Evaluating the Efficacy of Simulated Augmented Reality Cueing in Virtual Reality

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I. Introduction

Can navigational cues help a user develop spatial knowledge in a virtual environment?

- Through the use of Augmented Reality (AR) technology, AR cueing can supplement and enhance existing landmark information, making it easier to acquire the spatial knowledge needed to navigate a complex environment.
- Prior research has shown that using distal cues and navigational aids can guide wayfinding in a virtual environment [1, 2].

Does utilizing these navigational cues increase cognitive load while navigating?

- Prior work has shown that navigational cues run the risk of impacting a user's performance due to the potential tradeoffs AR cueing can have on a navigator's situational awareness [3, 4].

We ran an experiment to analyze the potential tradeoffs of AR cueing on:
1 – navigational efficiency
2 – survey spatial knowledge
3 – cognitive load

- We hypothesized that AR cues would positively impact navigational efficiency and supplement survey knowledge, but increase cognitive load.

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SCAN FOR VIDEO OF PROCEDURE DEMO

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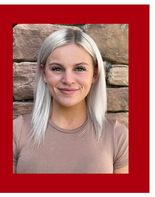


II. Methods

Participants

- Between-subject design - 2 primary factors that varied across subjects: map type and cue condition.
- 40 participants - 10 in each map type x cue condition (10 Dynamic x Cues ON, 10 Dynamic x Cues OFF, 10 Static x Cues On, 10 Static x Cues OFF)

Materials

- HTC Vive Pro Head-mounted Display
- DRT (Detection Response Task- Device that is taped onto clavicle that provides a vibrating stimulus that prompts the user to respond via a button secured to their finger.

Virtual Environment

- We utilized two different 3x3 block virtual city environments for the participants to navigate, counterbalanced for order.

Figure 1 – example image of a user's view of the map (see left), example image of a target's AR overlay in the virtual environment (see right).

Cues

- Two cue conditions: Cues ON or Cues OFF
- Two map types: Static vs Dynamic

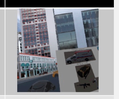
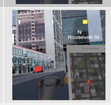
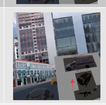
	CUES	No CUES
Static Map		
Dynamic Map		

Figure 2 – example images of the city environment displaying AR cues and the dynamic updating nature of the map.

Procedure

- ***Search***: locate 3 distinct targets that are placed around the virtual city.
- ***Return***: after all the targets have been found, navigate back to the starting location.
- ***Pointing***: point at the given target from Home to indicate spatial knowledge of the located targets.

III. Results

Do cues help develop survey spatial knowledge?

Pointing Error: the difference in degrees between the actual target and where the participant points.

- We ran a 3 (Pointing location) x 2 (Cues On vs Cues OFF) x 2 (Static vs Dynamic map) repeated measures ANOVA analysis.
- ➢ We found pointing error was lowest in the Cues ON condition when pointing from Home to Object (see Figure 3).

Do navigational cues increase cognitive load?

Response Time: time in which participant responds to DRT sensory stimulus.

- We averaged response times and performed a 2 (Cues ON vs Cues OFF) x 2 (Static vs Dynamic map) ANOVA to determine effects.
- ➢ We did not find any significant effects of cues or map type on DRT response times (see Figure 4).
- We ran a one-way ANOVA for the effect of location (Intersection vs Street) on response time.
- ➢ We found a significantly higher reaction time while the participant was in an intersection (see Figure 5).

***Map Calls*:** amount of times user pulled up the map.

- We used a 2 (Cues ON vs Cues OFF) x 2 (Static vs Dynamic map) ANOVA analysis to assess cues and map type on map usage.
- ➢ There was no significant effect of cues on map calls, but post-hoc analysis showed that users called the dynamic significantly more than they called the static map (see Figure 6).

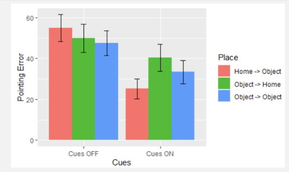


Figure 3 - Pointing Error for cues and pointing location.

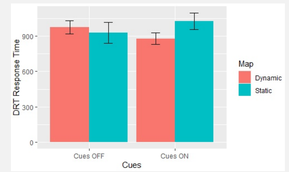


Figure 4 - DRT Response Times for cues and map type.

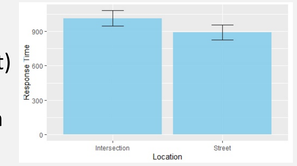


Figure 5 - DRT Response Time for intersection vs street.

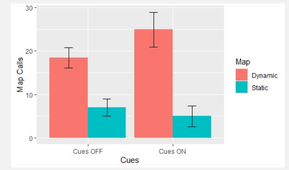


Figure 6 - Map calls for cues and map type.

IV. Conclusions

- Navigational cues aid spatial memory (as shown by decreased pointing error) without increasing cognitive load (as shown by the DRT data).
- Reaction time is slower in an intersection, showing that more decision making increases cognitive load.
- The DRT is an effective measure that can and should be used in future situational awareness research in Virtual Reality.
- Dynamic maps attract more attention without impairing situational awareness or spatial memory.

References

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