Heading perception depends on time-varying evolution of optic flow

Response

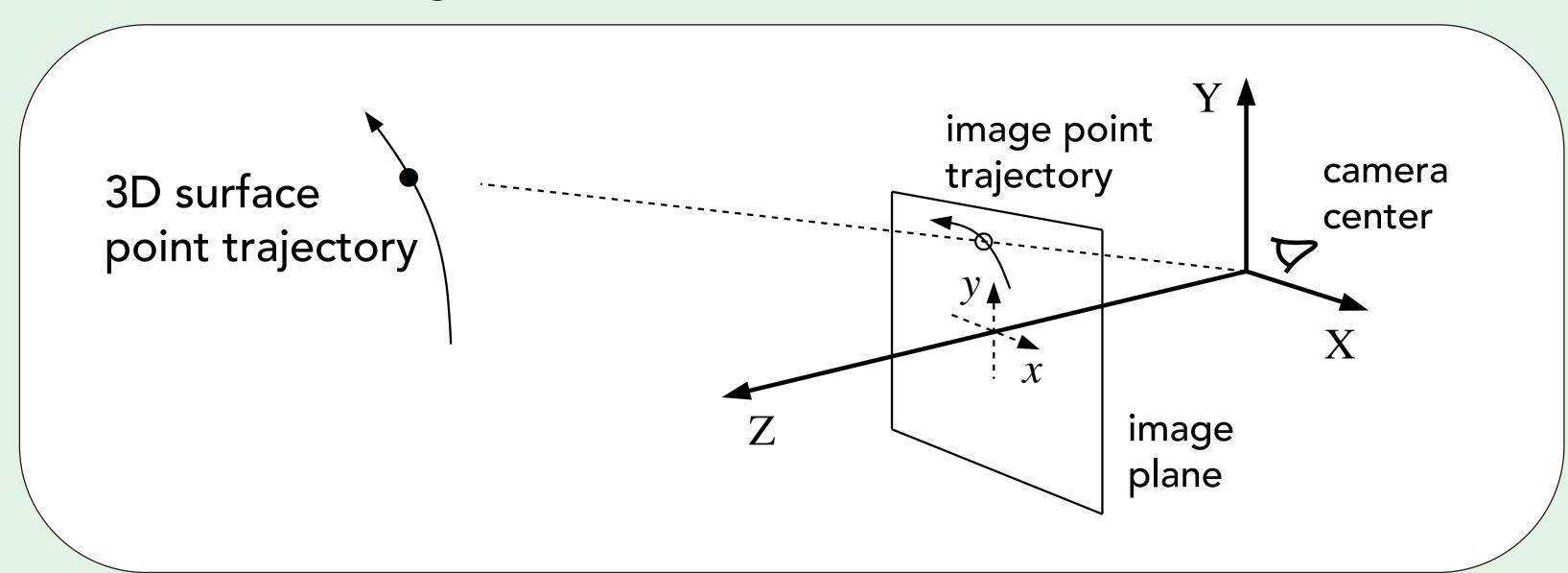
NYU | Charlie S. Burlingham^{1*} & David J. Heeger^{1,2}

1 Department of Psychology, New York University, 2 Center for Neural Science, New York University.

Aim: Is instantaneous optic flow sufficient for heading perception?

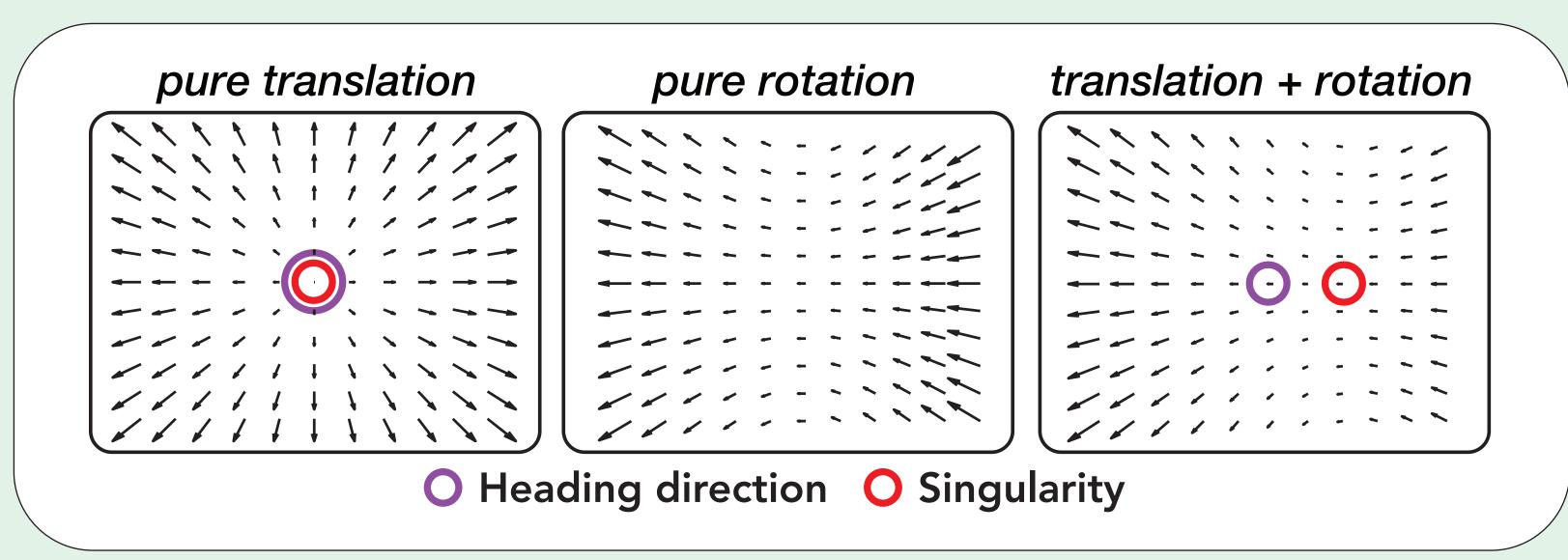
Background

• Optic flow field: retinal image motion caused by an observer's movement through their environment.



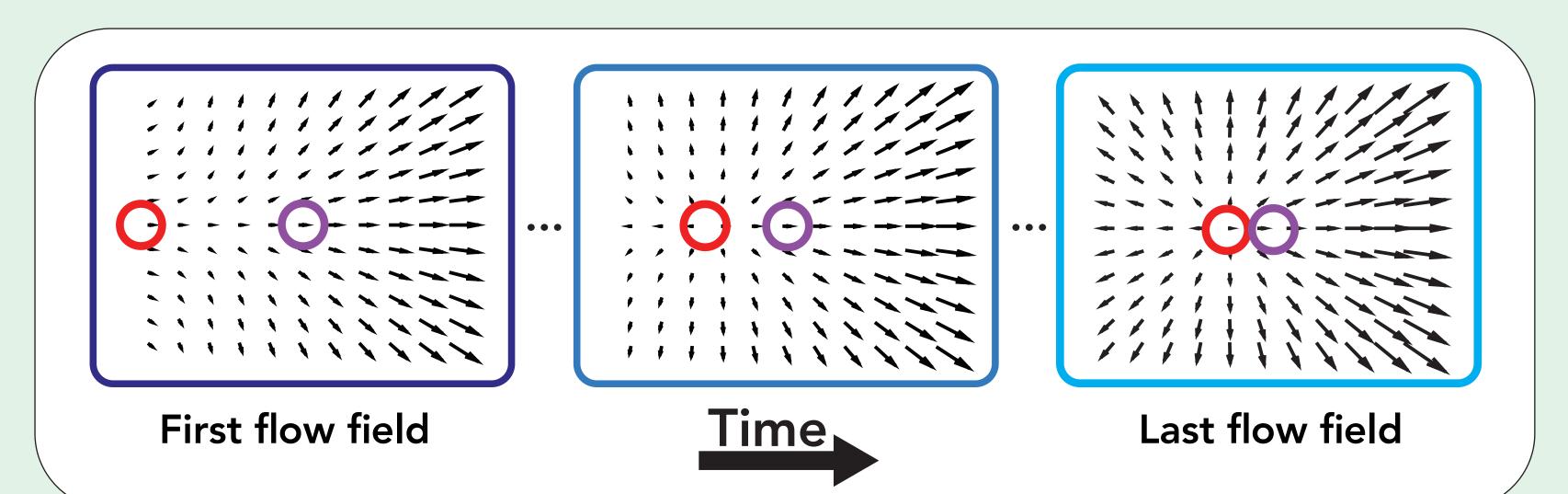
Viewer-centered coordinate frame and perspective projection

• Rotation problem: heading direction corresponds to singularity for pure translation, but not for translation + rotation.



Three cues could be used to solve the rotation problem and estimate heading:

- (1) Instantaneous optic flow
- (2) Time-varying optic flow
- (3) Image point trajectories



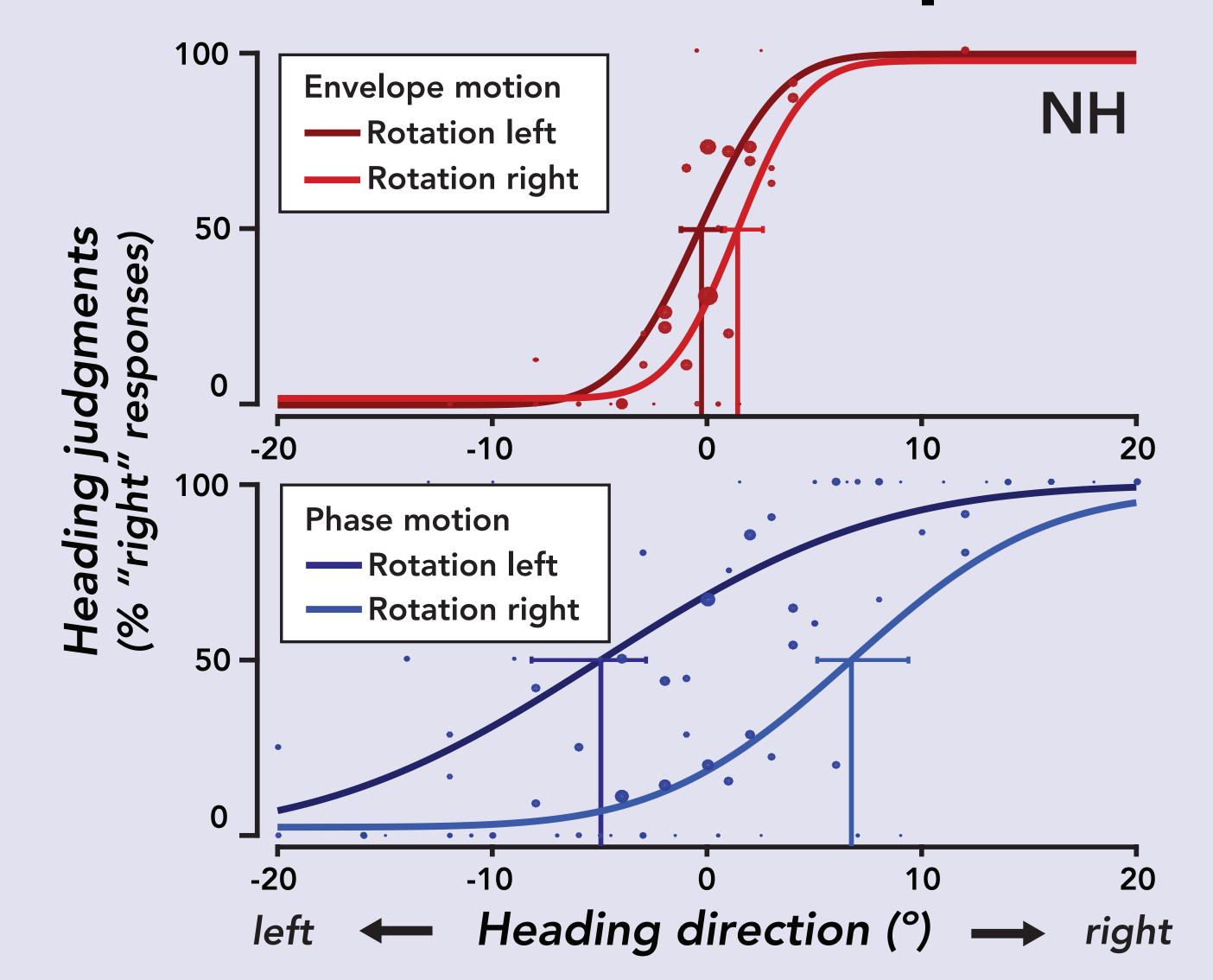
Time-varying evolution of optic flow: singularity (*\color) moves over time due to forward heading (*\color) and leftward rotation.

Experimental protocol 500 ms ITI 500 ms Stimulus Phase motion

Task: 2-AFC heading discrimination, relative to straight ahead.

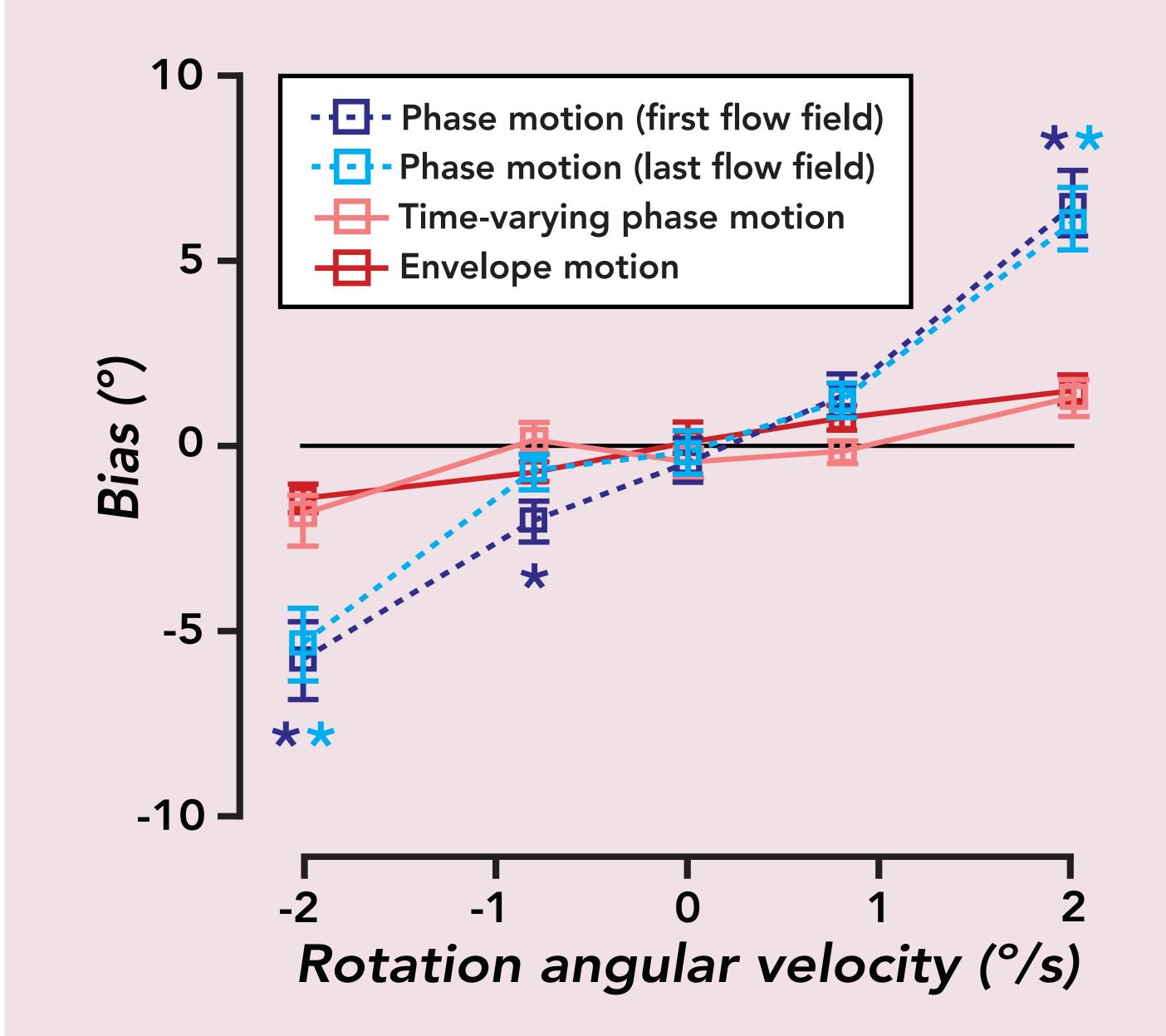
Cues Stimuli	Envelope motion	Time-varying phase motion	Phase motion
Instantaneous optic flow			
Time-varying optic flow			
Image point trajectories			

Heading bias much larger for phase motion than envelope motion



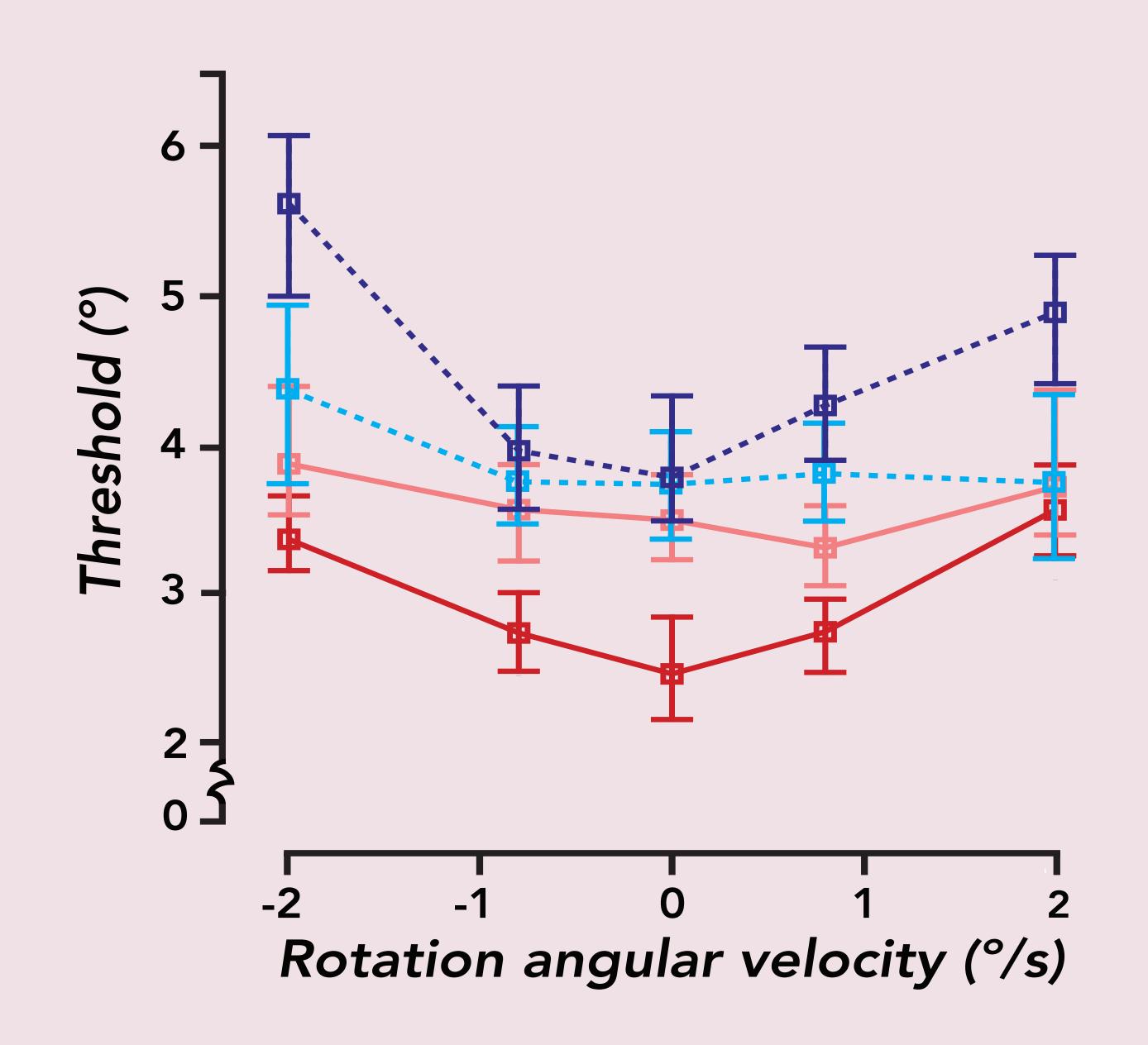
Heading bias: point of subjective equality of psychometric function. Heading discrimination threshold: 1 / slope of function.

Heading bias



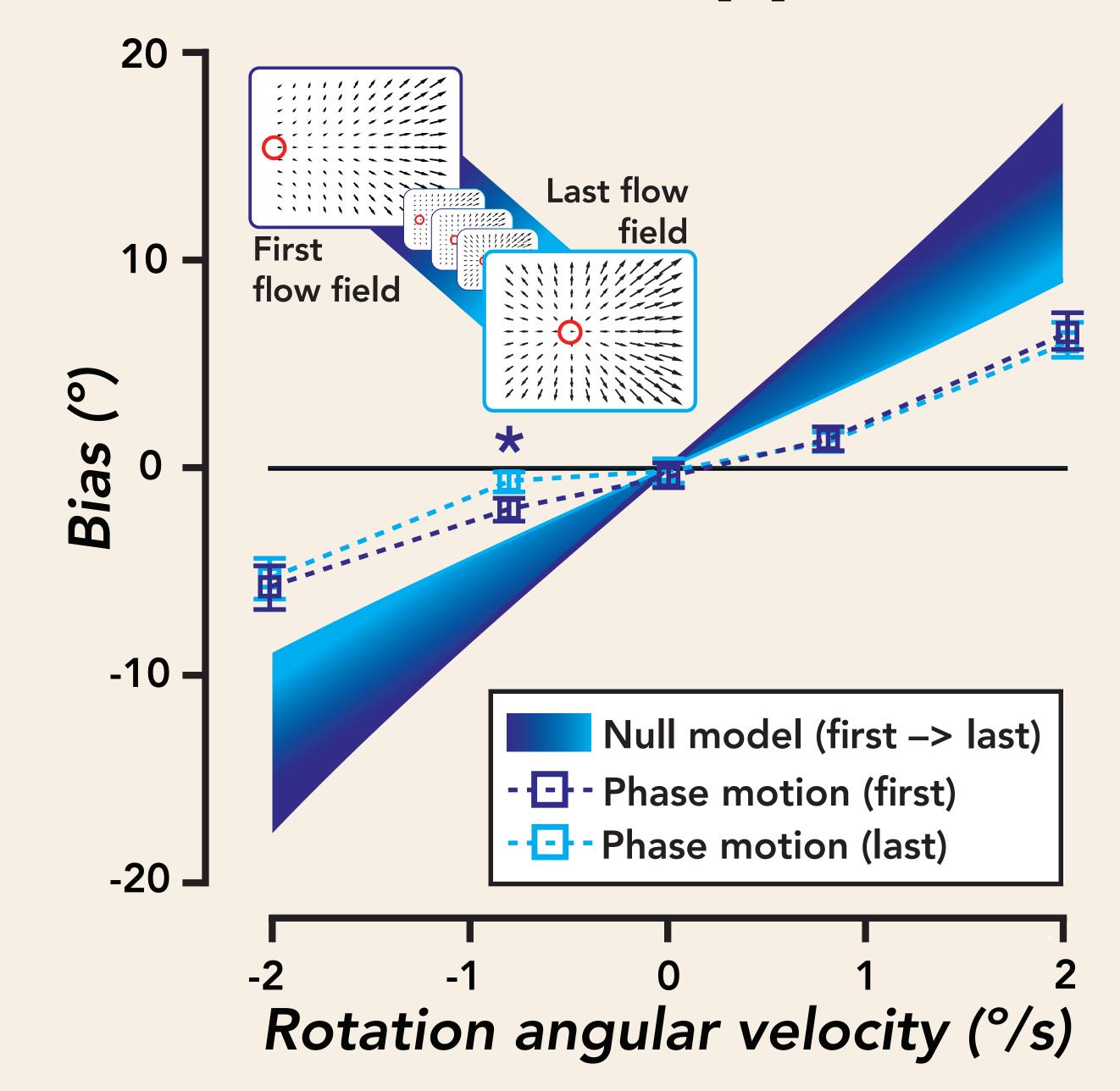
- Heading perception strongly biased for phase motion, but nearly veridical for time-varying phase motion.
- Little difference in bias between first and last flow fields; i.e., bias depends on rotation velocity, not singularity.

Discrimination threshold



 Heading discrimination thresholds higher for phase motion than for time-varying phase motion.

Null model: an upper bound on heading bias



- Null model: computes heading as singularity location, a biased strategy for translation + rotation.
- Observers interpret rotation as additional translation when only given access to instantaneous optic flow.

Conclusion: Instantaneous optic flow is insufficient. Time-varying optic flow is needed for accurate and precise heading perception.

*Email: charlie.burlingham@nyu.edu
Support: NEI VNTP T32EY007136 (to C.S.B. through NYU), NDSEG (to C.S.B.).
Thanks to: Ionatan Kuperwajs, Davis Glasser, Eli Merriam, Shannon Locke, Emmanouil Protonotarios, Mike Landy, and Eero Simoncelli.