

Real-World Clutter Improves Egocentric Distance Judgments in Optical See-Through Augmented Reality



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Motivation

In near action space (2–10 m), the highest-weighted depth cues for **egocentric distance** are occlusion, height in visual field, binocular disparity, and motion parallax; pictorial cues like relative size and texture gradient rank much lower [1, 2].

OST-AR breaks the high-weight cues. HoloLens 2 virtuals don't fully occlude, cast no shadows, lack ground contact, and users **underestimate** distance [3].

Q: *Can low-weight virtual cues (clutter) substitute for the missing high-weight ones?*

Predictions

$PDE = \text{Proportional Distance Error} = \text{Walked} / \text{Actual}$.

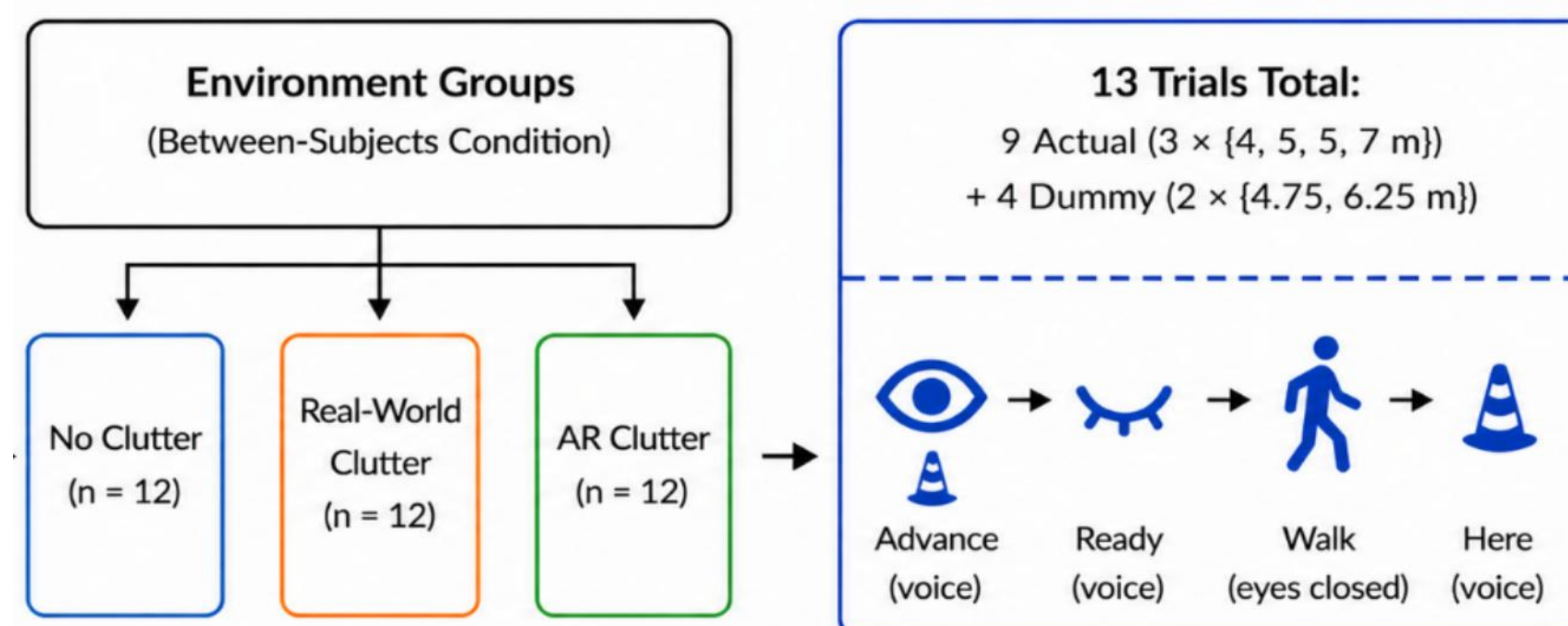
RWC = Real-World Clutter; ARC = AR Clutter; NC = No Clutter.

P1 : Pictorial cues alone suffice: $PDE(RWC) \approx PDE(ARC) > PDE(NC)$

P2 : Cue fidelity matters (shadows, occlusion): $PDE(RWC) > PDE(ARC) \approx PDE(NC)$

P3 : Both contribute: $PDE(RWC) > PDE(ARC) > PDE(NC)$

Study Design



Conditions & Available Depth Cues

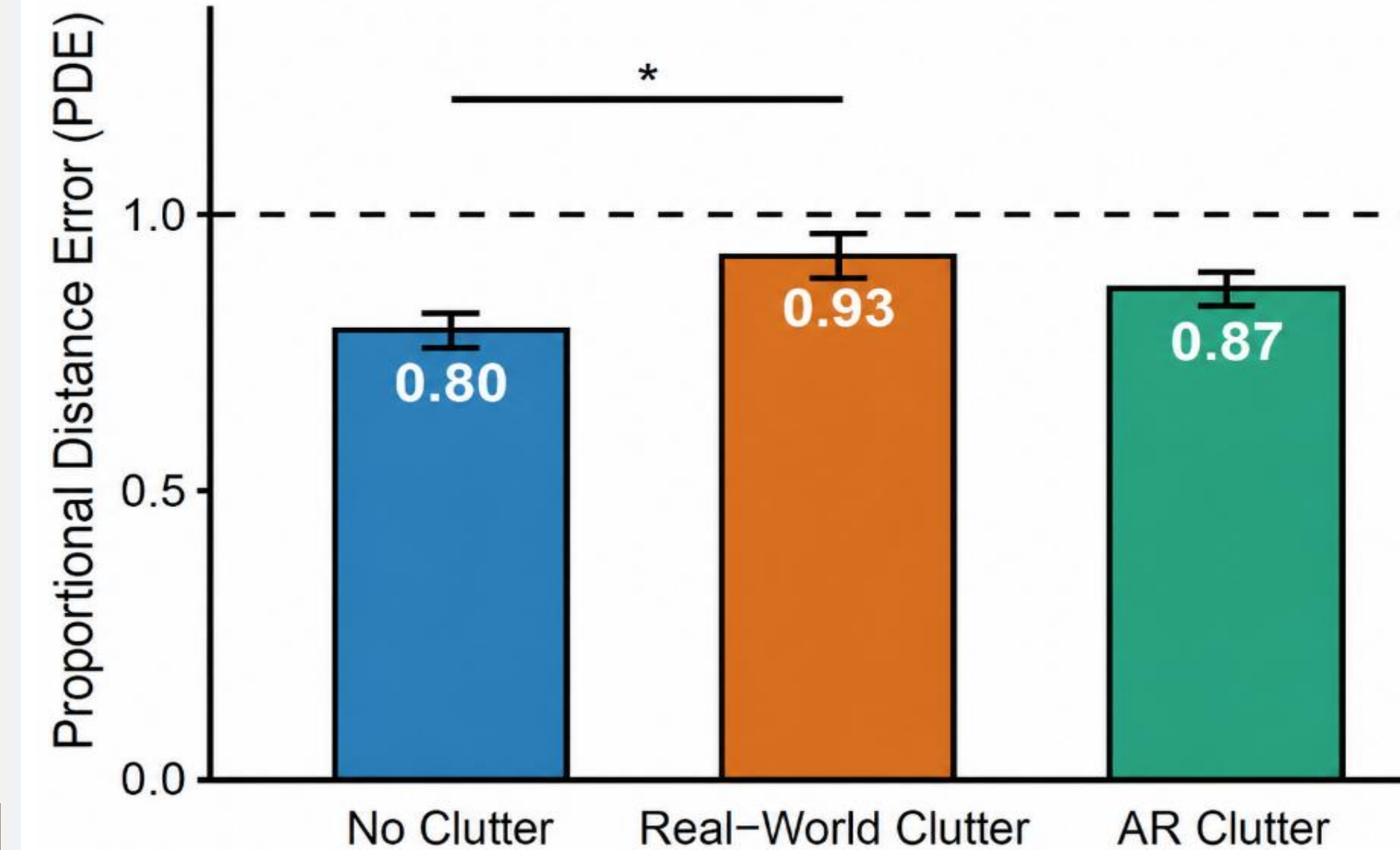
Depth Cue	No Clutter	Real-World Clutter	AR Clutter
Occlusion		✓	△
Relative size		✓	✓
Linear perspective	✓	✓	✓
Cast shadows		✓	
Texture gradient		✓	△
Height in visual field	△	✓	△
Ground contact		✓	

✓ = cue exists △ = cue limited or degraded



Results

Real clutter helps; AR clutter does not — yet.



Main effect of Environment: $F(2,30) = 4.21$, $p = .025$, $\eta^2_p = .22$

• BF_{01} : ARC vs NC = **0.39**, ARC vs RWC = **0.64**; BFs cannot yet rule out P2 (full benefit).

• **Pattern is most consistent with P3 (partial benefit).**

Discussion & Implications

• **Pattern:** $RWC \sim 7\% < ARC \sim 15\% < NC \sim 25\%$. ARC sits midway, most consistent with **P3 (partial benefit)**.

• **Why partial?** OST-AR delivers degraded but non-zero high-weight cues [4]. **Not registration:** HoloLens 2 error (~ 2 cm) $\ll$ observed bias (~ 60 – 175 cm) [5]. AR compression is a scene problem, not a display problem.

References

- [1] Cutting & Vishton (1995). Perceiving layout and knowing distances.
- [2] Loomis et al. (1992). Visual space perception and visually directed action.
- [3] Masnadi et al. (2023). Scene structure & egocentric distance in VR. IEEE VR.
- [4] Adams, Stefanucci & Creem-Regehr (2022). Visual realism & distance in AR. IEEE VR.
- [5] Livingston & Ai (2009). Registration error & distance perception in AR. IEEE VR.