

# Characterization of Intrinsic Visual Biases in Arm Position Estimation

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## INTRODUCTION

- Proprioception, including position sense, is essential for motor planning and coordination [5]
- Arm position is strongly influenced by visual input through integration with somatosensation [4]
- Vision and somatosensation exhibit intrinsic biases that can reduce movement accuracy [2]
- Improved understanding of these biases can have important implications for understanding motor control and for neurorehabilitation

- A recent study showed that systematic motor biases can be used to infer arm position estimates used during movement planning [1]

- Here, we expanded upon this method to characterize intrinsic visual biases in arm position estimation

- We hypothesized that intrinsic visual biases would be idiosyncratic across subjects but similar across different multisensory conditions

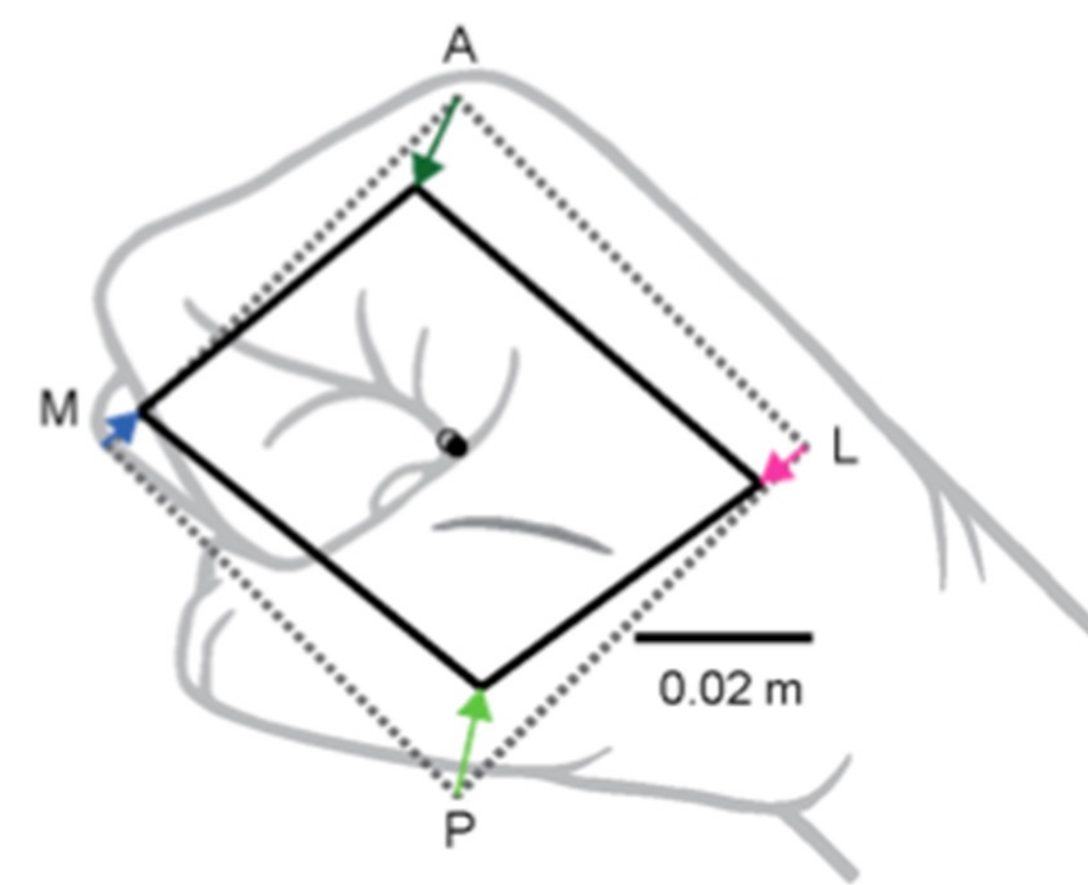


Figure 1: Example average trapezium with vectors showing distortion direction and magnitude from each visual cue [3]

## METHODS

### Experimental Setup

- KINARM recorded center-out movements from fixed start to 8 radial targets of participant's dominant arm
- Arm occluded, virtual hand cue displayed

### Experimental Design

- Trials were randomized across 10 visual conditions for 640 trials
  - 8 directional cursor shifts
  - 2 baseline conditions: one with a visual cursor, one without



Figure 2: KINARM End-Point Lab System (BKIN Technologies) Participant Setup

- Cursor shifts were at one of three magnitudes: 2, 4, or 6 cm
- Directional biases were calculated by taking the difference between initial movement directions on shifted trials and corresponding initial movement directions on baseline trials
- Simulated and experimental directional biases were then used to 'reverse-engineer' arm positions used during movement planning
- Differences in position estimates derived using the 'vision' and 'no vision' baselines were used to estimate visual biases

## RESULTS

### Data Processing & Analysis

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

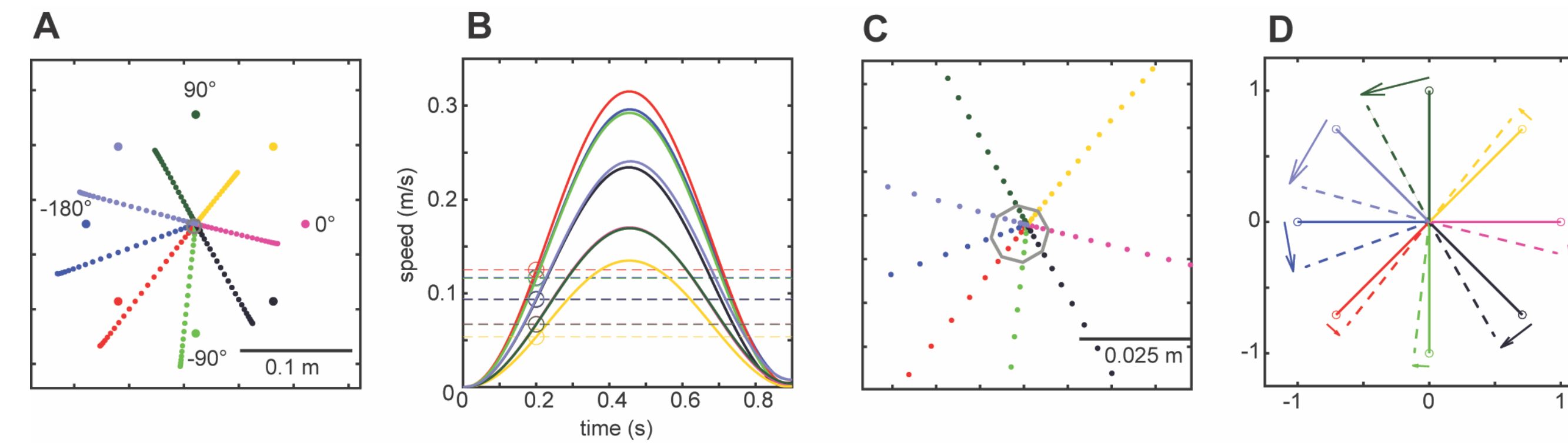


Figure 3. Simulated motor biases. **A.** Movement trajectories in the presence of an arm position bias of 45° and 0.04 m. **B.** Velocity profiles. **C.** Expanded view of trajectories in A. **D.** Directional errors.

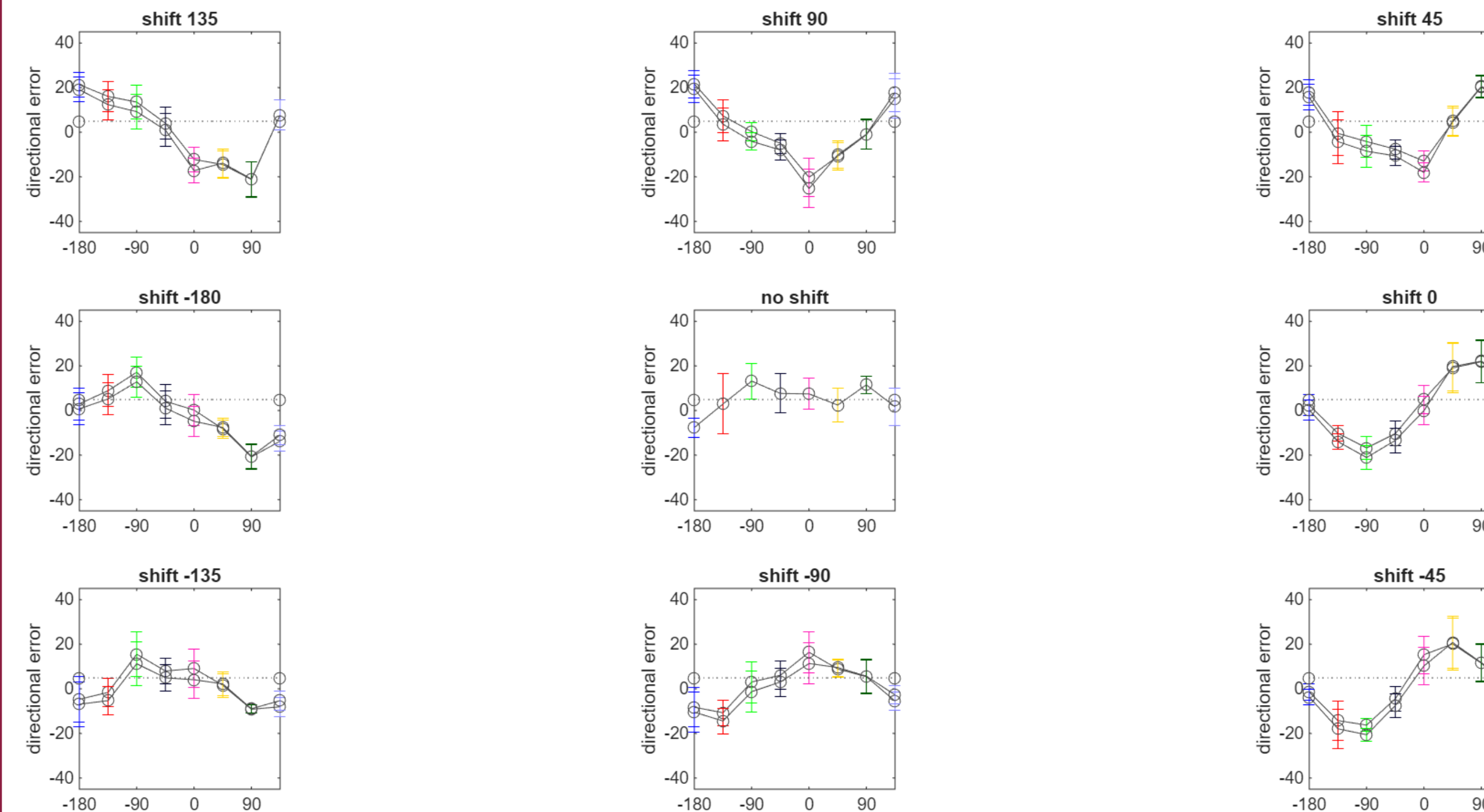


Figure 4. Directional errors for both baseline conditions in each shift direction (0.04 m)

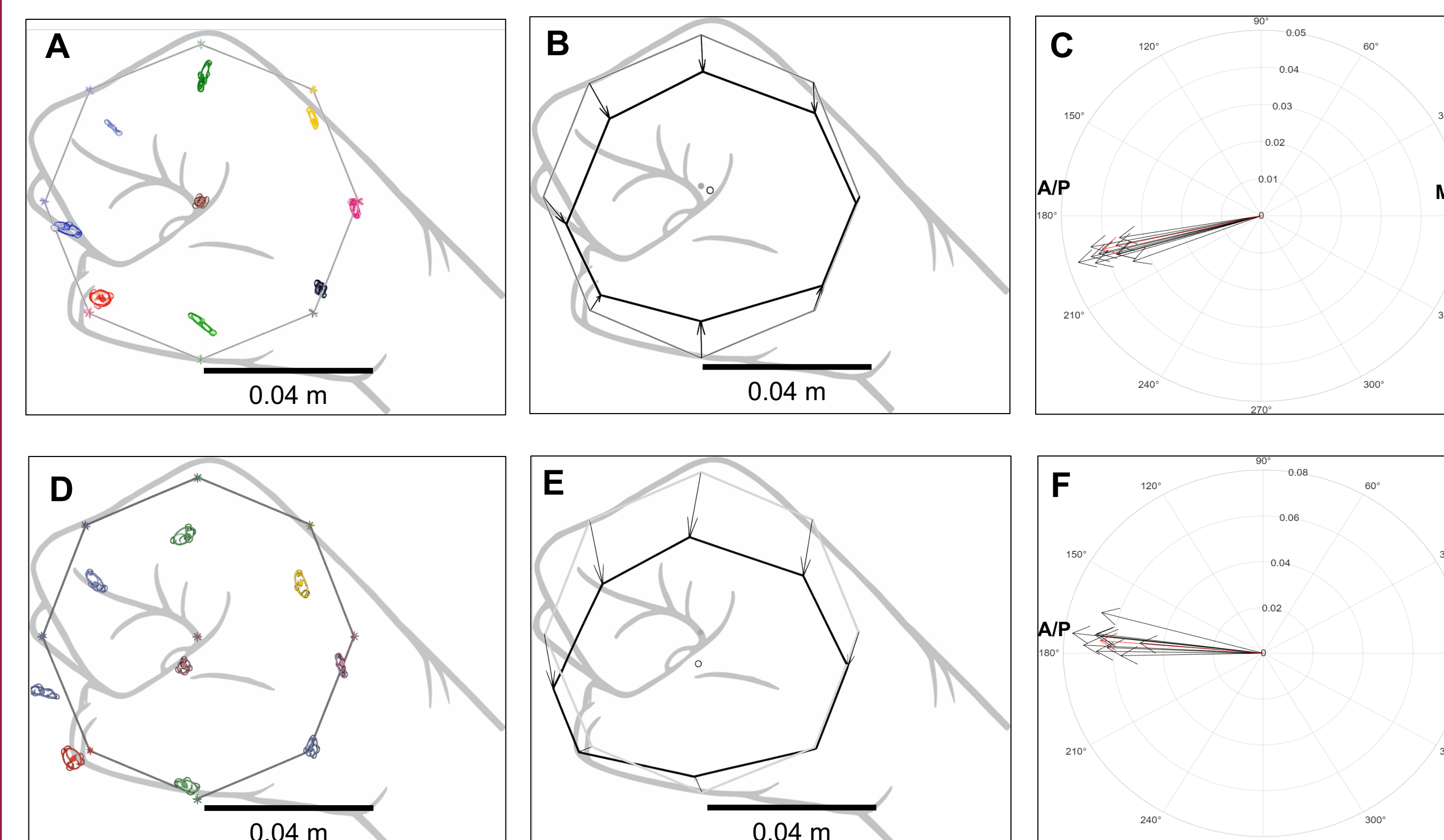


Figure 5. Participant Position Estimates with **A-C** using vision baseline and **D-F** using no vision baseline. **A.** Position estimates. **B.** Position estimates and distortion vectors. **C.** Resultant distortion vectors. **D.** Position estimates. **E.** Position estimates and distortion vectors. **F.** Resultant distortion vectors.

## RESULTS

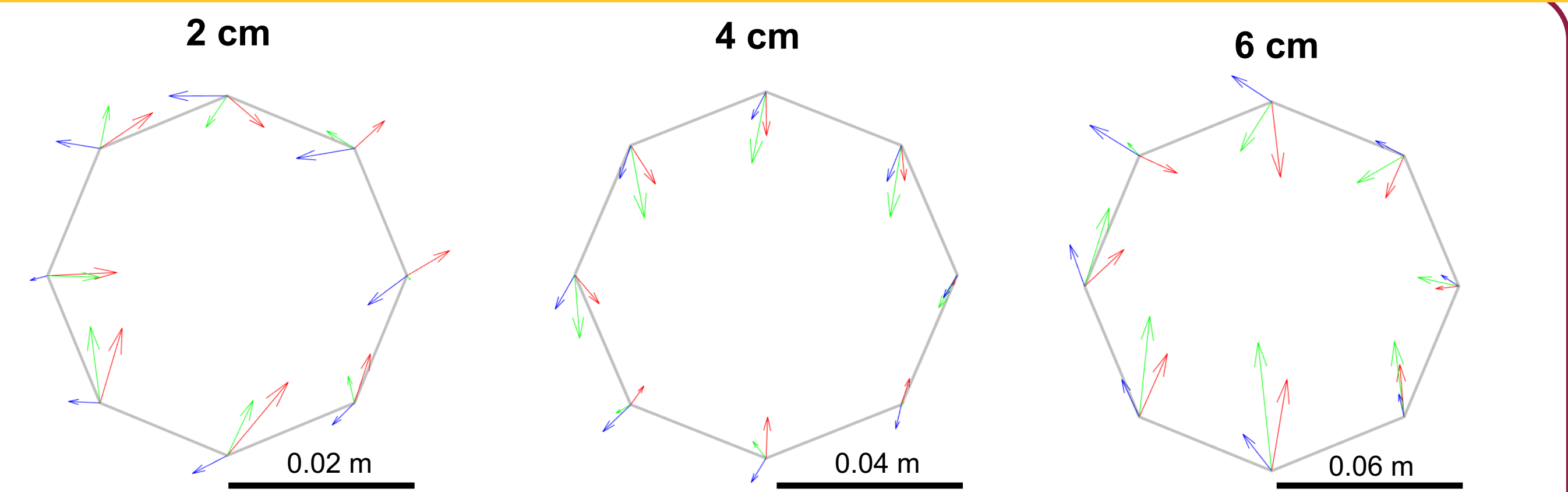


Figure 6. Visual bias vectors for different participants at each shift magnitude (0.02 m, 0.04 m, 0.06 m).

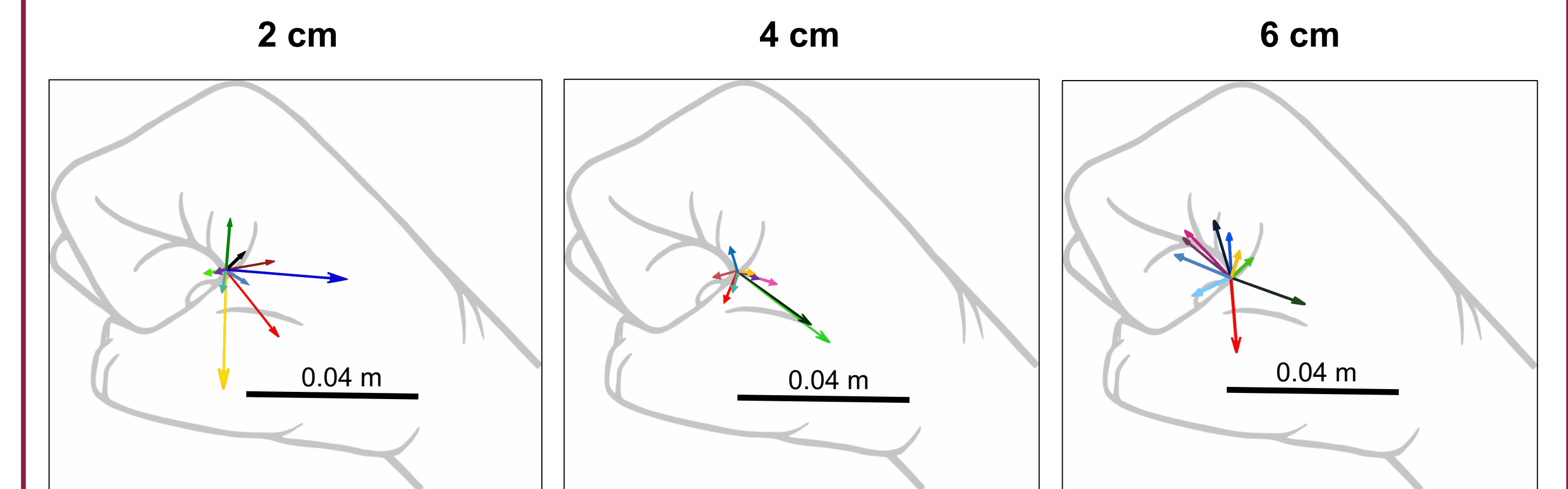


Figure 7. Summary visual bias vectors for all participants at each shift magnitude (0.02 m, 0.04 m, 0.06 m).

## SUMMARY, CONCLUSIONS AND FUTURE DIRECTIONS

- Visual bias vectors were directionally consistent across multisensory conditions, with many vectors maintaining similar orientations across shift magnitudes, suggesting stable intrinsic visual bias patterns.
- Biases were idiosyncratic across subjects, with each participant showing a unique vector pattern.
- Future work should collect more data to determine whether larger visual shifts are associated with predominantly diagonal visual bias vectors.

## REFERENCES

- [1] Abishek, K., Muzammal, H., Lee, H., & Buneo, C. A. (2025). Arm position estimates derived from motor biases. bioRxiv.
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- [4] Ernst, M. O., & Banks, M. S. (2002). Humans integrate visual and haptic information in a statistically optimal fashion. *Nature*, 415(6870), 429–433. <https://doi.org/10.1038/415429a>
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