Viewing geometry inferred from optic flow strongly biases perception of motion and depth: behavior and neural correlates

Zhe-Xin Xu Jiayi Pang Akiyuki Anzai Gregory C. DeAngelis

Dept. of Brain & Cognitive Sciences, Center for Visual Science, University of Rochester, NY, USA
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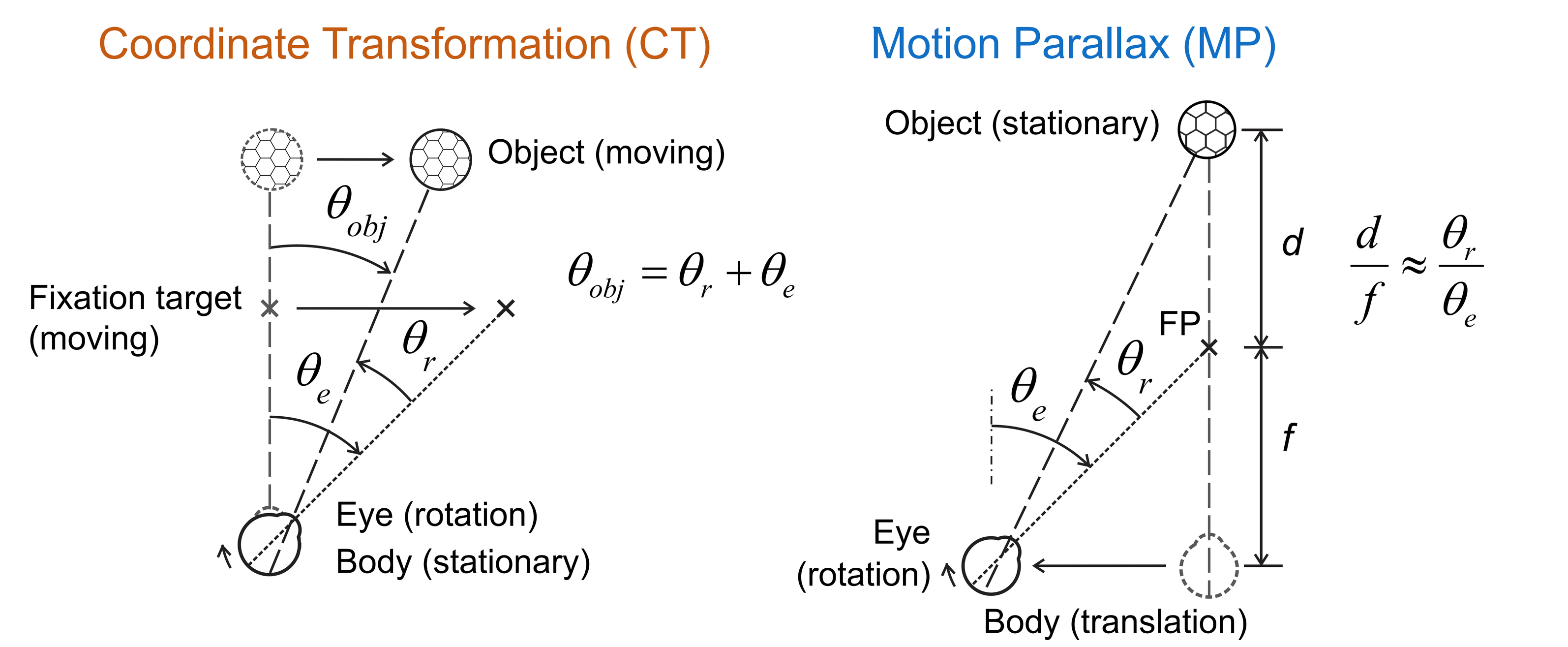
Introduction: 3D Viewing Geometries

During active movements, perceiving **motion and depth** of an object requires compensating for self-generated image motion. Although traditionally this is thought to involve a simple vector subtraction, the exact computations depend crucially on the 3D viewing geometry. The role of 3D viewing geometry is examined in the context of two well-known computations:

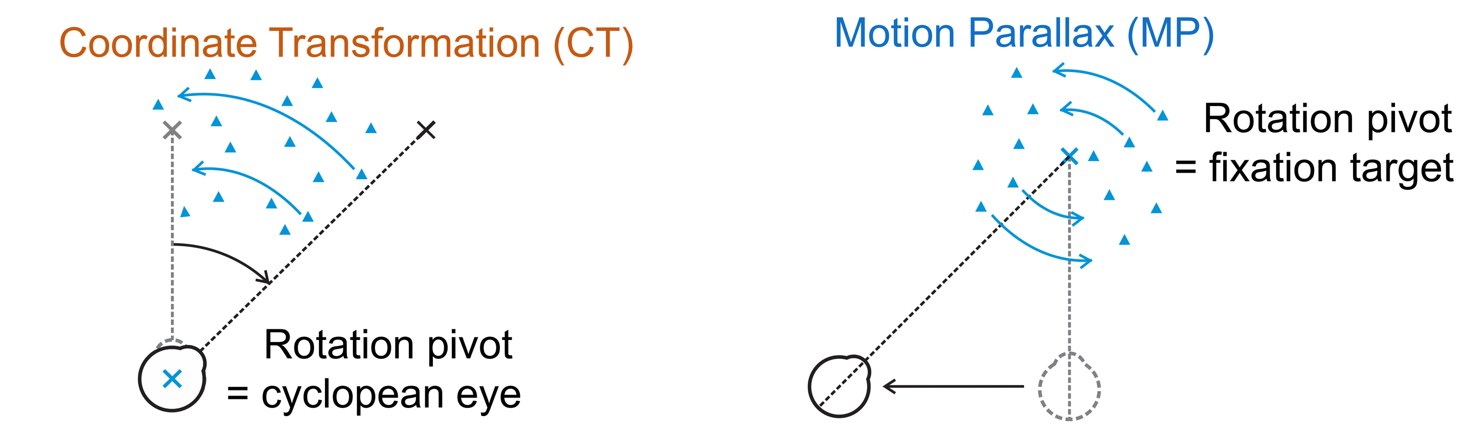
Coordinate Transformation (CT): A stationary observer rotates their eye to follow a target ('x'), while another object moves independently in the world. The retinal image velocity of the object is a combination of eye velocity and object motion in the world. Object **motion** in world coordinates is given by the **sum** of retinal and eye velocities[1-3]

Depth from Motion Parallax (MP): An observer translates laterally and counter-rotates their eye to maintain fixation on a stationary target ('x'), while the image of a stationary object at certain distance moves on the retina, providing motion parallax cues to its depth. The object's relative **depth** is proportional to the **ratio** of retinal and eye velocities[4]



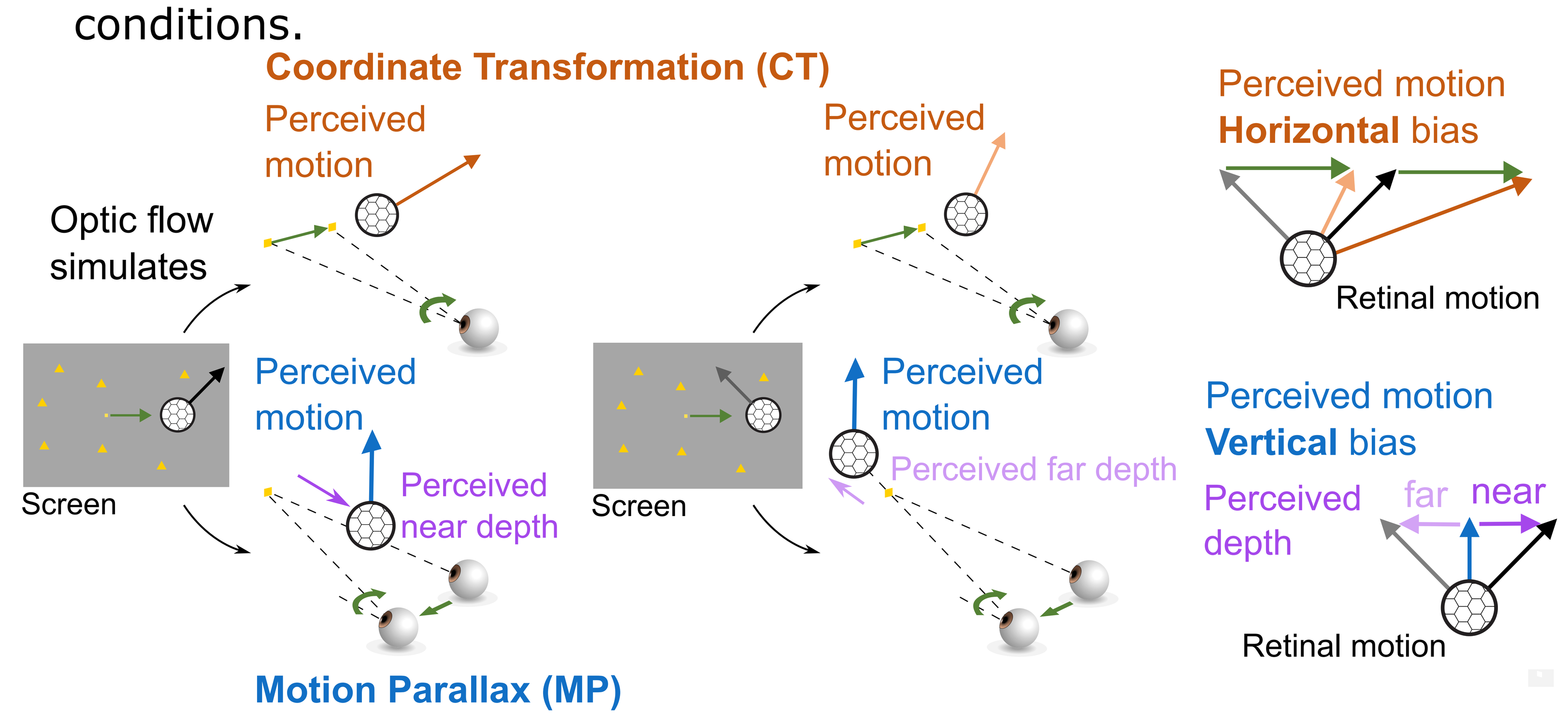
Hypothesis: The Role of Optic Flow

Distinct optic flow patterns are produced in CT and MP viewing geometries. Do humans use optic flow to infer the viewing geometry and compute motion and depth accordingly?

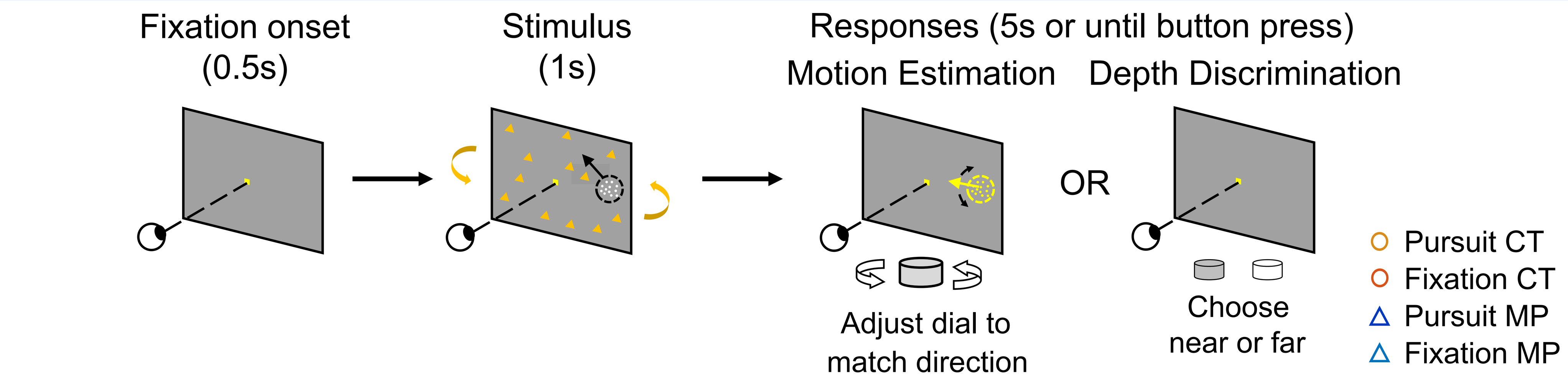


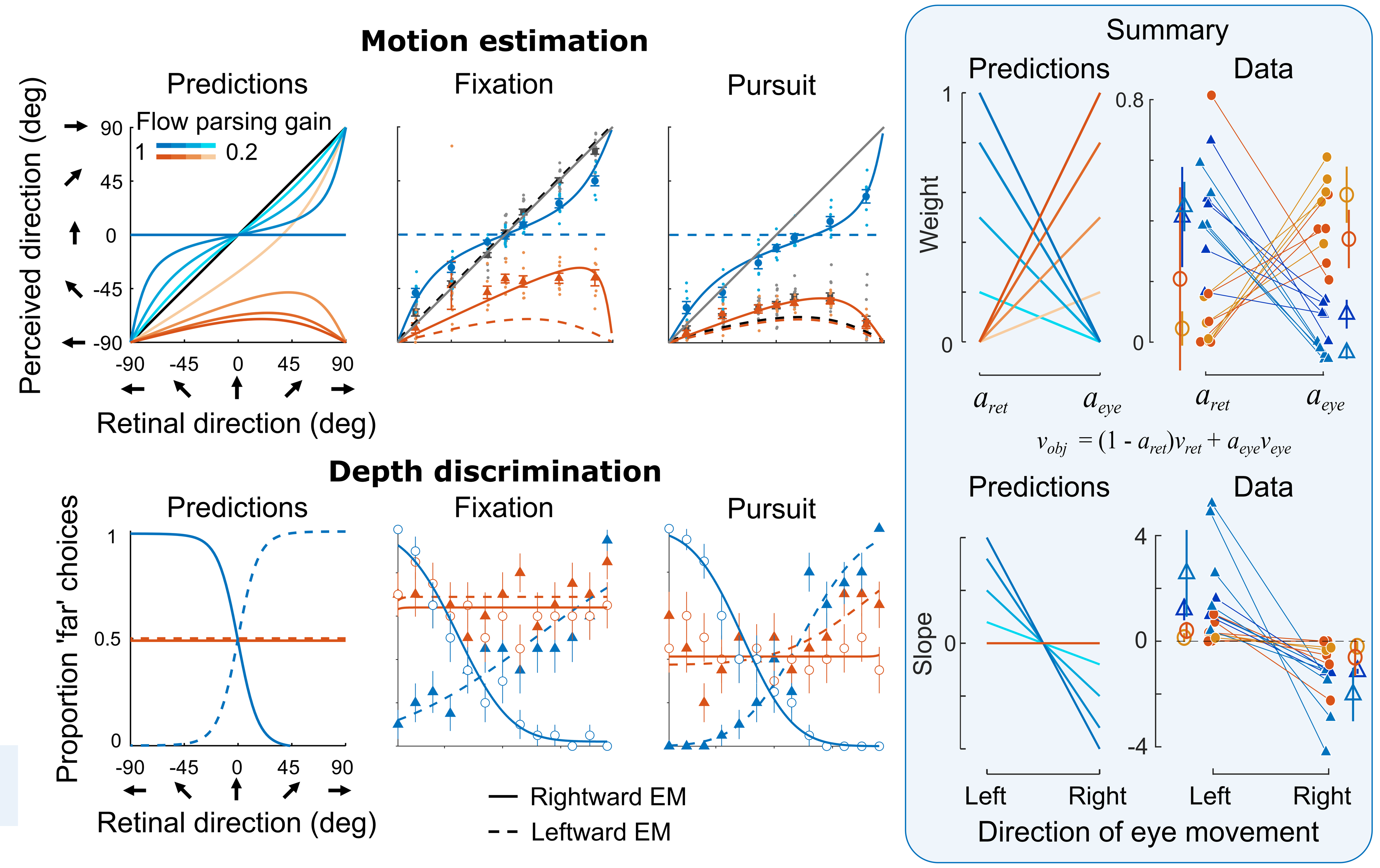
Experimental Design

Retinal motion and eye movement are identical in the CT and MP conditions, while background optic flow simulates the viewing geometry. Different biases are expected between the CT and MP conditions.



Behavioral Results from Human Psychophysics

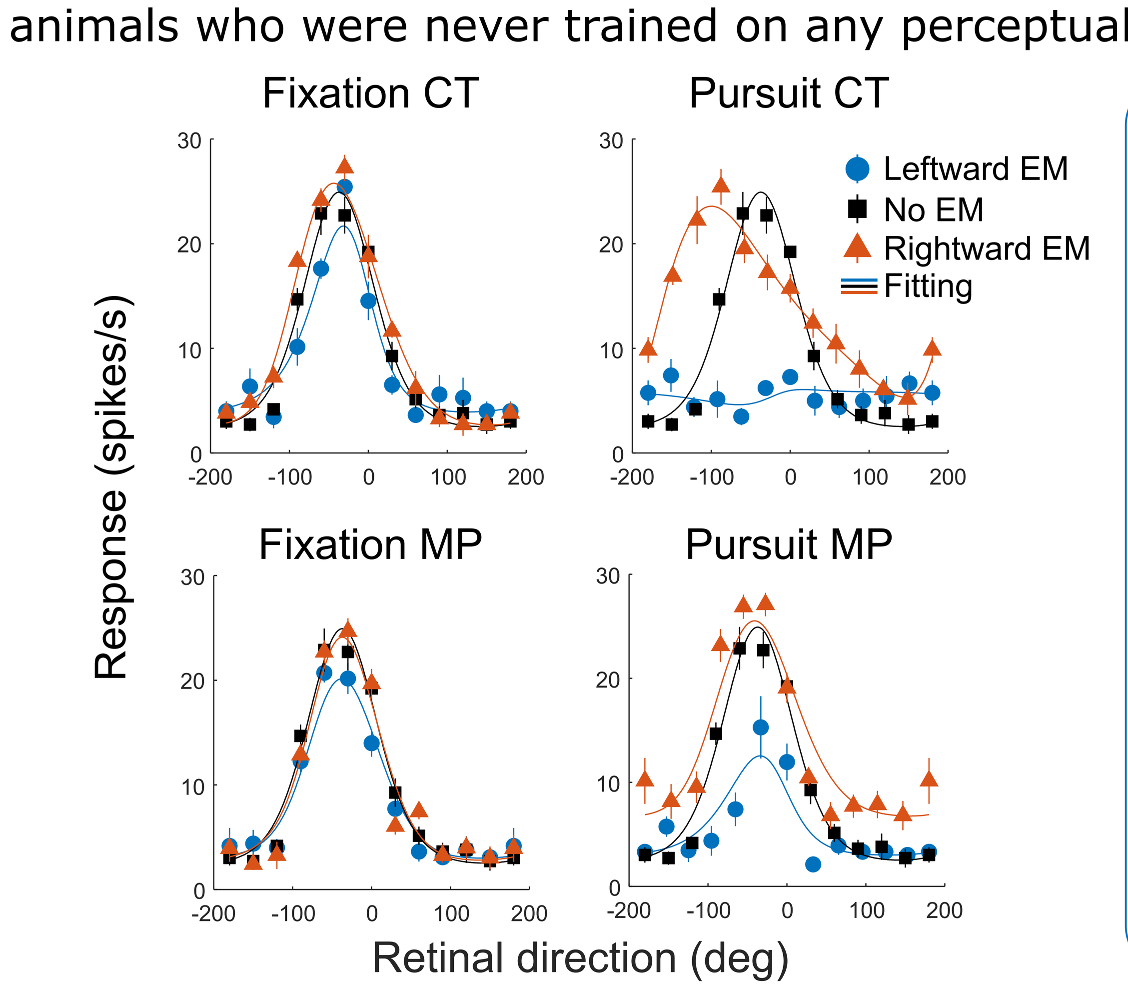


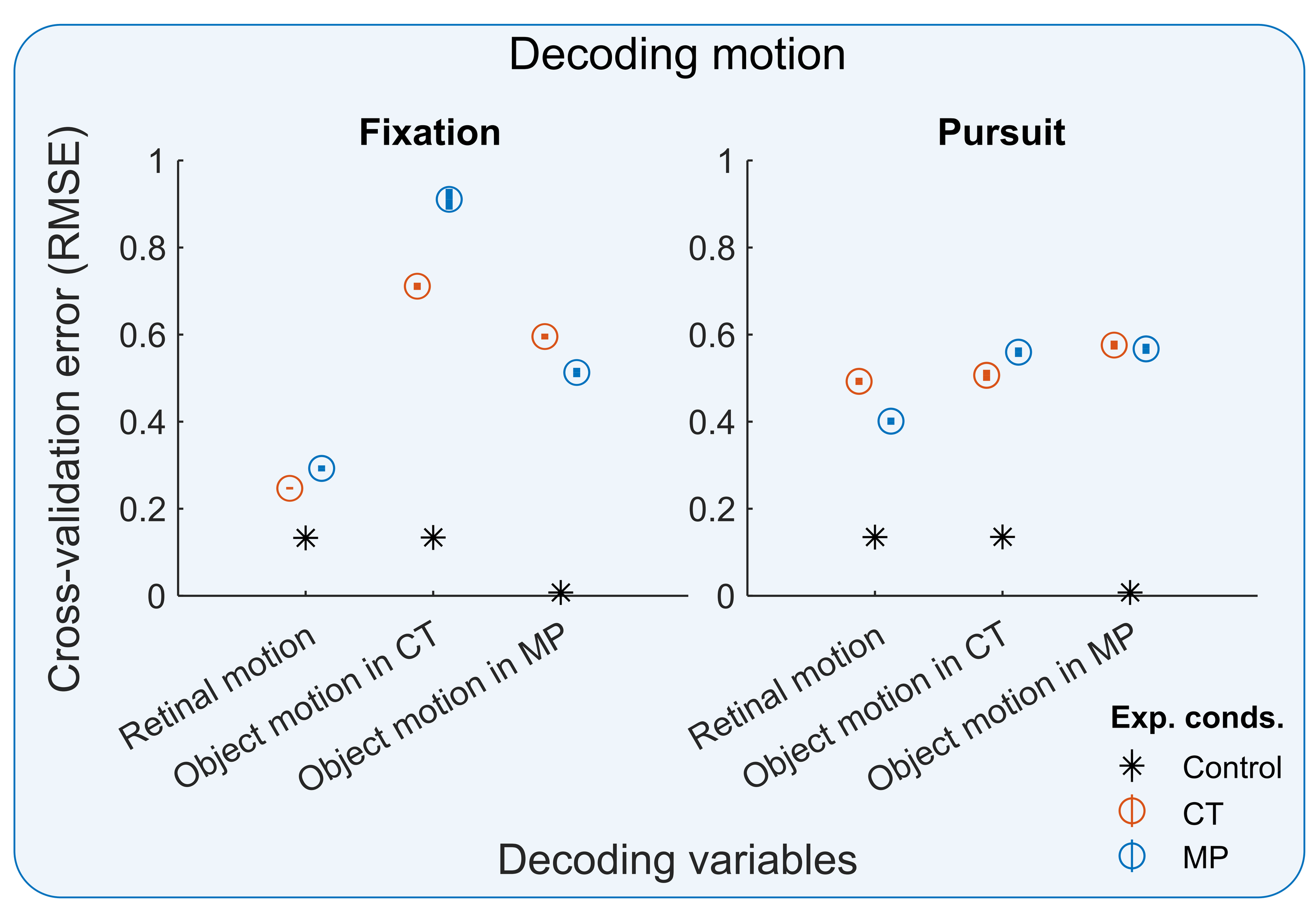


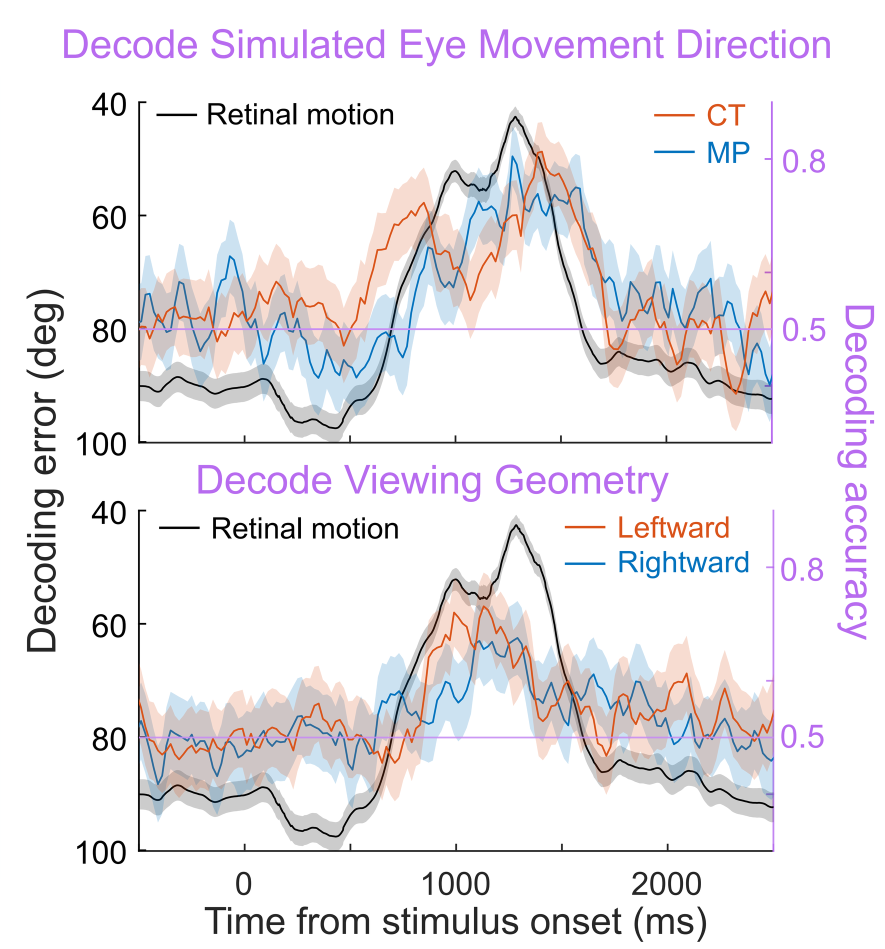
- Opposite direction biases are observed in the CT and MP viewing geometries
- Reliable depth perception was induced only in the MP viewing geometry
- Humans automatically perform distinct motion and depth computations, based on inferred viewing geometry, without any feedback or training

Neural Correlates in Macaque Area MT

Responses of MT neurons were recorded by 32-channel Plexon S-probes while macaques viewed the visual stimuli used in the psychophysics. Two animals who were never trained on any perceptual decision-making tasks participated in the study. In total, 252 units were recorded across 22 sessions.







- Viewing geometry modulates neural tuning and the population representation in MT. These modulations are flexble and depend on the simulated viewing geometry. Changes in population responses enable more accurate read-outs of the corresponding variable.

Take Home Messages

1) The interpretation of retinal image motion and pursuit eye movements depends strongly on 3D viewing geometry. Under more general conditions, compensation for putsuit eye movements is not a simple vector subtraction.

2) Humans automatically perform distinct computations of motion and depth under different viewing geometries simulated by optic flow, without any feed-back or training

3) Responses of neurons in area MT are differentially modulated by viewing geometries simulated by optic flow, supporting a role of MT in processing high-level perceptual variables, such as motion in world coordinates and depth from motion parallax

References

[1] Filehne 1922; [2] Wertheim 1987; [3] Freeman & Banks 1998 [4] Nawrot & Stroyan 2009