Confidence responses in global motion discrimination task are well predicted by visual reliability

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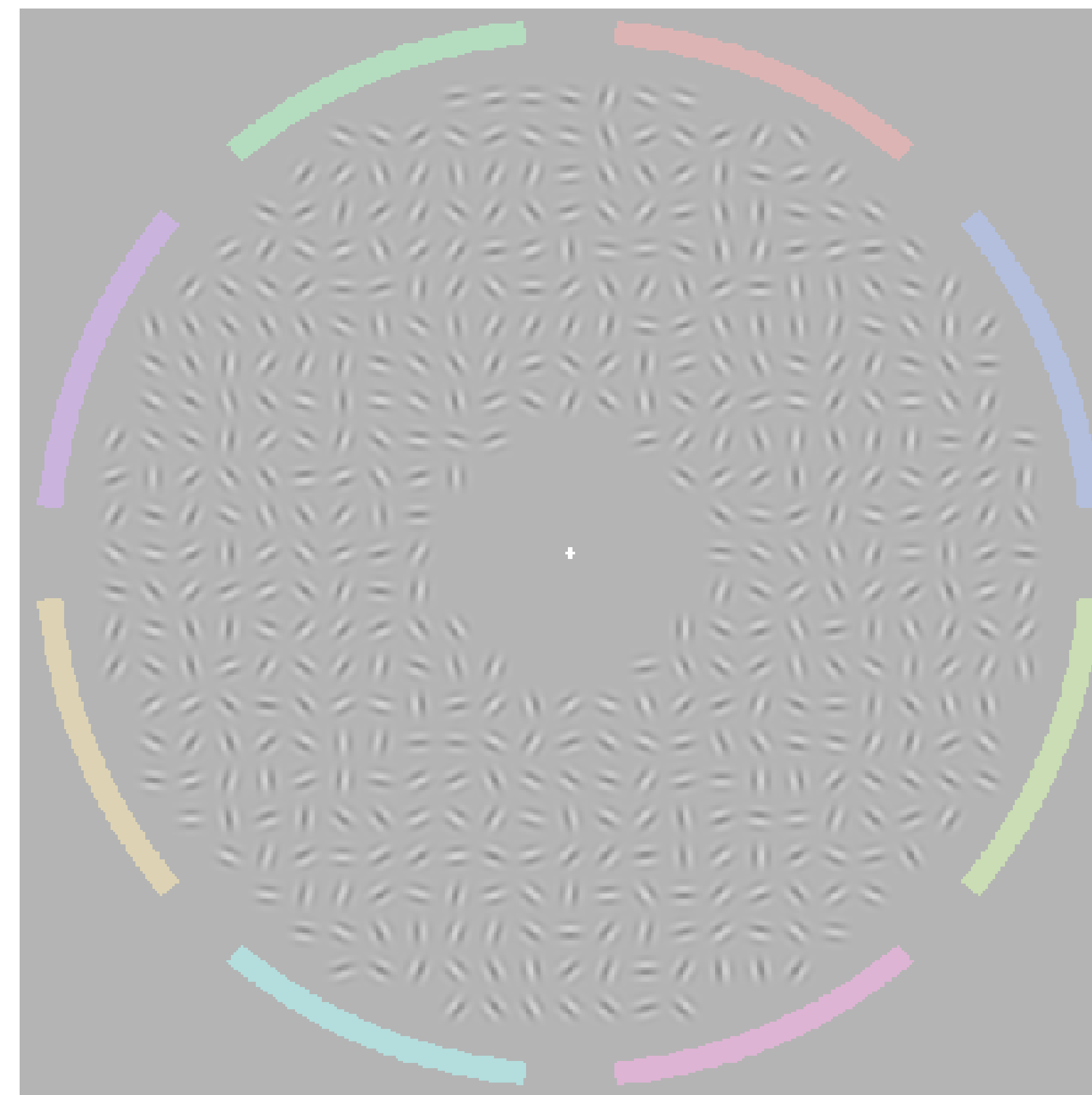
Motivation

Humans can be very accurate in estimating their own performance on simple perceptual decisions about a single sensory feature.

Understanding the mechanisms of confidence formation in a global motion direction discrimination task requiring the integration across a large number of local motions

Stimuli and Task
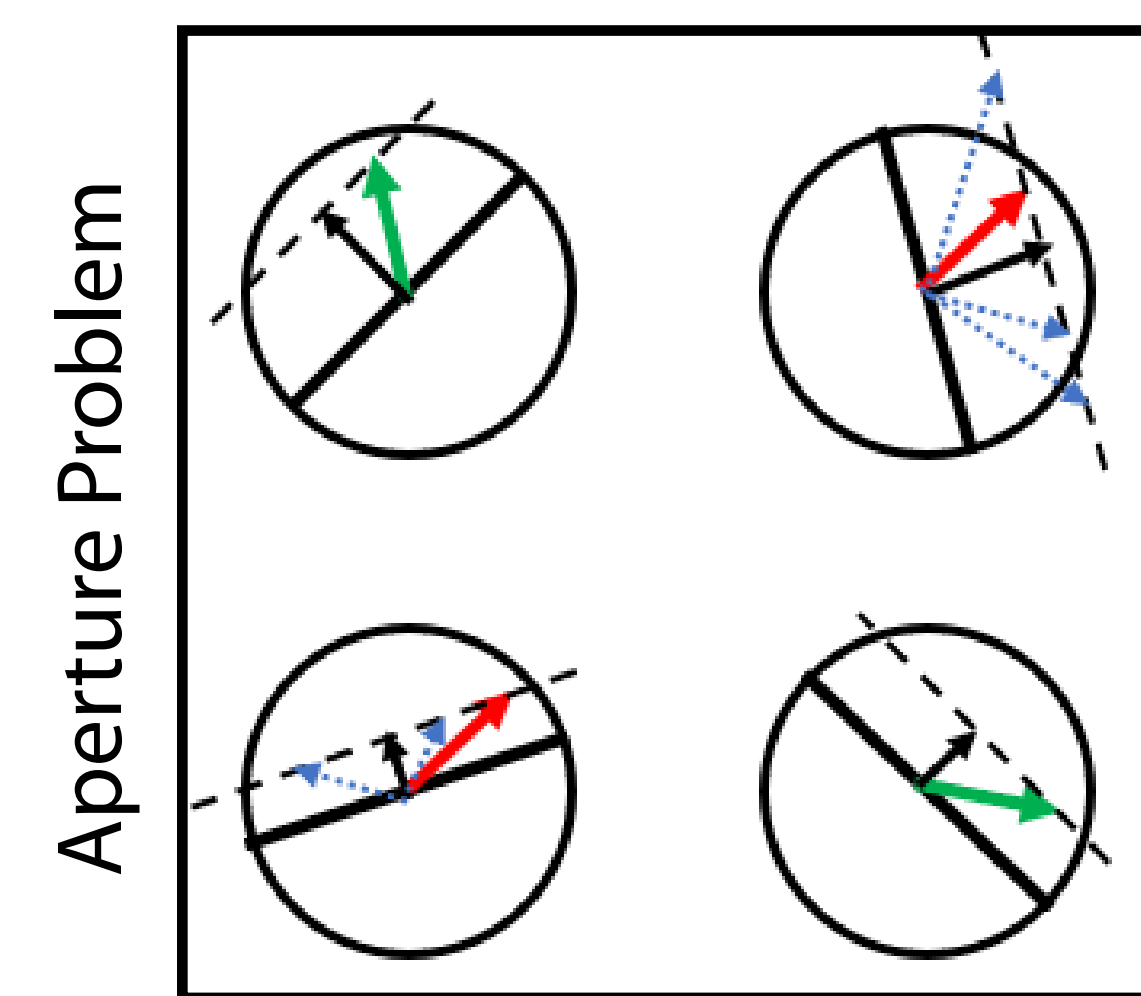

Drifting Gabors Stimuli (Amano et al., 2009, JoV)

16° diameter stimuli (4° diameter blank)

468 drifting Gabors of identical:
-size (0.5° diameter),
-spatial frequency (4 cpd),
-contrast (0.4 Michelson),

- phase and orientation independently randomly sampled every trial.
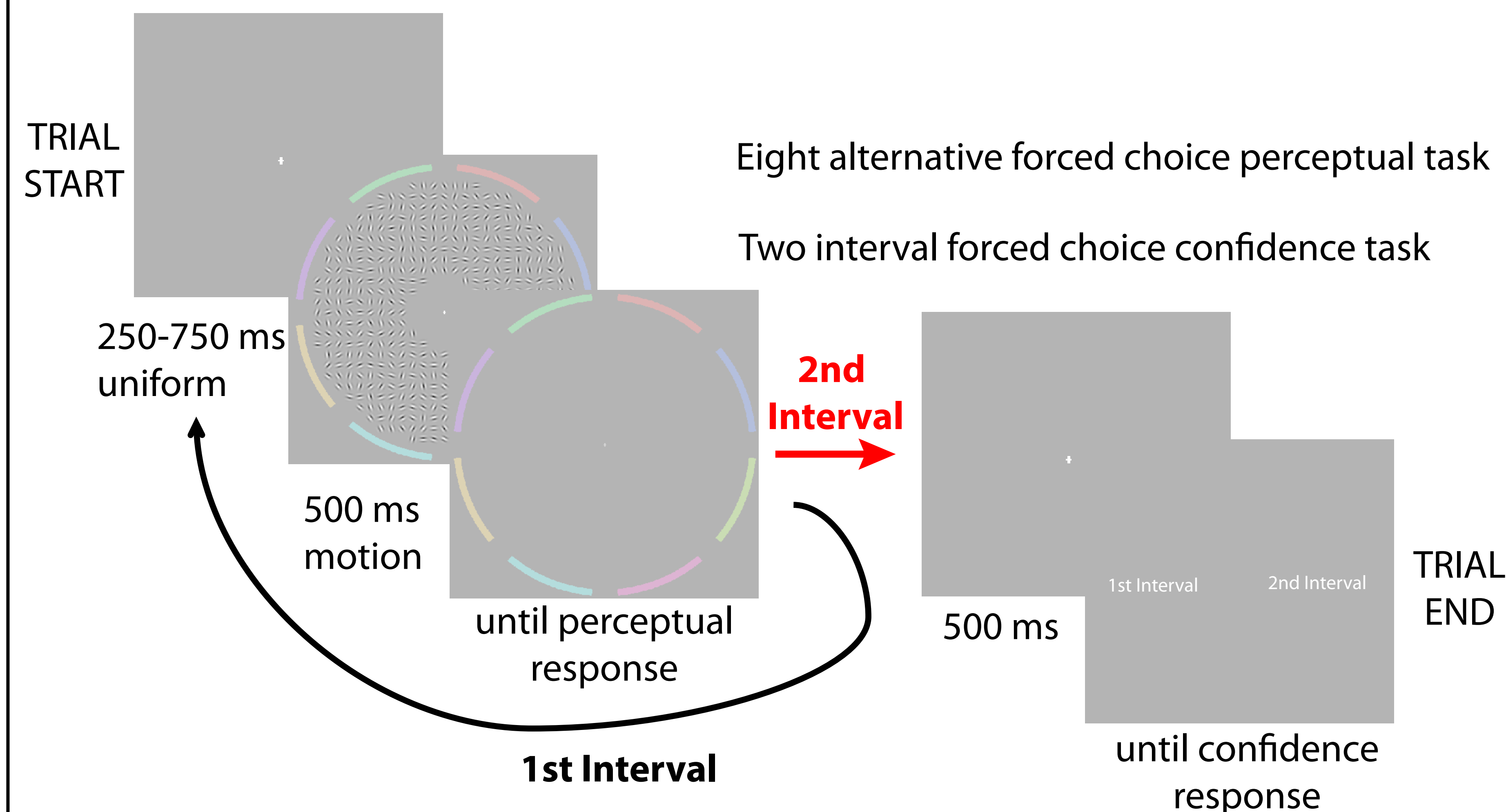
Global motion speed: 0.5° per second

8 possible directions of global motion (2D)

4 Coherence levels: 0.3, 0.5, 0.7 and 0.9
(fraction of Gabor patches consistent with global motion)

Random direction global motion with same speed
Local (1D) motion
Alternative global motions (2D)

Aperture Problem

• Perceived local motion in isolation is most of the time different than global motion.

TRIAL START

250-750 ms uniform

500 ms motion

until perceptual response

1st Interval

2nd Interval

500 ms

until confidence response

TRIAL END

Eight alternative forced choice perceptual task
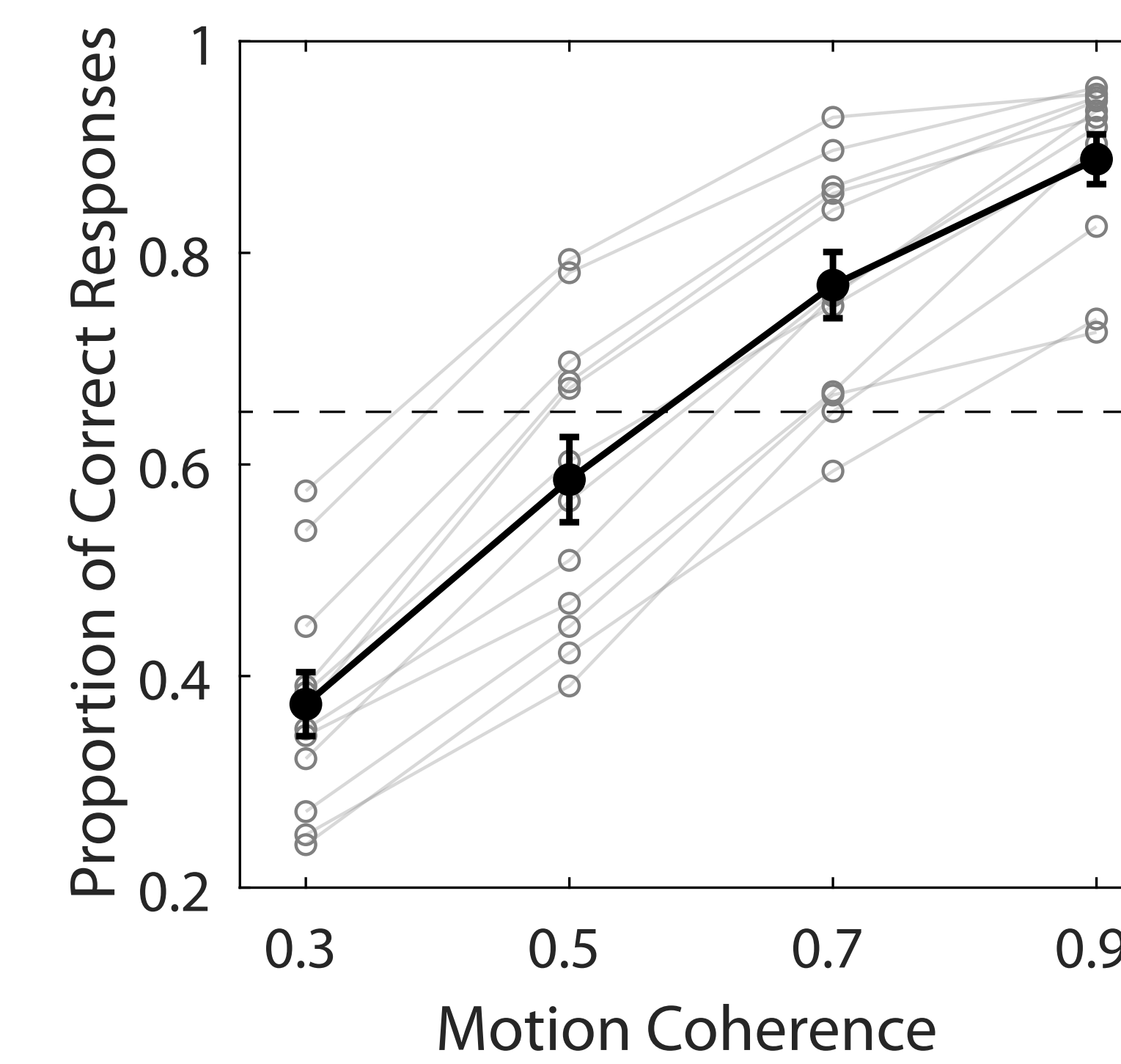
Two interval forced choice confidence task
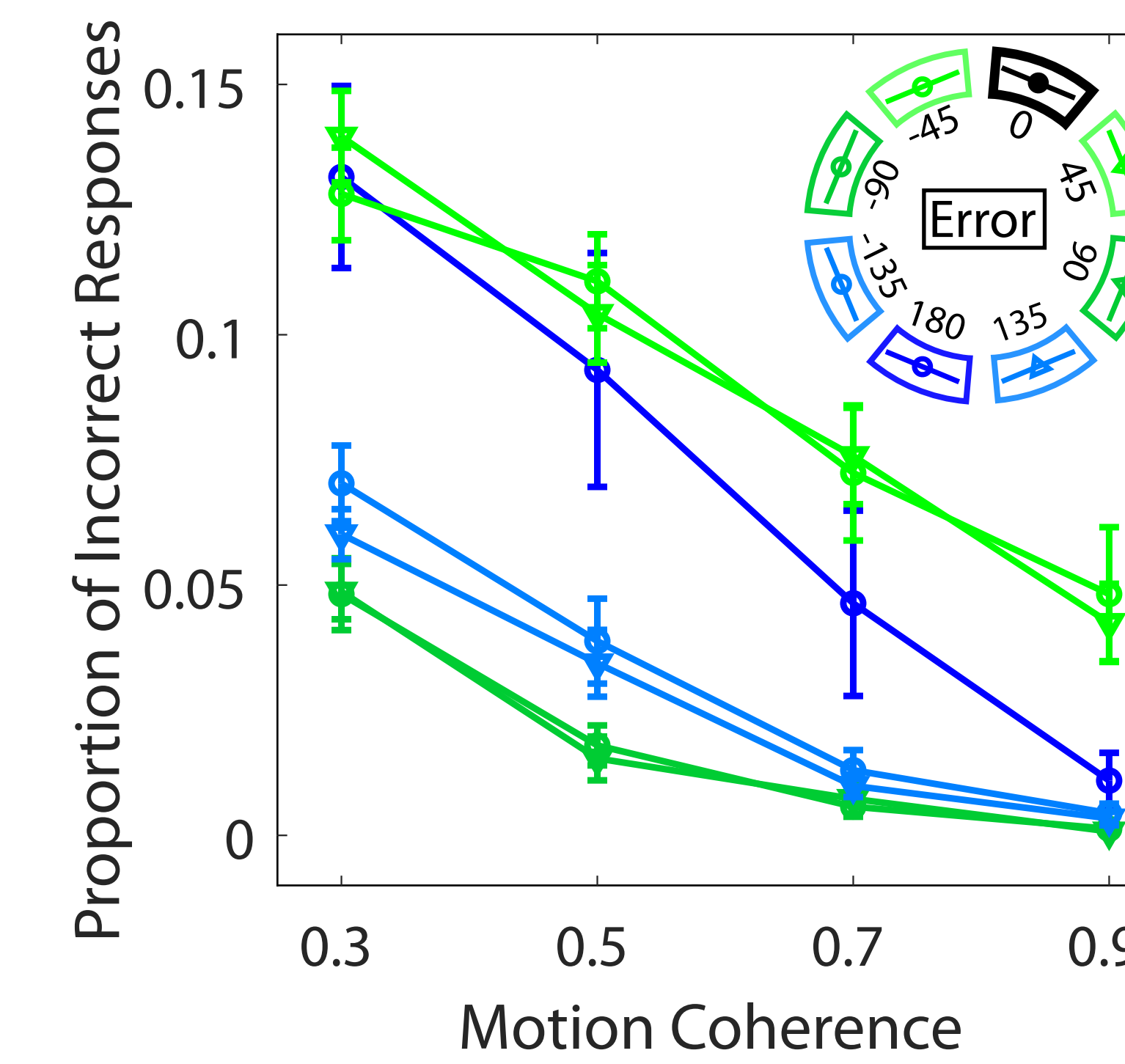
12 Participants, 7680 trials

No systematic bias for direction or interval but high individual variability in performance

Experimental Results
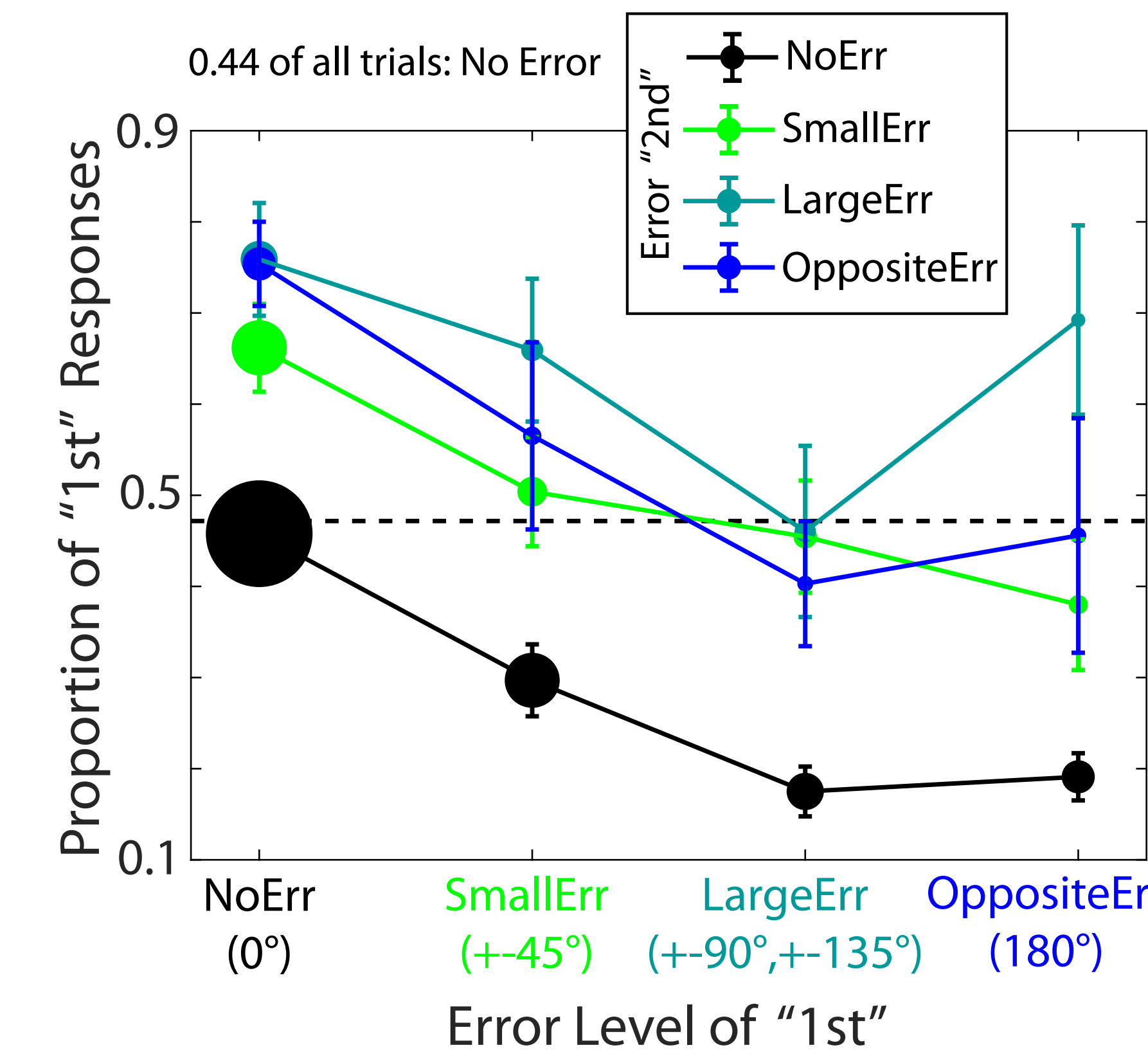
Perceptual Responses (Type-1)


• Performance increases with motion coherence

• Opposite-direction effect

Confidence Responses (Type-2)

0.44 of all trials: No Error

Error "2nd": NoErr, SmallErr, LargeErr, OppositeErr

Error Level of "1st": NoErr (0°), SmallErr (+-45°), LargeErr (+90°,+-135°), OppositeErr (180°)

Coh. "2nd": 0.9, 0.7, 0.5, 0.3

• Successful confidence judgments tied to perceptual performance

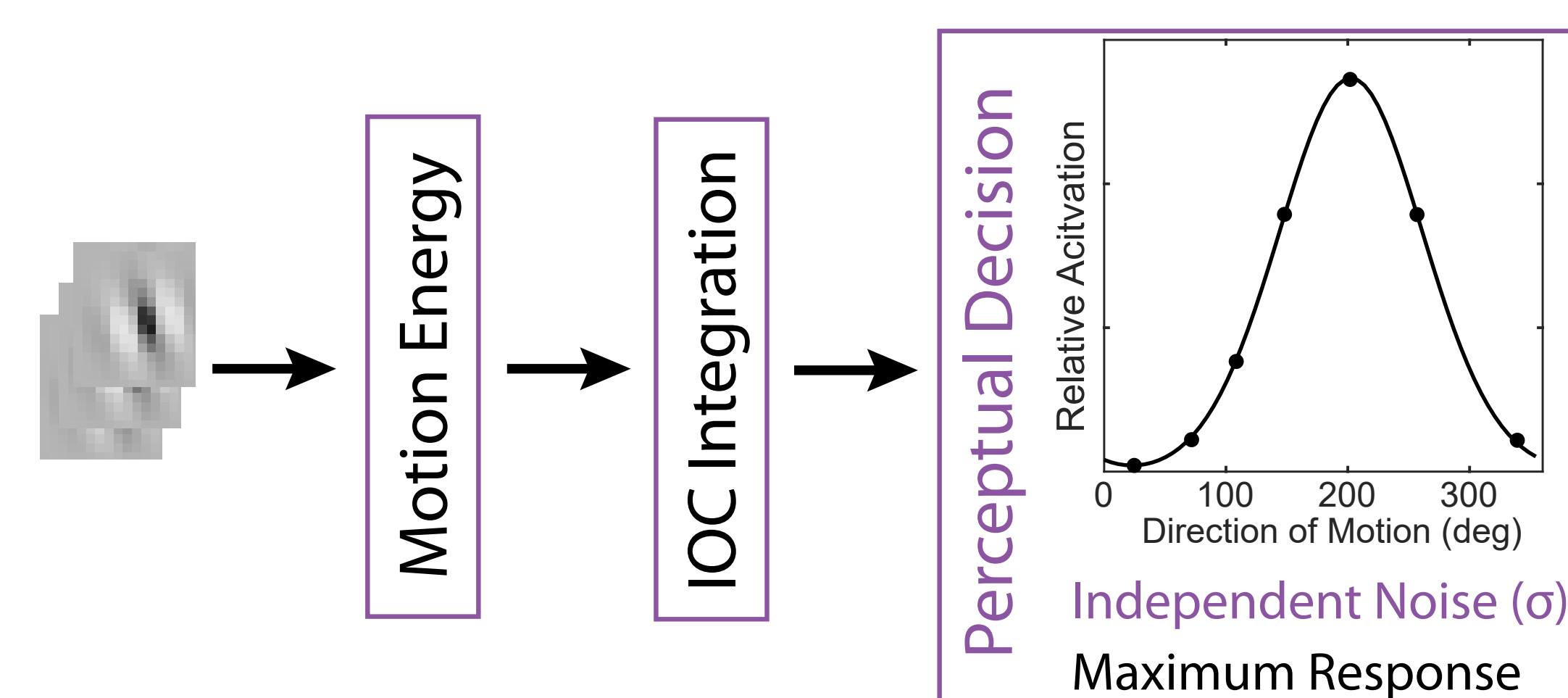• Opposite-direction effect in confidence
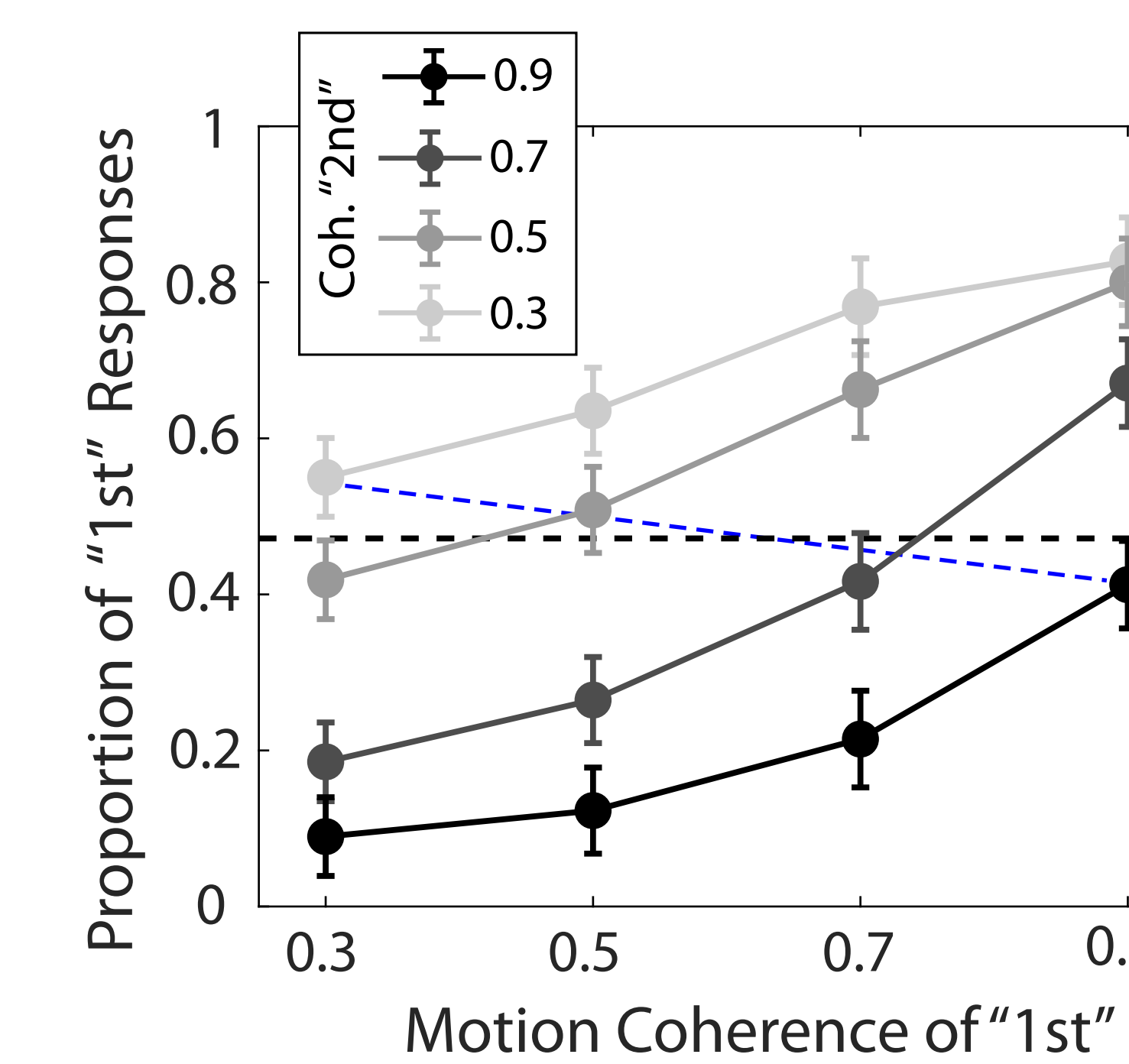
• Successful confidence judgments tied to motion coherence
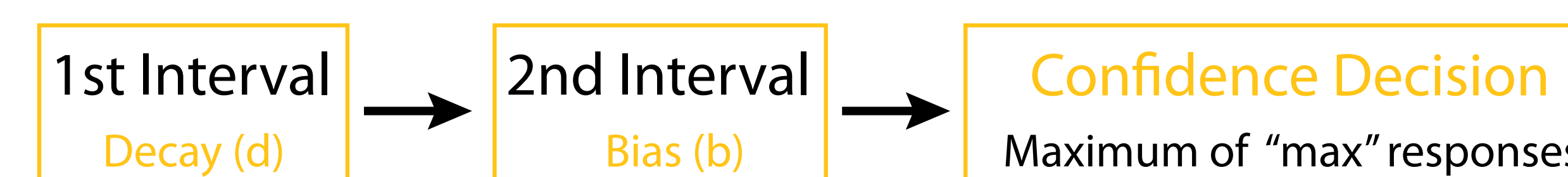
• Decay Bias (Raviv et al., 2012)

Modeling Methods

• A computational model that combines a standard model with two plausible mechanisms

The Standard Motion Energy Model with IOC Integration

Motion Energy → IOC Integration → Perceptual Decision

Independent Noise (σ)
Maximum Response

Model is similar to:
Simoncelli & Heeger, 1998;
Rust et al., 2006; Kane et al., 2011

1st Interval Decay (d) → 2nd Interval Bias (b) → Confidence Decision
Maximum of "max" responses

Addition of two plausible mechanisms

Opposite-direction effect

Strong Tuned Inhibition
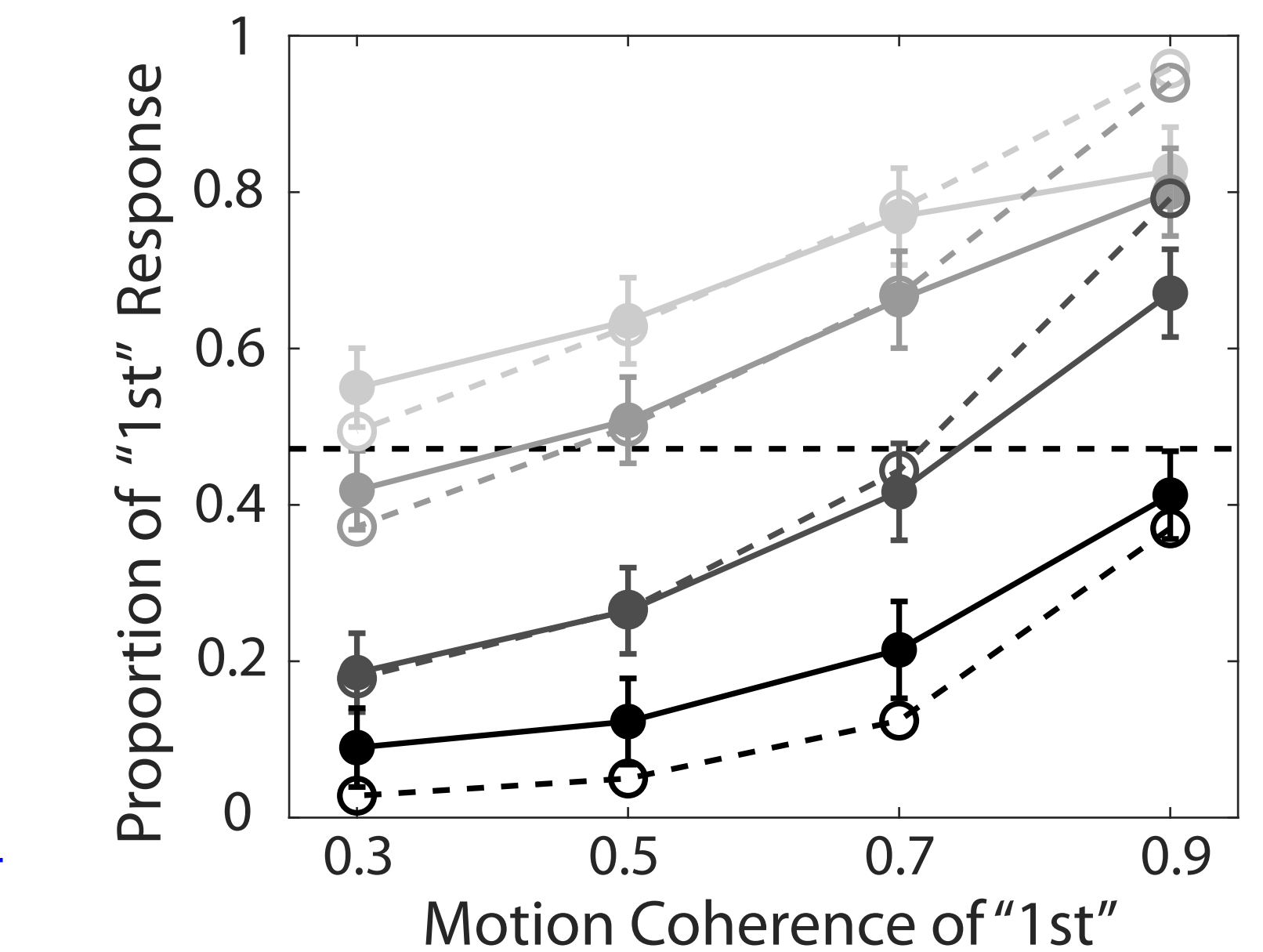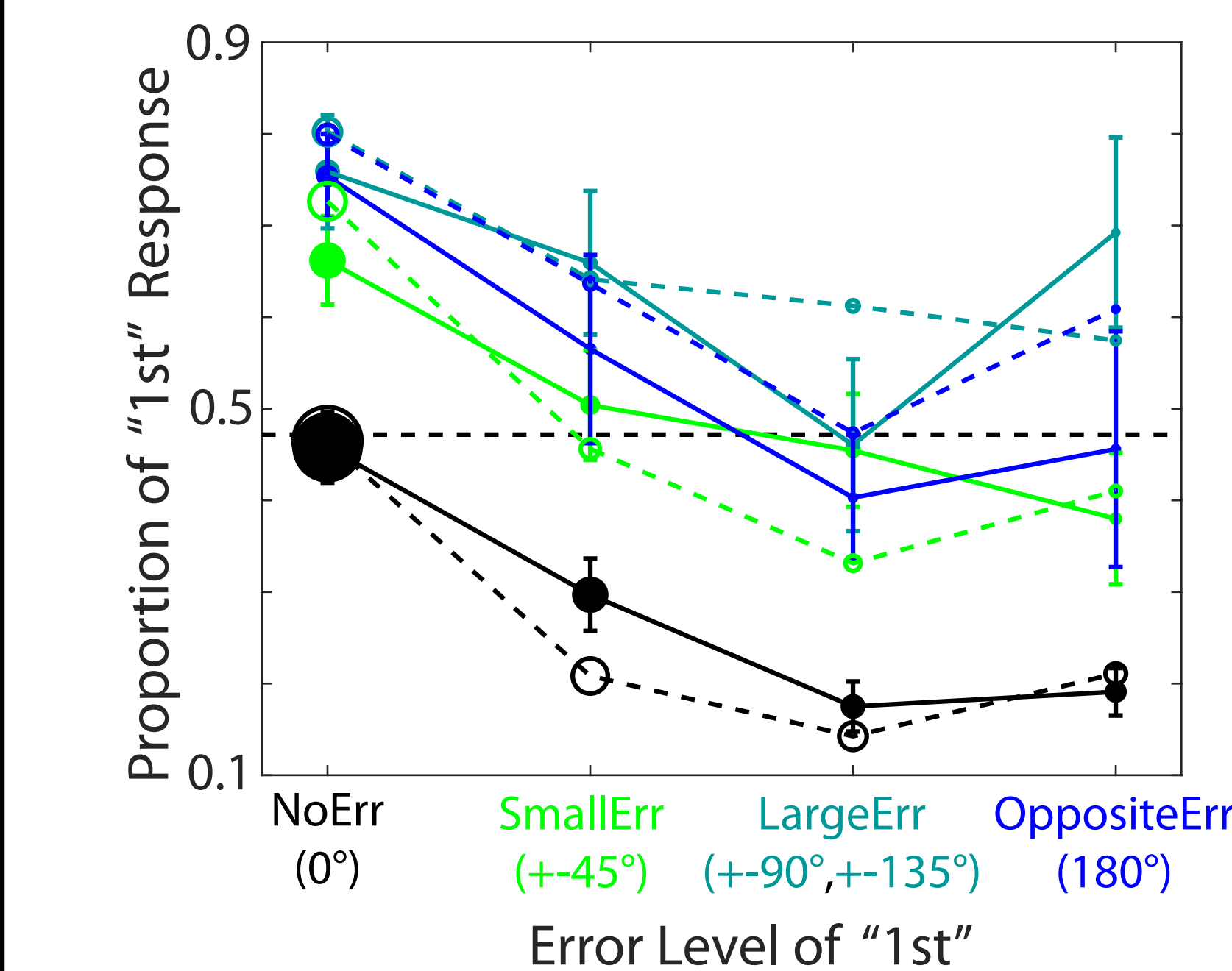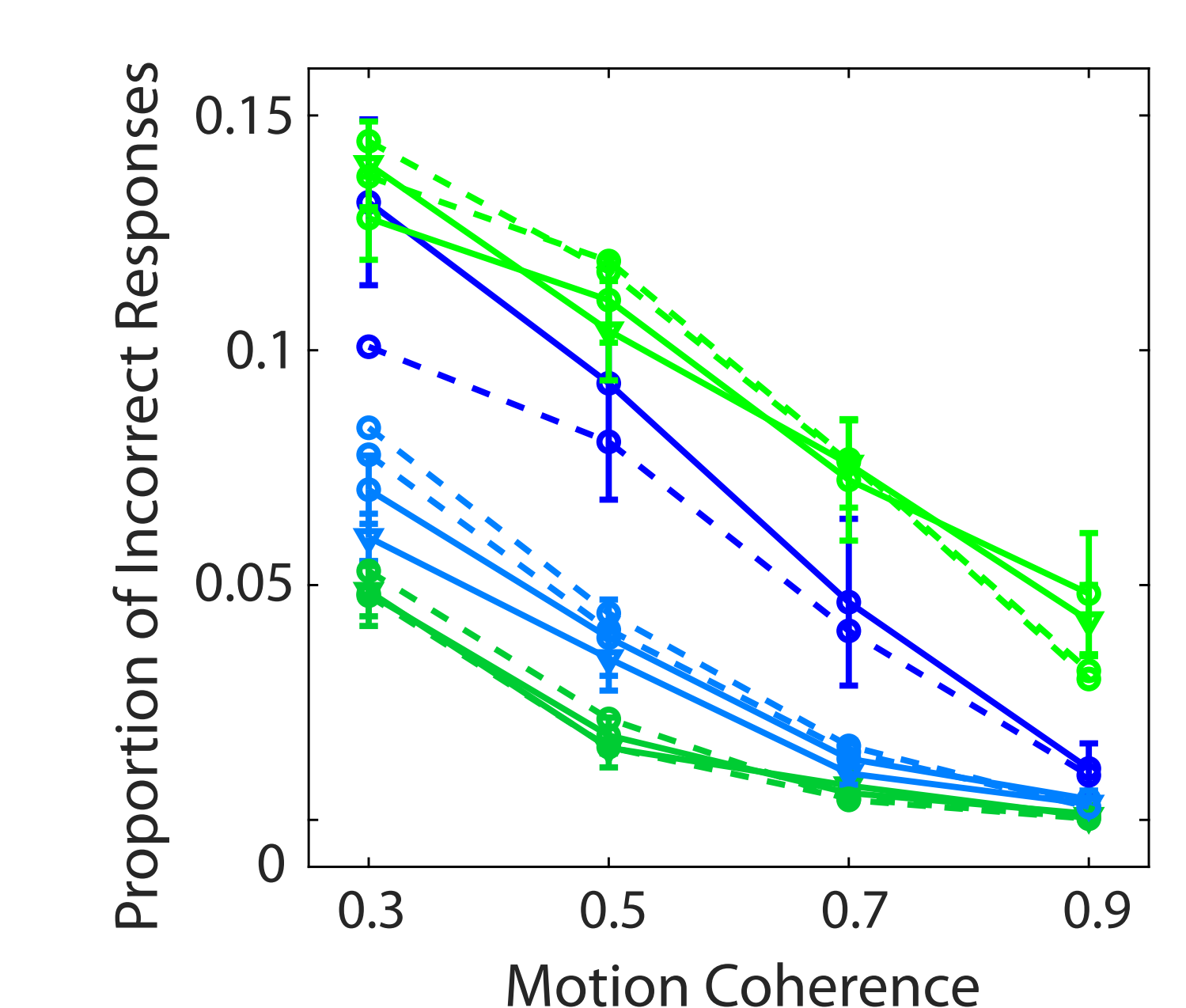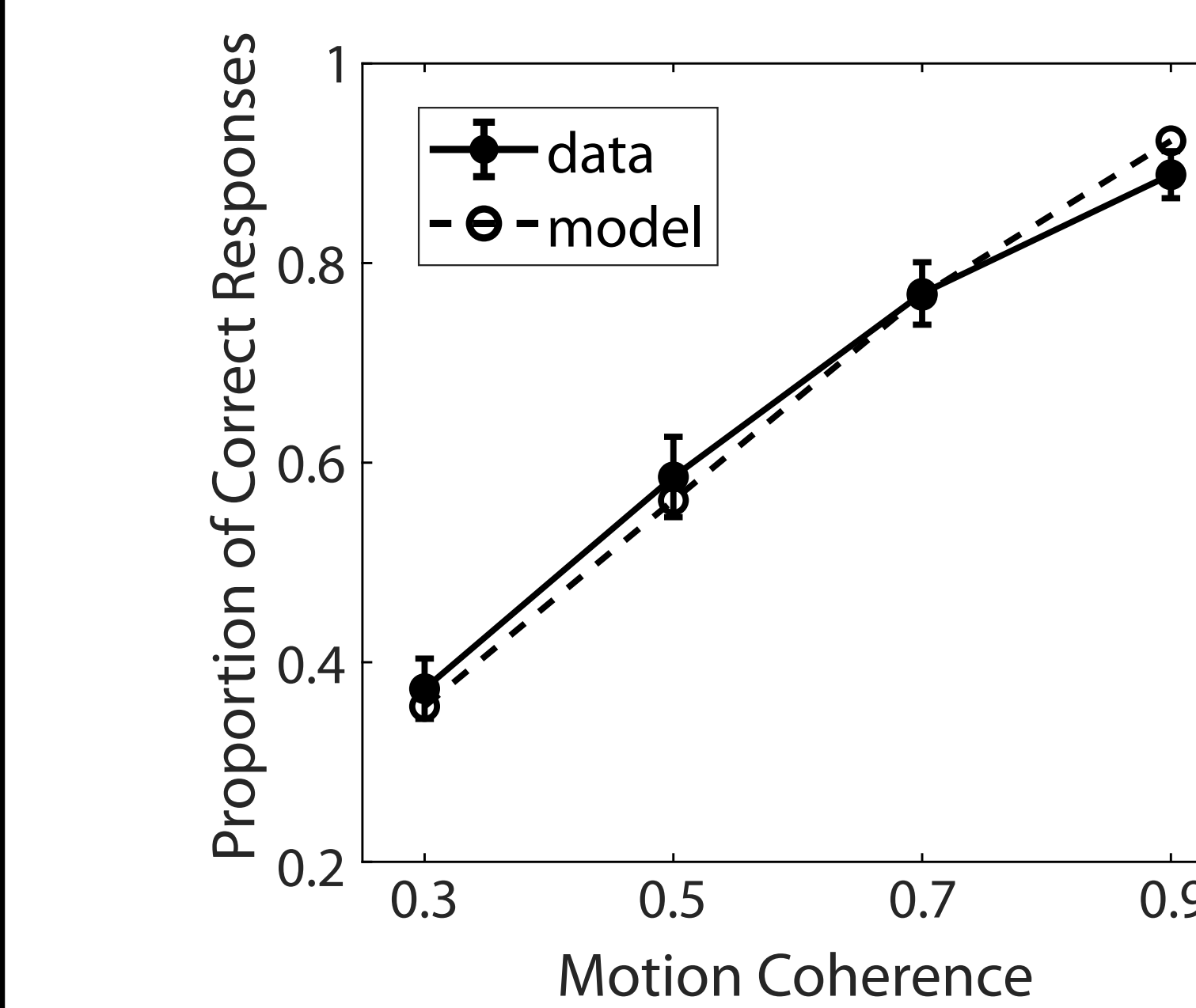width (w) , relative total inhibition (i)

Dependency between motion coherence and total response

Gain-like Untuned Inhibition
gain factor (g)

Parameters: σ,w,i (Perceptual responses), d,b,g (Confidence responses)

Modeling Results

data
model

Error Level of "1st": NoErr (0°), SmallErr (+-45°), LargeErr (+90°,+-135°), OppositeErr (180°)

• Six free parameters explain most of the variance in perceptual and confidence responses.

Conclusions

P: Opposite-direction effect (Lee et al., 2023; Bae & Luck, 2022; Mc Keown et al., 2023; Chetverikov & Jehee,2023)
Mechanisms: +strong tuned inhibition, + early motion energy, -motion streaks.

C1: Confidence responses are strongly tied to perceptual reliability and predominantly inherit characteristics from the associated visual mechanisms (e.g., Kiani & Shadlen, 2009)

C2: Importance of developing and testing image-computable models (Webb et al., 2023; Shekhar & Rahnev, 2024), especially for understanding disassociations (Koizumi et al., 2015; Spence et al., 2016; Lee et al.,2023)

fMRI experiment next!