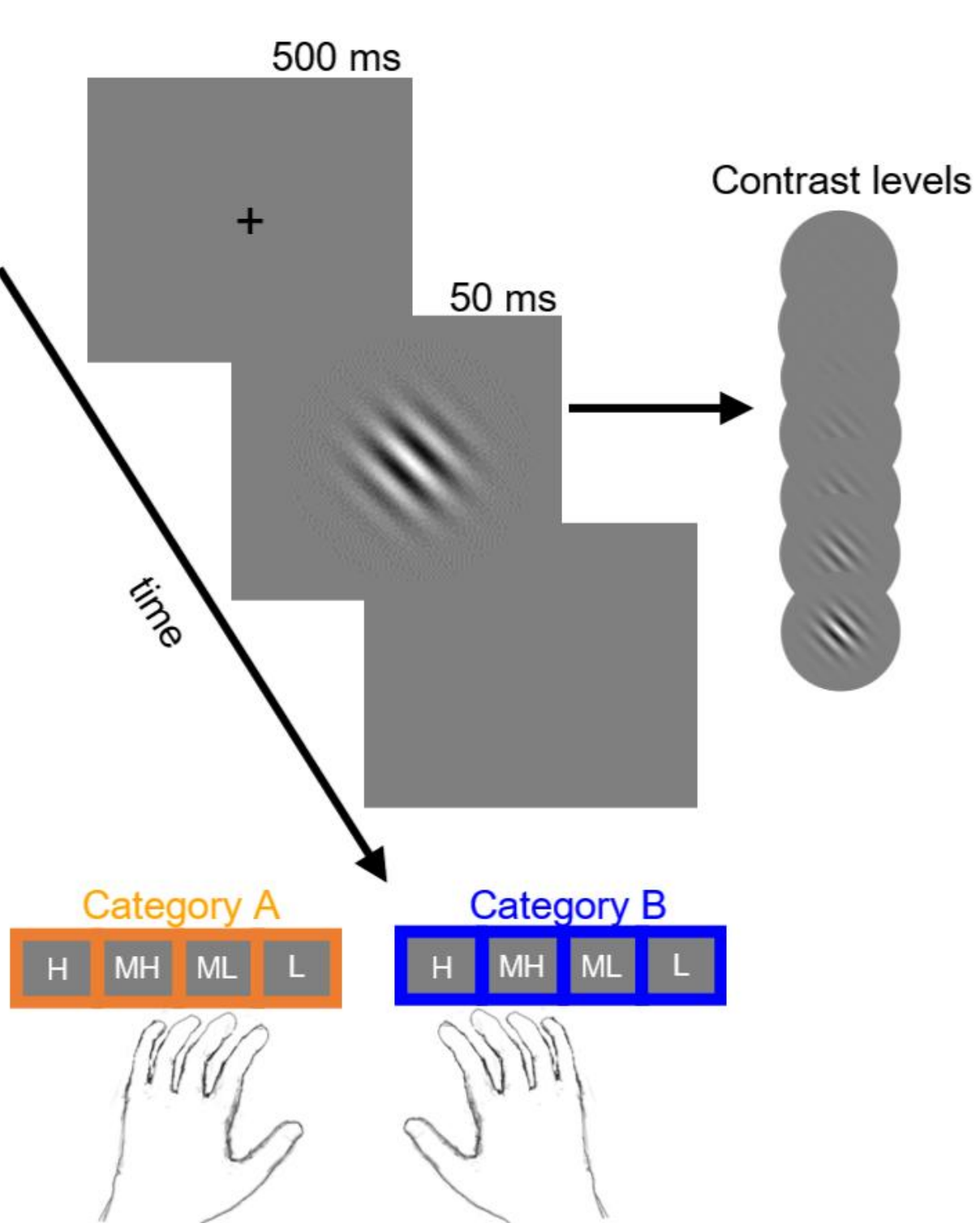
Research gap: perceptual metacognitive abilities remain largely unquantified in autism

Objectives

- Directly investigating metacognitive abilities in autism using **perceptual decision-making** in a **Bayesian framework**:
 - Model system that distinguishes first-order (perceptual inference) from second-order (confidence in first-order decision, reflecting metacognitive abilities).
 - Perceptual decisions = inference process combining **sensory uncertainty** (likelihood), **prior expectations** (internal models), and **reward** (cost function).
- Quantifying metacognitive abilities using psychophysics and computational modeling of confidence.

Methods

Trial sequence



Main manipulation

1. Prior experiment

Category base-rate
A = 25% | A = 50% | A = 75%

2. Reward experiment

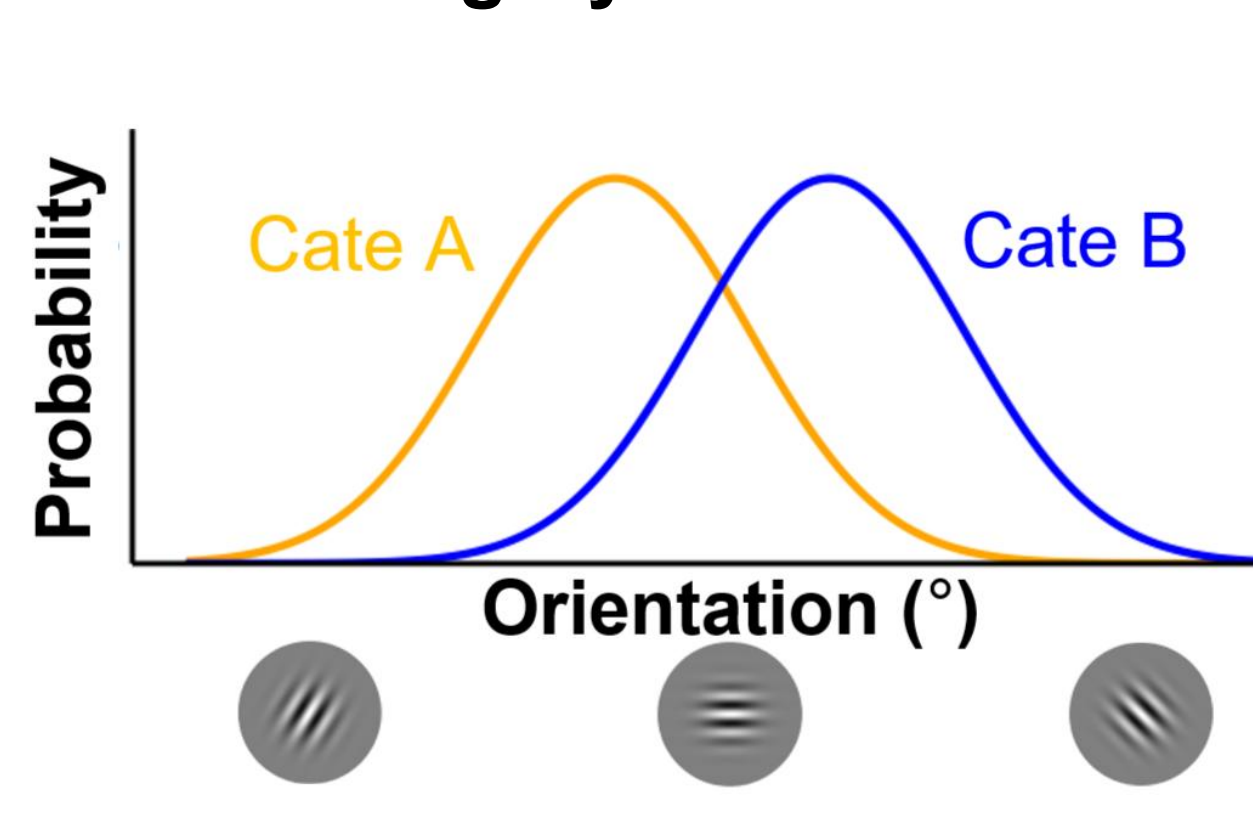
Points per correct answer
A = 1 pt | A = 2 pt | A = 3 pt

3. Sensory uncertainty experiment

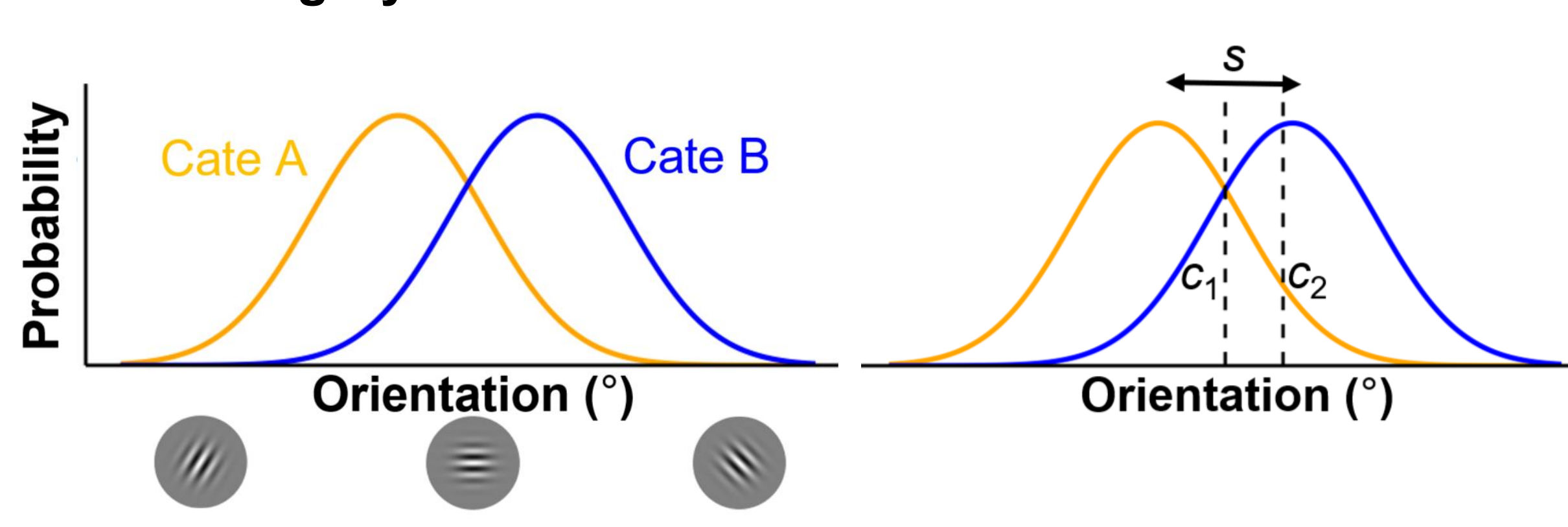
Contrast levels

	n_{autistic}	$n_{\text{non-autistic}}$
Prior	34	49
Reward	32	48
Sensory uncertainty	34	44

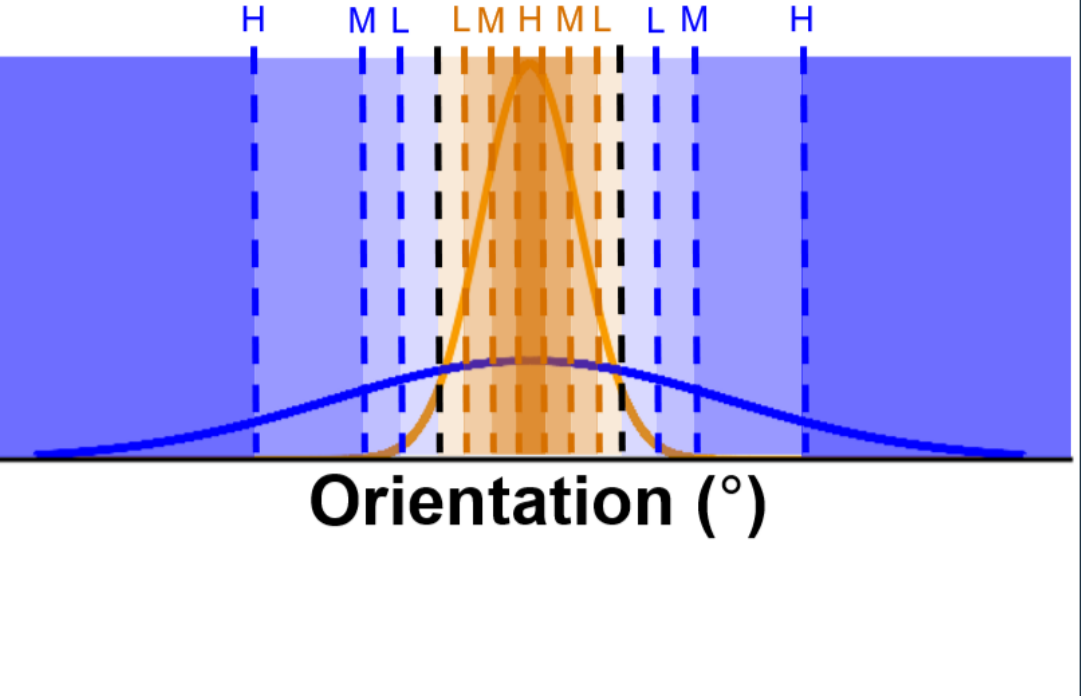
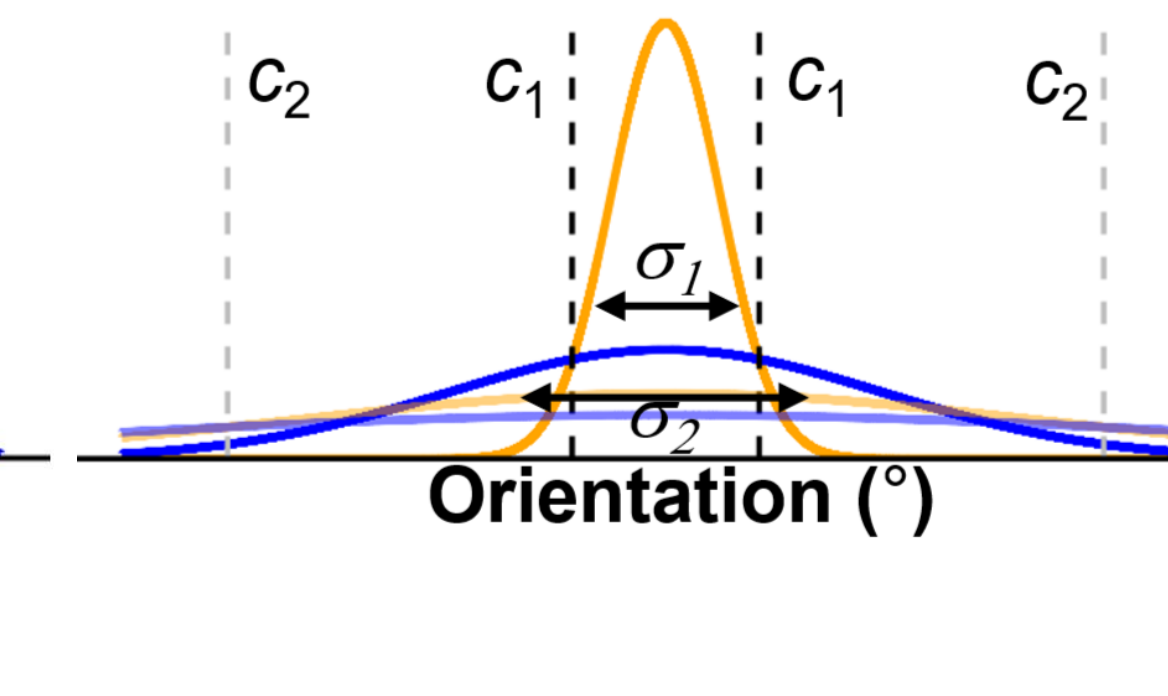
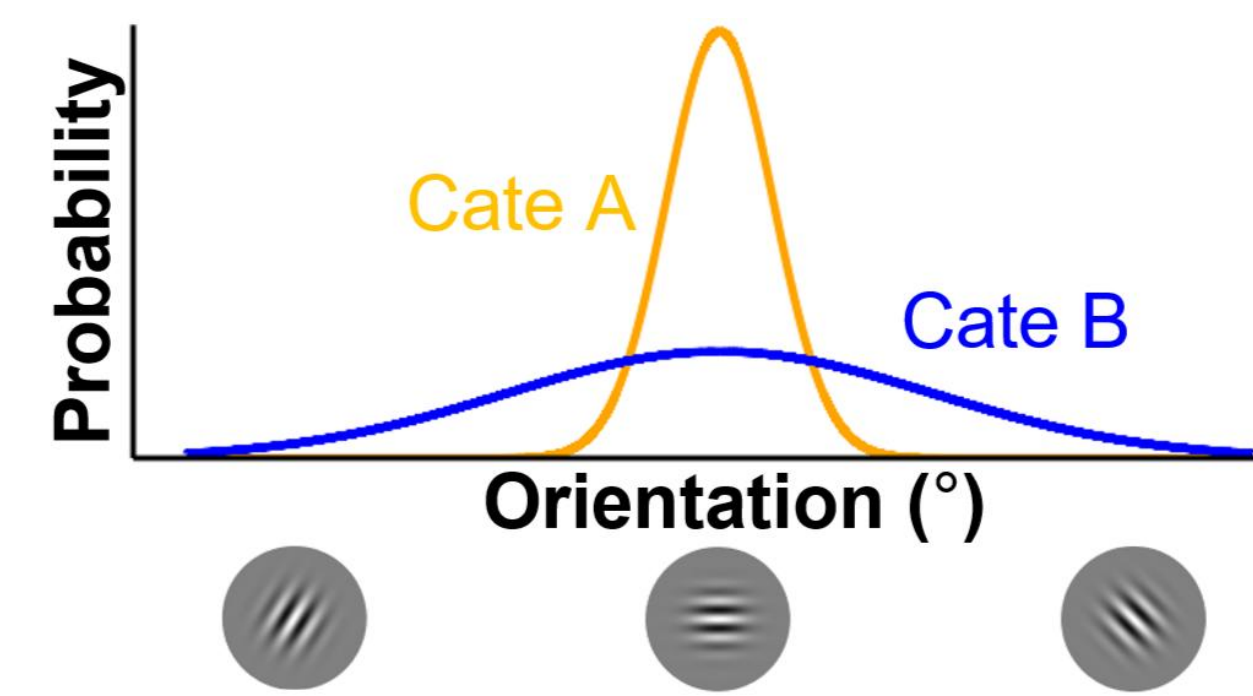
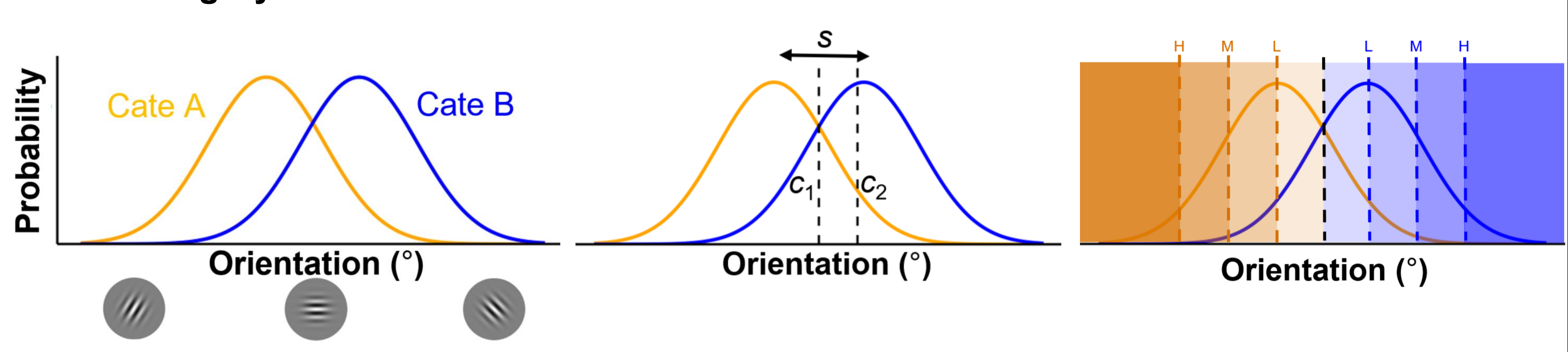
Category distributions



First-order decision



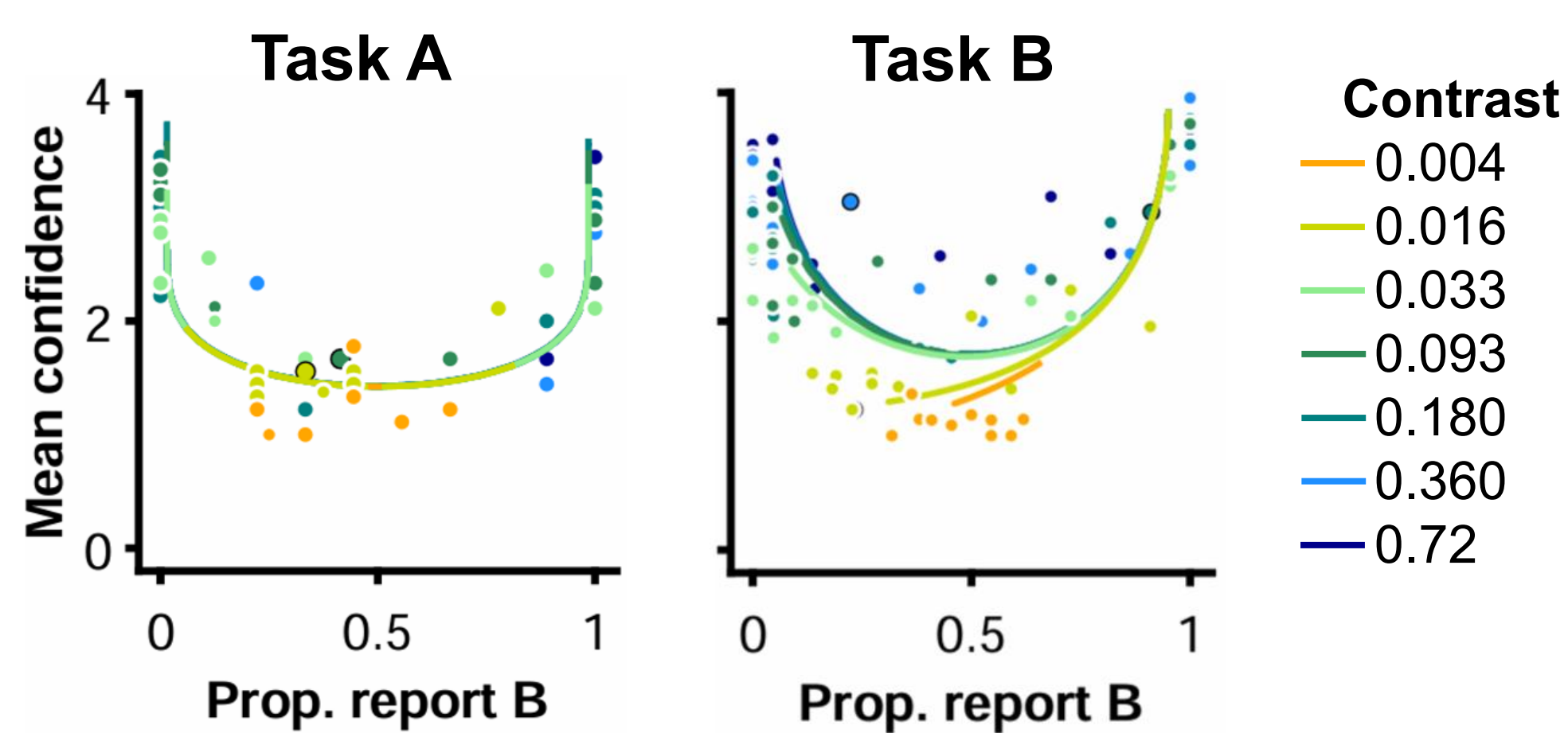
Second-order decision



Meta-uncertainty model

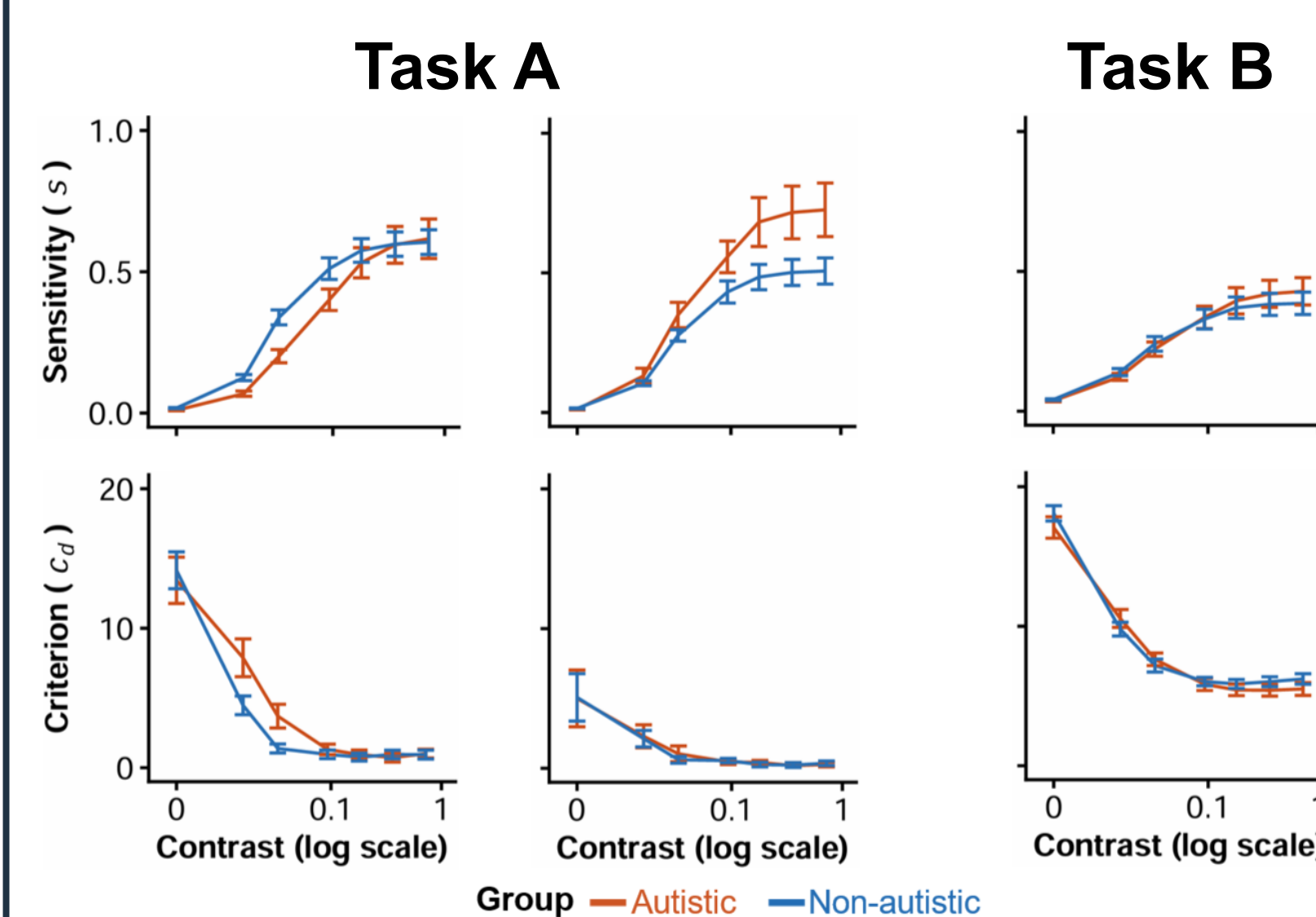
= Computational model, which quantifies the noise corrupting internal estimates of uncertainty⁴.

Meta-uncertainty (σ_m) = consistency with which internal decision uncertainty—arising from evaluating sensory noise—is mapped onto confidence reports across trials.

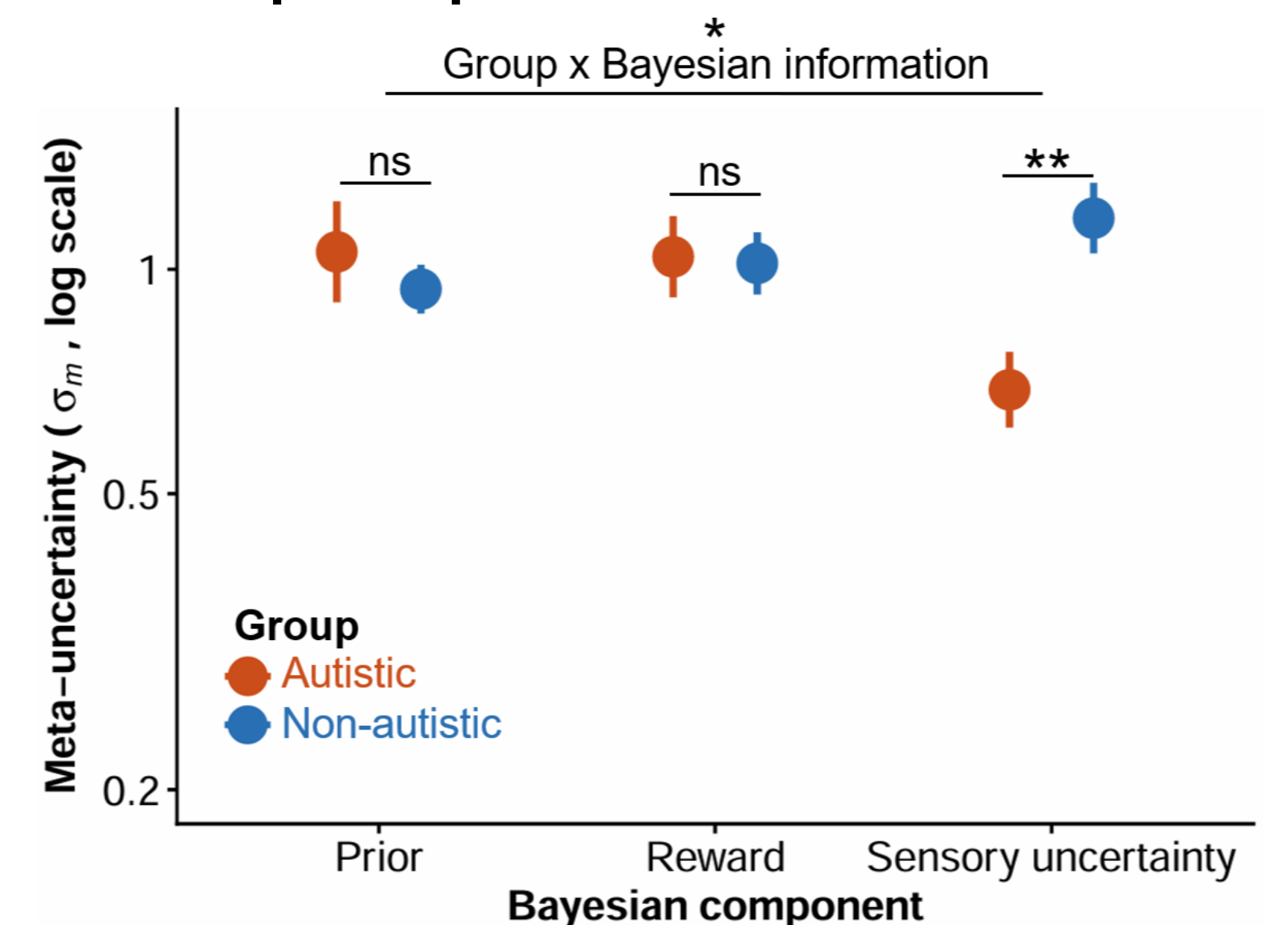


Results

Autistic and non-autistic participants performed the first-order task similarly, as they exhibited similar sensitivity and decision criterion when integrating each Bayesian component.



Autistic participants exhibit enhanced performance when perceptual decisions rely solely on sensory information, relative to non-autistic participants.



Discussion

- While non-autistic individuals demonstrate stable metacognitive abilities across tasks (domain general capacities), **autistics' metacognitive abilities are context-dependent**.
- Autistic individuals show qualitative differences in perceptual metacognitive abilities, rather than generally reduced abilities. In particular, they show **enhanced ability when assessing decisions that rely solely on sensory evidence**.
- These findings suggest that reports of enhanced perception in autism may reflect differences at higher-order stages of processing, rather than improvements in basic perceptual discrimination.
- A bias toward sensory information at a higher-order level of decisions can potentially explain hyper- and hypo-reactivity to sensory information.

References

- Flavell, J. H. (1979). Metacognition and cognitive monitoring: A new area of cognitive–developmental inquiry. *American psychologist*, 34(10), 906.
- Lee, D. G., & Hare, T. A. (2023). Value certainty and choice confidence are multidimensional constructs that guide decision-making. *Cognitive, Affective, & Behavioral Neuroscience*, 23(3), 503-521.
- Carpenter, K. L., & Williams, D. M. (2023). A meta-analysis and critical review of metacognitive accuracy in autism. *Autism*, 27(2), 512-525.
- Boudy-Singer, Z. M., Ziemba, C. M., & Goris, R. L. (2023). Confidence reflects a noisy decision reliability estimate. *Nature Human Behaviour*, 7(1), 142-154.