

Effects of Visual-Proprioceptive Cue Disparities on Arm Position Sensing During Movement Planning

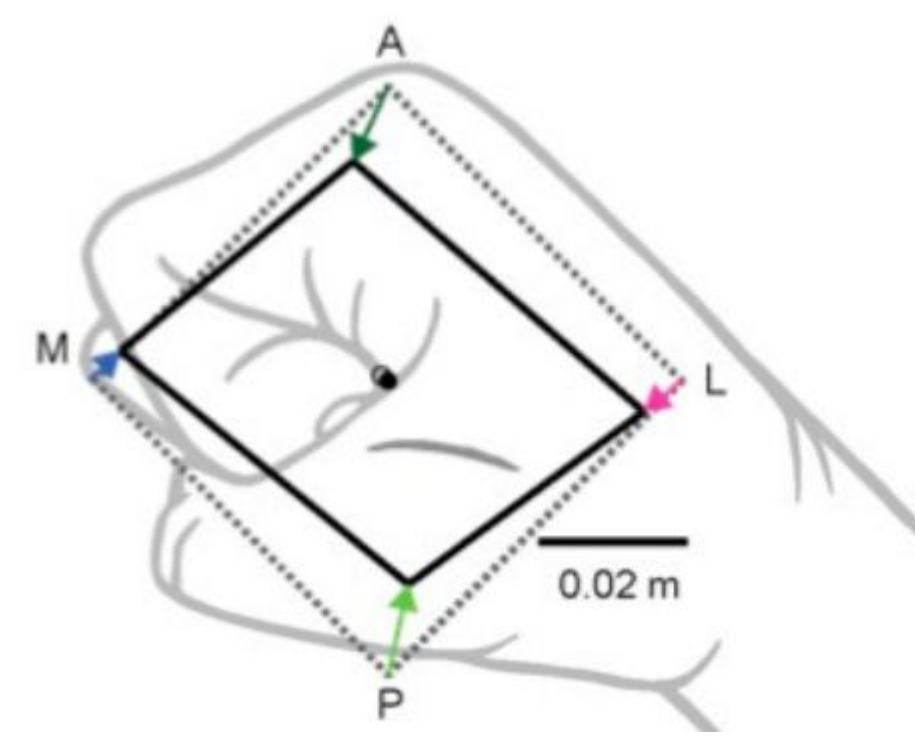
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INTRODUCTION

- Proprioception plays a critical role in estimating arm position during movement planning
- The brain integrates visual and somatosensory signals to form this estimate
- Small mismatches between seen and felt hand position can induce systematic motor biases
- We previously showed that these movement biases could be used to reverse engineer arm positions ('REAP') used to plan movements [1].
- We hypothesized that these REAP estimates reflect weighted integration of visual and proprioceptive inputs, such that smaller visual-proprioceptive disparities lead to stronger visual weighting and larger movement biases, while larger disparities reduce visual influence.
- To test this, we used the KINARM End-Point Lab to introduce controlled shifts in the visual representation of hand position across eight directions and three magnitudes (2, 4, and 6 cm). By analyzing early movement trajectories, we quantified motor biases as a proxy for the brain's internal estimate of hand position.



Abhishek et al [1]

[1] K. Abhishek, H. Muzammil, H. Lee, and C. A. Buneo, "Arm position estimates derived from motor biases," Jul. 31, 2025, *bioRxiv*. doi: 10.1101/2025.07.26.664535.

METHODS

- Participants performed center-out reaching tasks using the KINARM End-Point Lab.
- Visual hand position was shifted across 8 directions and 3 magnitudes (2, 4, and 6 cm).
- Conditions:
 - 8 visual cue shifts
 - 1 condition with no visual cue
 - 1 no-shift with visual cue
- Trials were randomized to prevent adaptation
- Primary metric: Initial directional bias (early trajectory)

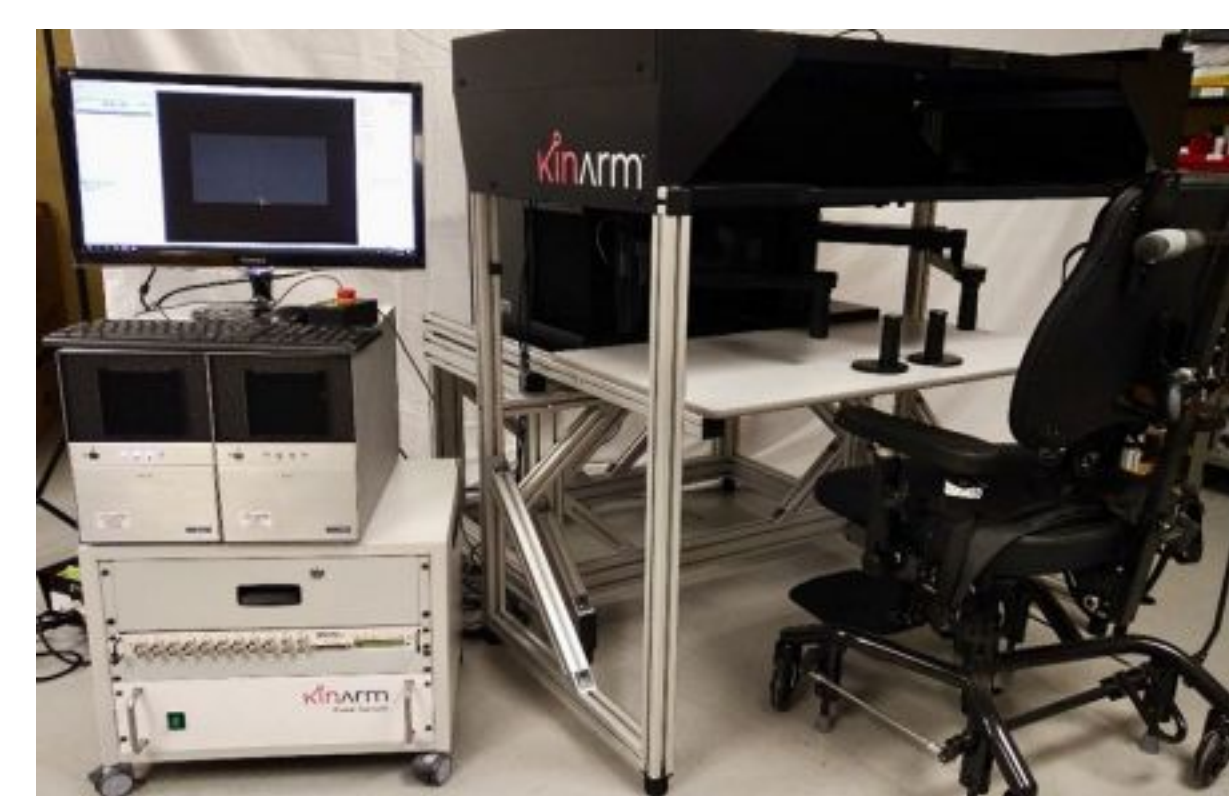


Figure 1. KINARM End-Point Lab System (BKIN Technologies)

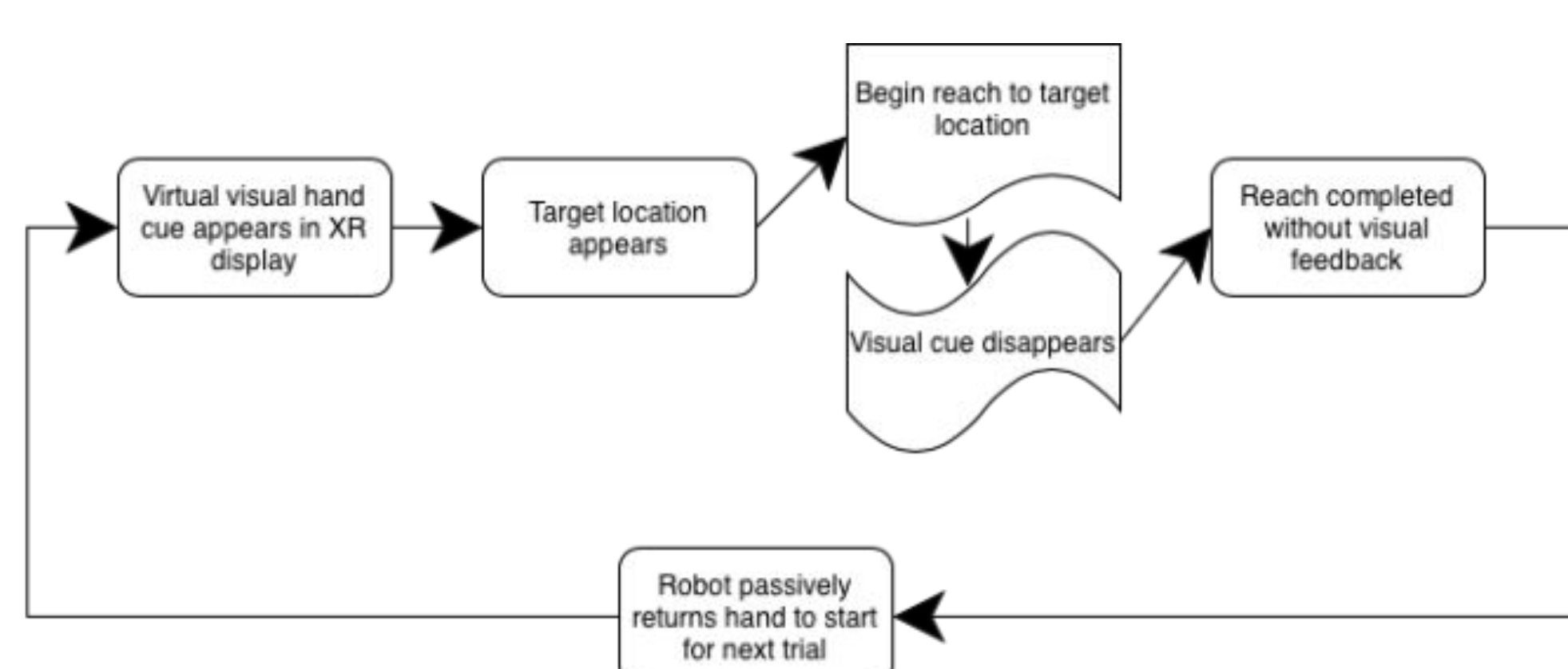


Figure 2. Behavioral Task

RESULTS

Data Processing & Analysis

- **Sampling & Filtering:** 1 kHz, double-pass, zero-lag 3 dB
- **Movement Detection:** 5% peak tangential velocity (MATLAB)

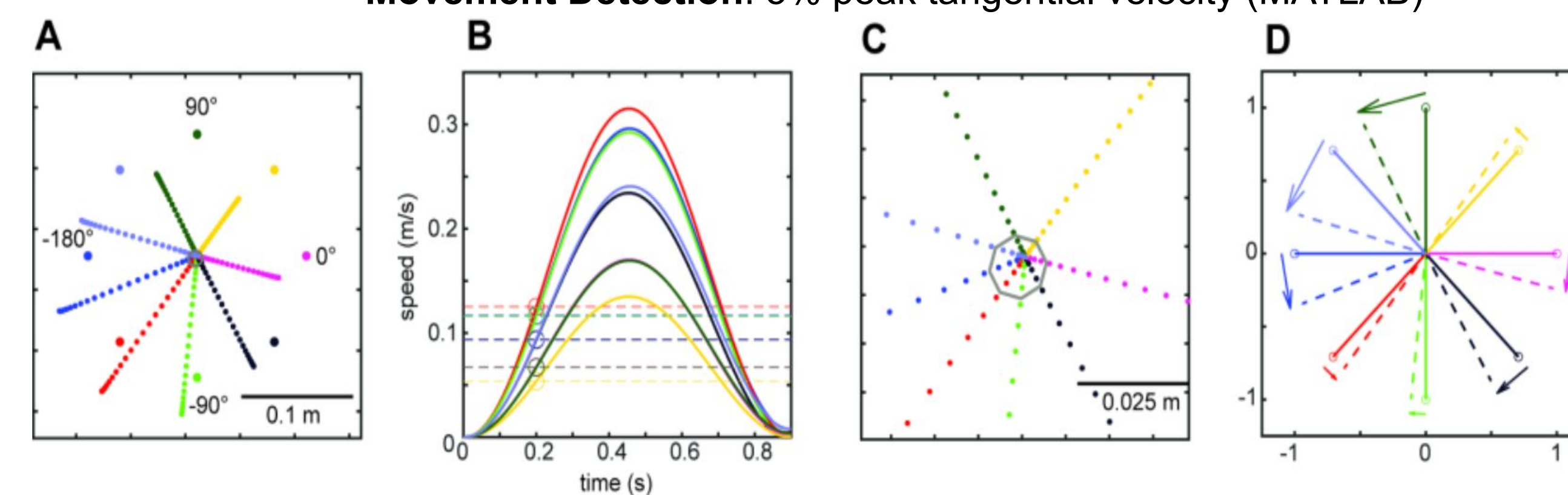


Figure 3. Simulated motor biases. **A.** Movement trajectories in the presence of an arm position bias of 45° and 0.04 m. **B.** Velocity profiles. **C.** Expanded view of trajectories in **A.** **D.** Directional errors

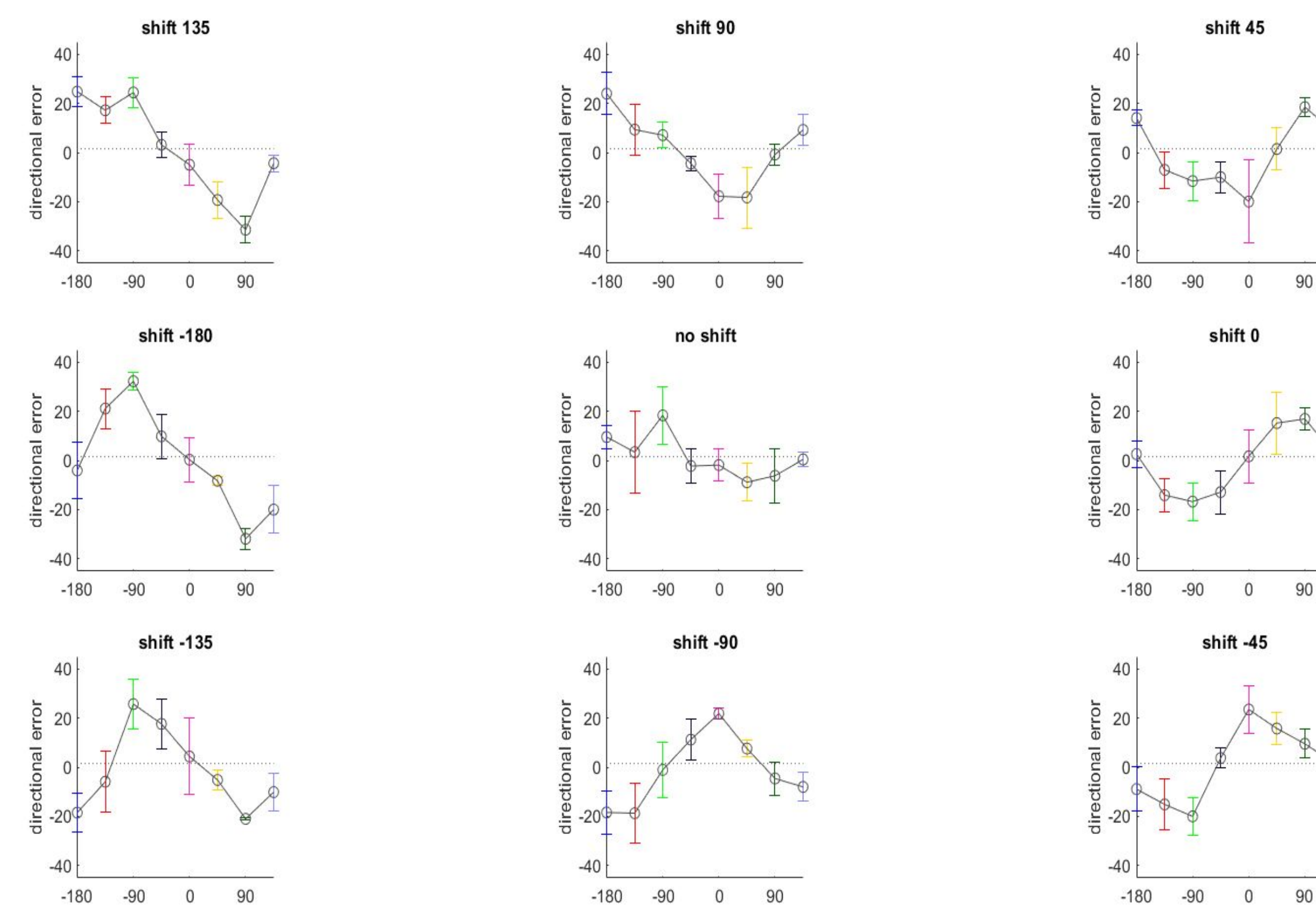


Figure 4. Directional errors for each shift direction (0.04 m magnitude bias)

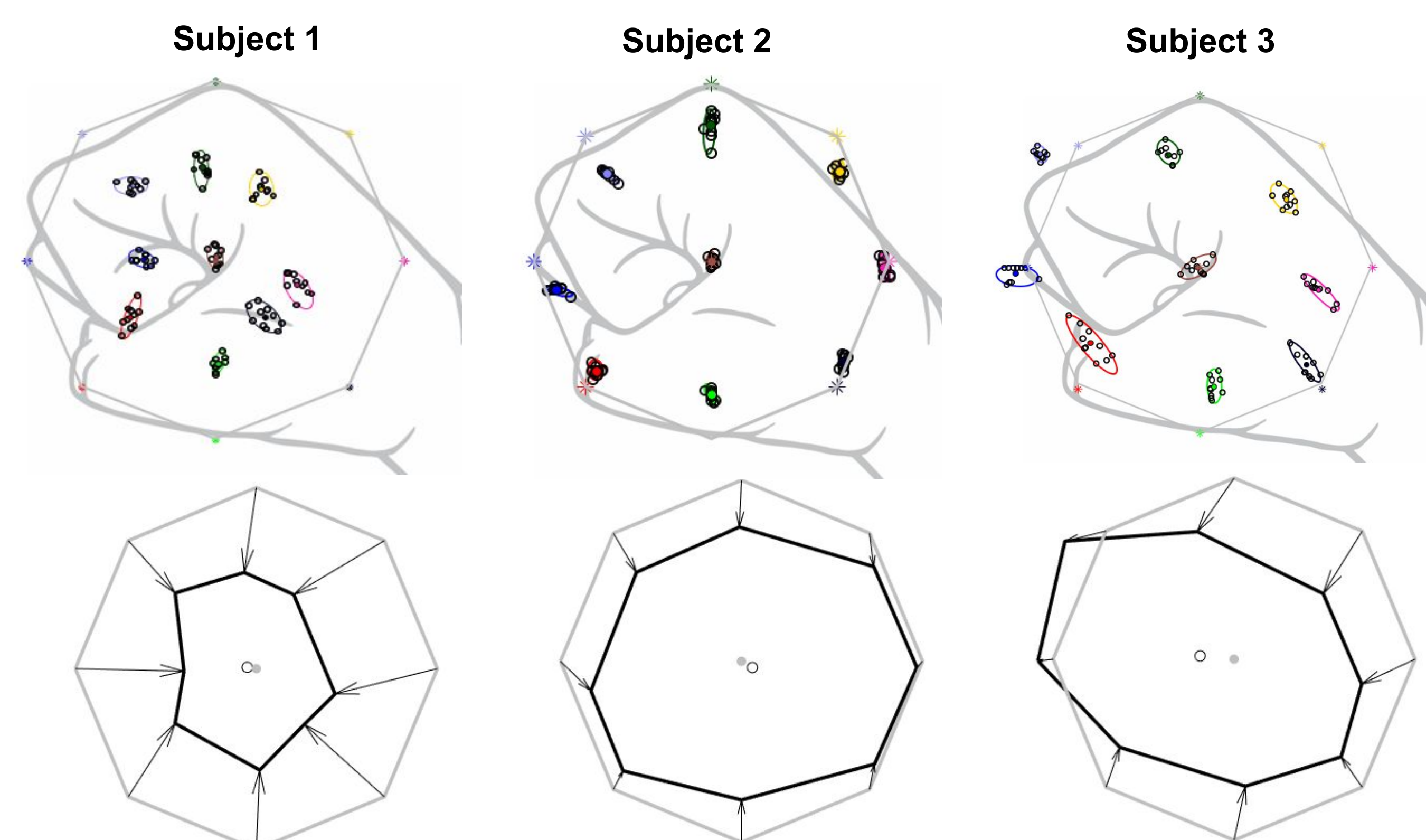


Figure 5. **Top:** Individual subjects' position estimates (0.04 m Magnitude Bias); **Bottom:** Multisensory integration induced distortion vectors of estimates.

RESULTS

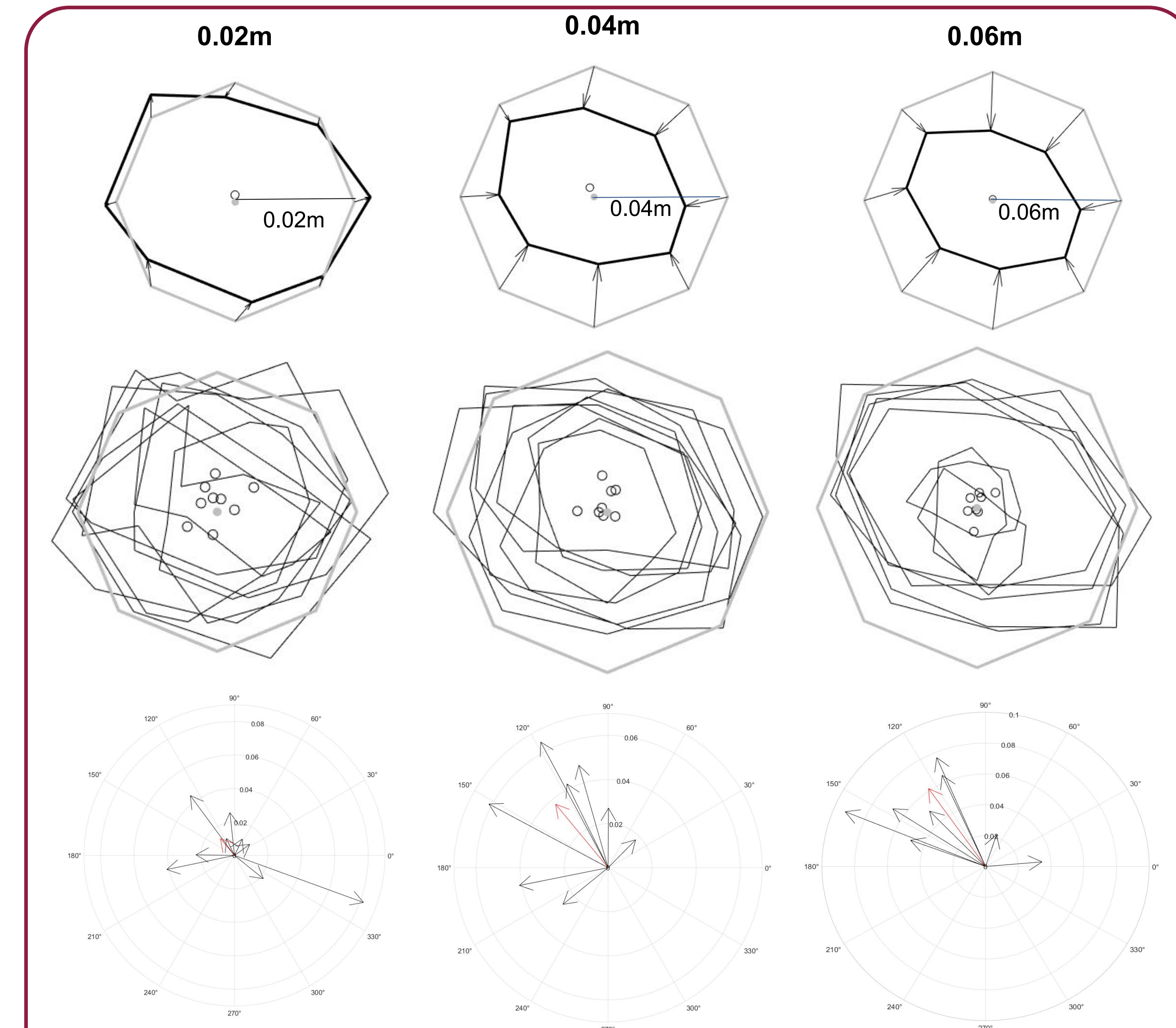


Figure 6. **Top:** Group average position estimates and distortion vectors; **Middle:** Position estimates for all individual subjects; **Bottom:** Resultants of individual subject distortion vectors (black) and group resultants (red)

- Vision dominates at smaller discrepancies as predicted.
- However, in the 6cm trials, a bimodal approach emerges: reliance on either vision or proprioception.

SUMMARY, CONCLUSIONS AND FUTURE DIRECTIONS

- Position estimates reveal visual-proprioceptive weighting that varies with direction and shift magnitude, with distortions increasing with disparity but reduced visual dominance at larger shifts.
- The results support the use of REAP to infer multisensory integration during movement planning.
- Future work will quantify subject-specific sensory weights, delineate the role of forward model-based processes, and examine how position estimates vary across arm configurations and workspace locations

ACKNOWLEDGEMENTS

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