Relative cue precision and prior knowledge contribute to the preference of proximal and distal landmarks in human orientation

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Introduction

❖ **Distal dominance**: A prevailing argument posits that distal landmarks dominate over proximal landmarks as orientation cues. However, no studies have tested or examined the underlying mechanisms in human navigation.

✓ ***Relative-precision hypothesis:*** **Distal dominance** is caused by the relative cue precision in experiments.

✓ ***Prior-knowledge hypothesis***: It is caused by prior knowledge of distal landmarks as a superior orienting cue.

✓ **Dual-factor hypothesis**: It is caused by both the relative cue precision in expeirments and prior knowledge.

❖ **Explaining distal cue dominance from a Bayesian lens**

$$\text{Posterior odds} = \text{Likelihood ratio} \times \text{Prior odds}. \qquad (1)$$

The posterior odds reflects participants' cue usage in a given experiment ($\text{posterior odds} = \frac{\text{Wd}}{\text{Wp}}$, the observed weight ratio of distal cues over proximal cues; $\text{Wd} + \text{Wp} = 1$).

The likelihood ratio can be measured by $\frac{\sigma_p^2}{\sigma_d^2}$, which is independent of the prior odds. Previous studies indicate that given a flat prior (prior odds=1), the weight ratio is reciprocal to the relative variance of estimates based on individual cues, i.e. $\frac{\text{Wd}}{\text{Wp}} = \frac{\sigma_p^2}{\sigma_d^2}$,(Chen et al., 2017; Nardini et al., 2008; Newman et al., 2023).

$$\frac{\text{Wd}}{\text{Wp}} = \frac{\sigma_p^2}{\sigma_d^2} \times \text{prior odds} \qquad (2)$$

The prior odds is the prior knowledge of a collective of $\frac{\sigma_p^2}{\sigma_d^2}$ that participants remember in experiment.

✓ ***Relative-precision hypothesis*** assumes $\frac{\text{Wd}}{\text{Wp}} = \frac{\sigma_p^2}{\sigma_d^2} > 1$

✓ ***Prior-knowledge hypothesis*** assumes $\frac{\text{Wd}}{\text{Wp}} = \text{prior odds} > 1$

✓ **Dual-factor hypothesis** assumes $\frac{\text{Wd}}{\text{Wp}} = \frac{\sigma_p^2}{\sigma_d^2} \times \text{prior odds} > 1$

❖ **Exp 1**: To test the three hypotheses of distal dominance.

❖ **Exp 2-3**: To examine the circumstances in which a proximal landmark can override a distal one for orientations

Method

Apparatus: Immersive virtual reality environments

General Procedure:

- **Learning**: standing at O, participants learned five objects at 1-4 and O, a proximal landmark (a traffic cone or L at O) and three distal landmarks.
- **Walking**: After walking a path with the targets and the landmarks being removed, they **were spun to be disoriented** at the end of path (P).
- **Testing**: They replaced the five targets to their original locations in conditions with different available landmarks.

Orientation-cue conditions (within-subject)

- **DLM**: only a distal landmark (being rotated 50°) ;
- **PLM**: only a proximal landmark (being rotated -50°)
- **Conflict**: a distal landmark (rotated 50°) and a proximal landmark available (rotated -50°) available

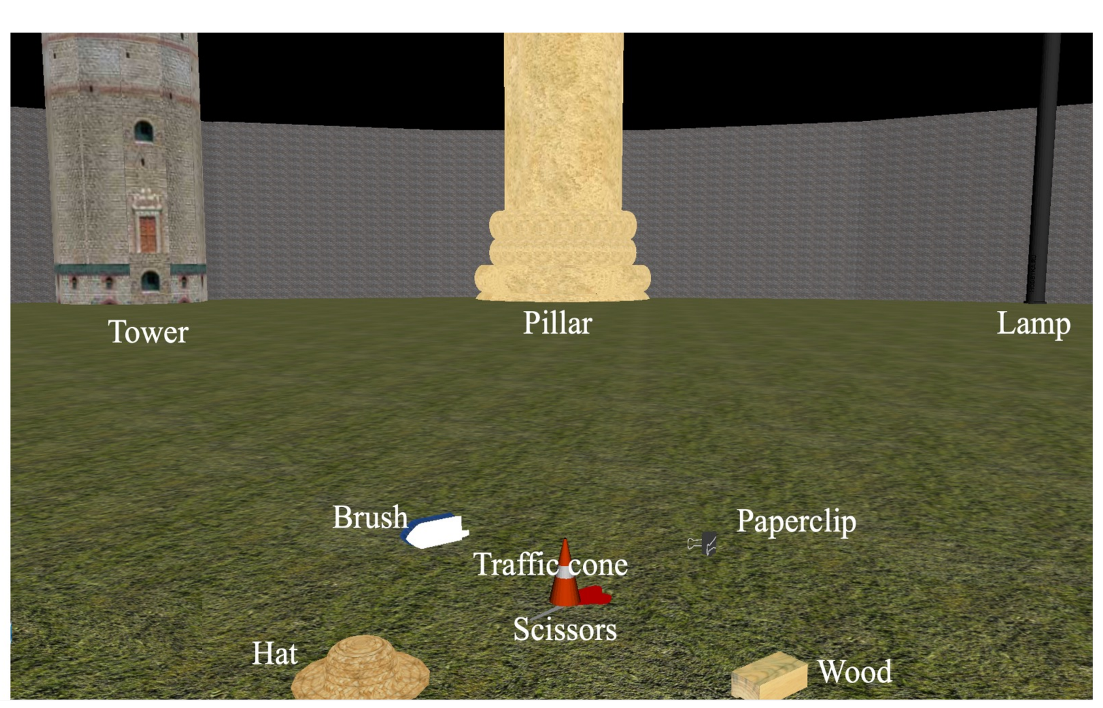

Fig 1. Virtual environment.

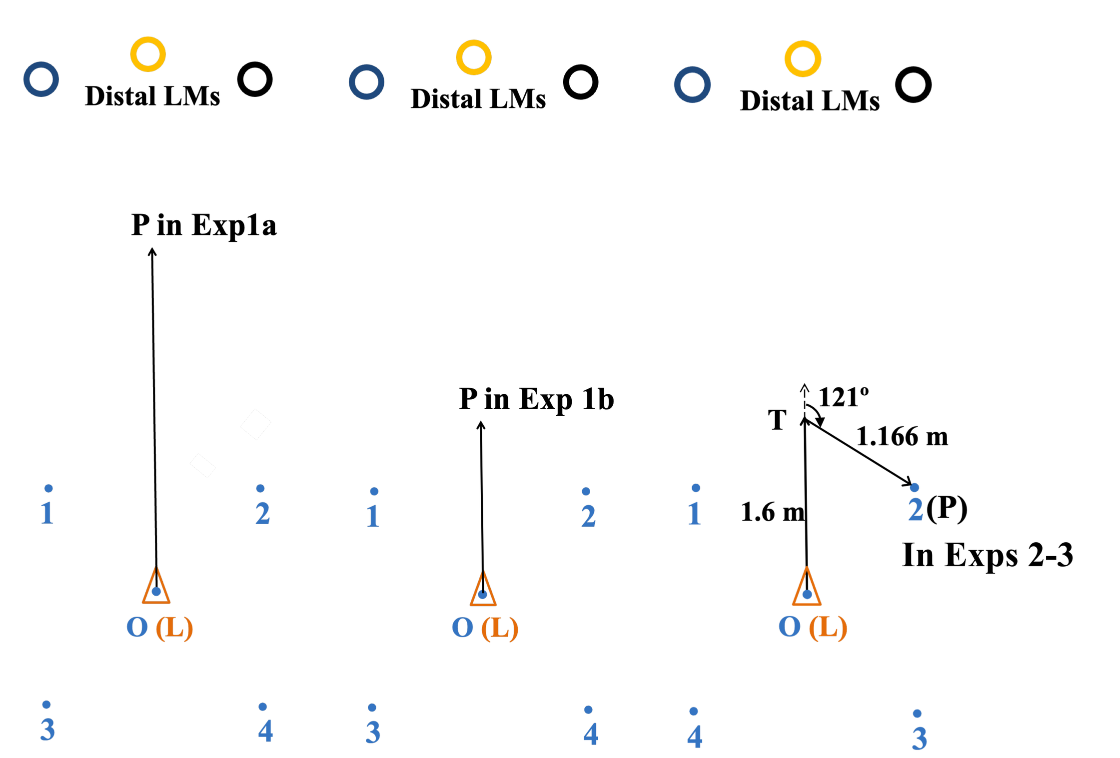

Fig 2. Layout and path configurations in Exp 1a, 1b and Exps 2-3.

Key measures: $\frac{\sigma_p^2}{\sigma_d^2}$, based on variances of heading error in DLM and PLM conditions. $\frac{\text{Wd}}{\text{Wp}}$, based on the proximity of the signed heading error to -50° (indicated by distal landmark) and 50° (indicated by proximal landmark) in Conflict.

❖ **Exp 1a** used a longer and **Exp 1b** used a shorter distance between the testing position and the proximal landmark (PL). The shorter the distance of PL, the less precise of the proximal cue (i.e., a larger $\frac{\sigma_p^2}{\sigma_d^2}$).

❖ **Predictions based on the three hypotheses.**

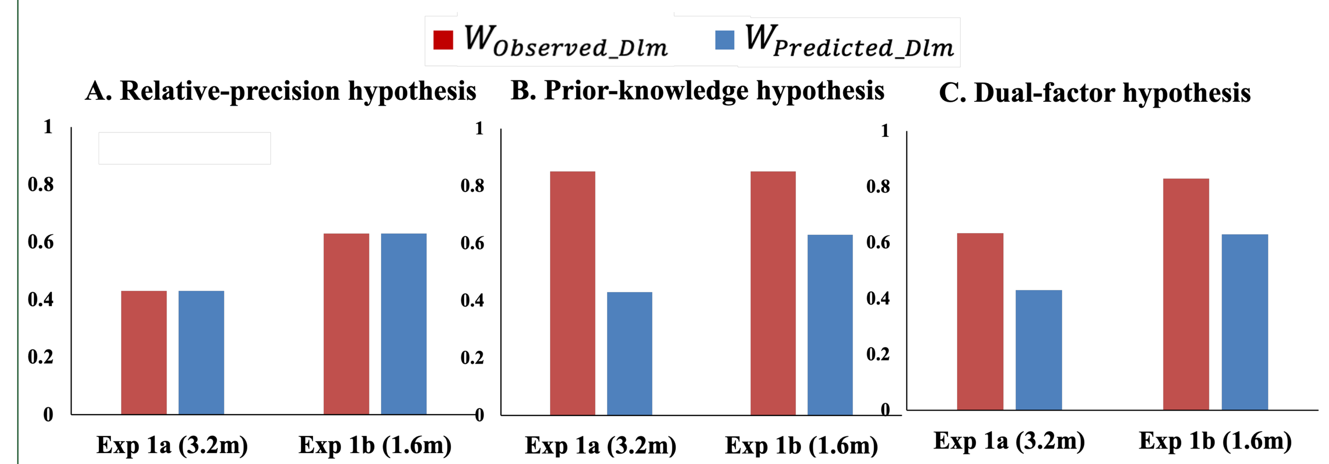

Fig 3. Predicted weights assigned to the distal cue based on their relative precision ($W_{Predicted\_Dlm}$) . Observed weights of the distal cue ($W_{Observed\_Dlm}$) in the Conflict condition.

❖ **Exp 2-3 with these changes:**

- Walked a two-leg path and stopped at one object location.
- **Being informed of their location at the endpoint P** by verbal instructions after disorientation **in Exp 2 but not in Exp 3** (E.g., "**You are now at the location of the paperclip**").

➢ **Conjecture**: When navigators to have a clear understanding of their position relative to a proximal landmark, they are more likely to rely on this vector (i.e., $\overrightarrow{PL}$ originating from their own position towards the nearby familiar landmark in Fig. 2) rather than seeking out distal landmarks to determine their orientations.

Results

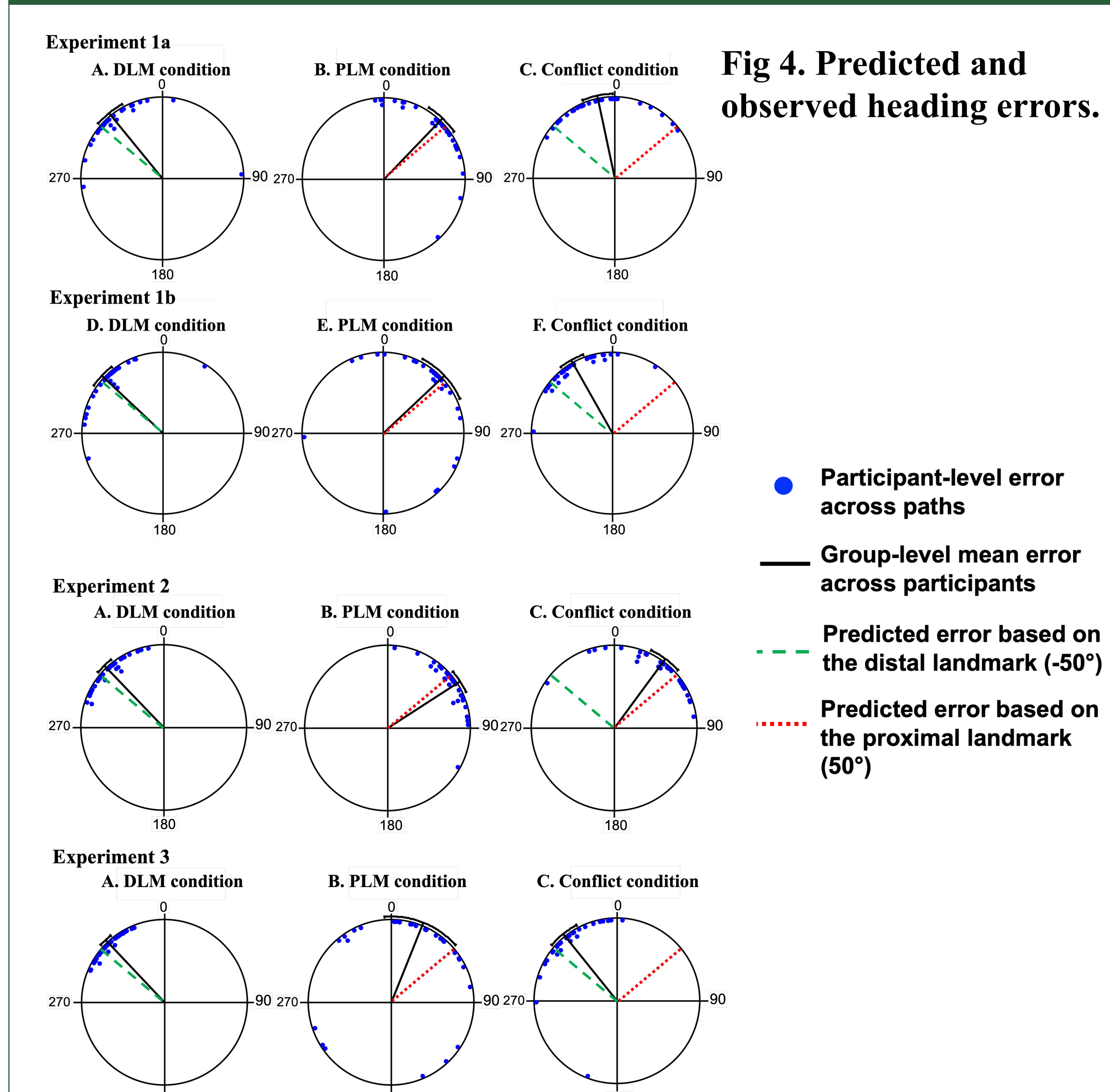

Fig 4. Predicted and observed heading errors.

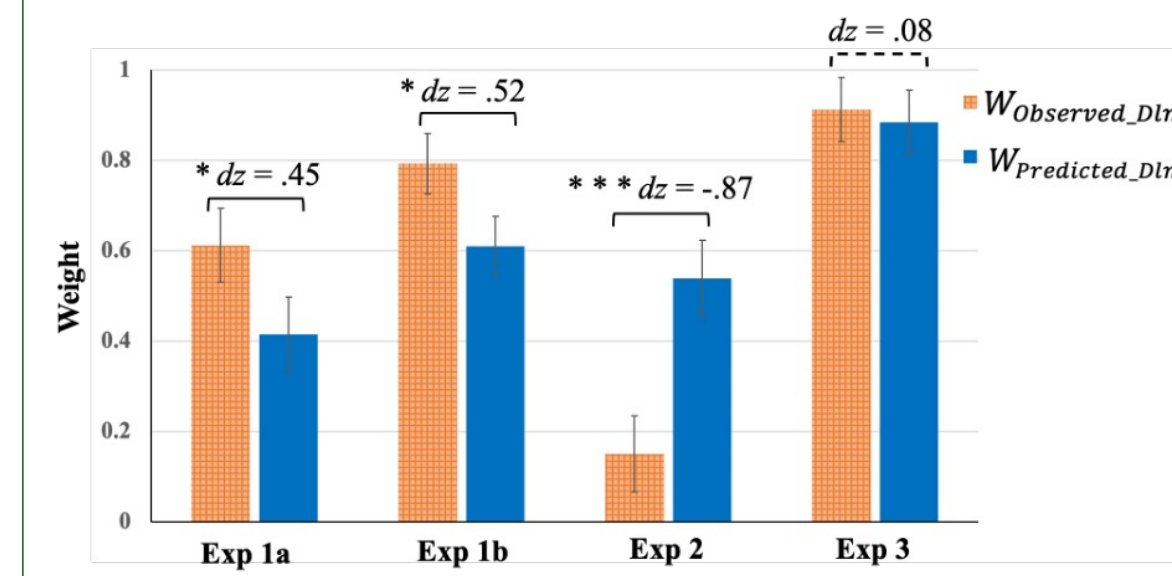

Fig 5. The observed weights of the distal cue ($W_{Observed\_Dlm}$) in Conflict condition and the weights of the distal cue based on its relative precision ($W_{Predicted\_Dlm}$) in all experiments.

Exp1 showed:

➢ greater observed weights to distal cues than the predicted weight based on the relative cue precision, against the relative-precision hypothesis.

➢ Observed weights were not constant, against the prior-knowledge hypothesis.

➢ The estimated prior odds were 2.22 and 2.43 in Exps 1a and 1b, showing a consistent effect of prior knowledge on orientation cue usage.

Exps2 and 3 showed:

➢ A proximal landmark dominated over a distal one as an orientation cue when navigators were explicitly informed of their self-location.

➢ The proximal cue dominance in Exp 2 but not in Exp 3 shows that the instruction of the self-location was the key to invoking the top-down process of preferring the proximal landmark.

➢ The estimated prior odds were 0.15 and 1.36 in Exps 2 and 3, showing different prior knowledge were remembered depending on instructions.

Conclusions

❖ Orientation cue usage is influenced by the cue relative precision in the specific environment and the prior knowledge people choose.

❖ People may choose prior knowledge favoring distal landmarks as a superior orienting cue, results in distal cue dominance.

❖ When possessing a clear understanding of their position relative to a proximal landmark, they choose the prior knowledge favoring the proximal landmark, leading to proximal dominance

References

Chen, X., McNamara, T. P., Kelly, J. W., & Wolbers, T. (2017). *Cognitive Psychology, 95*, 105-144.

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