Improving Navigation in Virtual Environments

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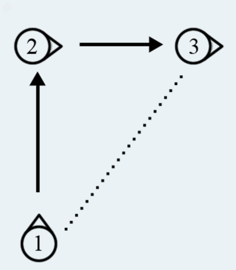
Overview

Virtual reality (VR) faces a unique challenge—it must allow users to navigate large virtual environments (VEs) within small physical spaces. Many navigation interfaces reduce the role of the body, causing disorientation, discomfort and disengagement[1].

Navigation interfaces can be described in terms of the concordance between movement of the user's body and visual movement through the VE:

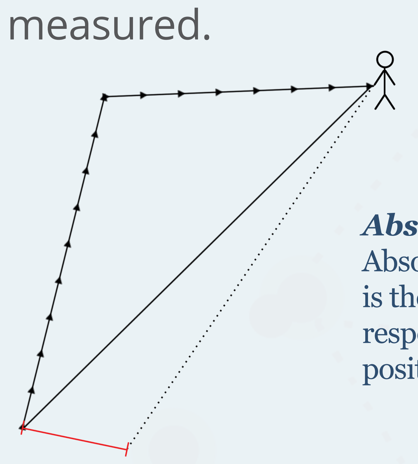
- **Concordant:** User physically walks and turns to move in the VE
- **Partially Concordant:** User physically turns to rotate but uses controller to change position in the VE
- **Discordant:** User uses controller exclusively to move and turn in VE

The study examined the effects of navigation interfaces on spatial updating. In addition, it examined how environments affect spatial updating, testing users in environments with and without **landmarks**. Performance was evaluated using a triangle completion task:



Triangle Completion Task
Participants travel along two legs of a triangle and are then asked to indicate the position where they started (dotted line).

In order to see how these factors affected spatial updating, **absolute distance error** (the distance between the actual starting position and the response) was measured.



Absolute Distance Error
Absolute distance error (marked in red) is the distance between the particpant's response (dotted line) and the actual start position of the triangle.

1) Klatzky, R. L., Loomis, J. M., Beall, A. C., Chance, S. S., & Golledge, R. G. (1998). Spatial Updating of Self-Position and Orientation During Real, Imagined, and Virtual Locomotion. *Psychological Science, 9*(4), 293-298.

Predictions

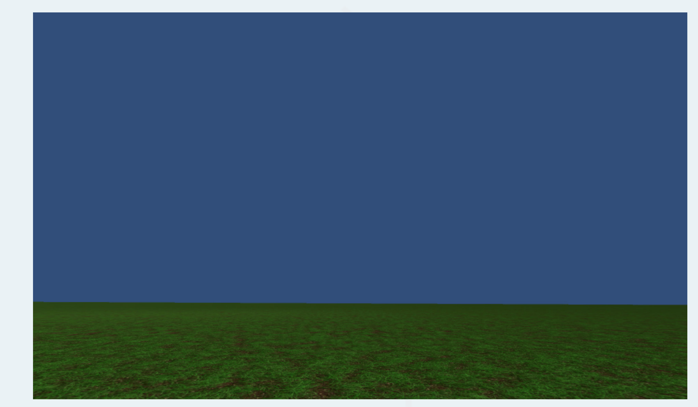
We had two predictions about how navigation interfaces and landmarks would affect navigation:

- Participants allowed to physically walk and turn (**concordant interface**) will have the most accurate performance and those who use teleportation to change position and rotation (**discordant interface**) will be the least accurate.
- The presence of **landmarks** will improve performance, especially with more disorienting navigation interfaces.

Methods

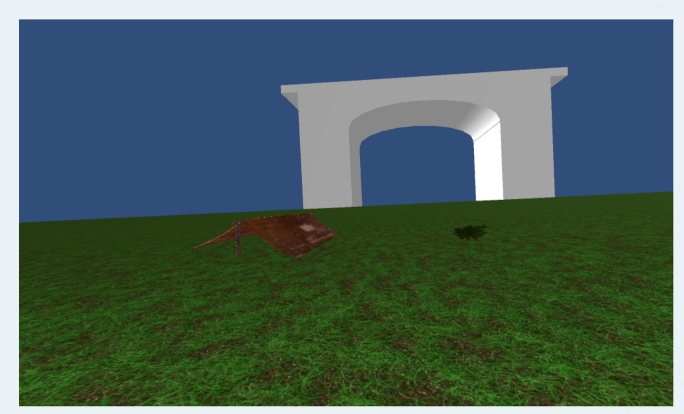
Each participant completed a total of 72 total triangle completion trials. Half of the trials were completed in each of the two environments (**Landmarks** and **No Landmarks**):

Landmark environment
Nearby and distant landmarks are placed throughout the environment.



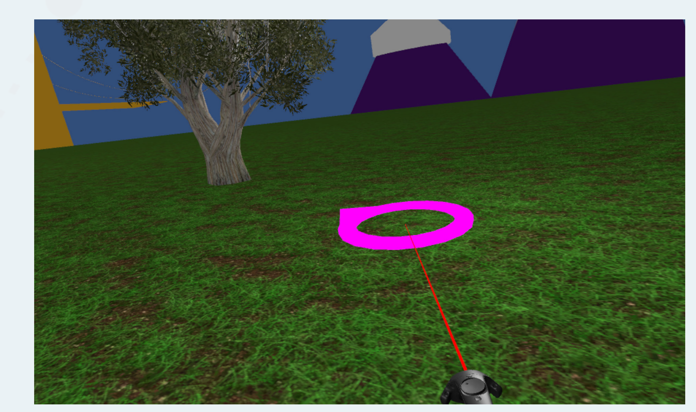
No Landmark environment
Environment features a plain blue skybox and a grass-textured plane.

Within each environment, one third of the trials were completed in each of the three interfaces (**Concordant**, **Partially Concordant**, and **Discordant**):



Concordant interface
Participants physically walk and turn to move through the environment.

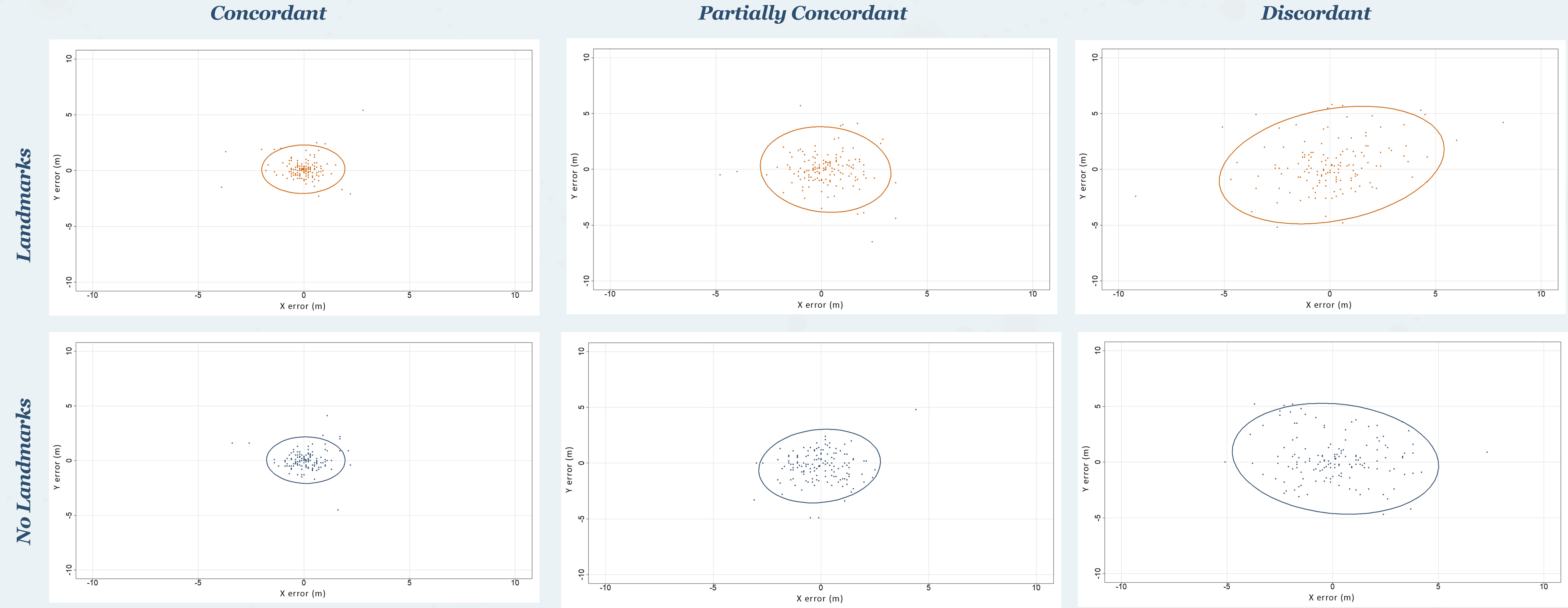
Partially concordant interface
Participants use the controller to change position but physically turn in the environment.



Discordant interface
Participants use the controller to change position and orientation in the environment.

Participants were guided along each leg of the triangle using three colored markers that disappeared on contact. Sides and angles of the triangles used were randomly generated. The first side length was either 1.52, 1.68, or 1.83 meters; the second side length was 1.22, 1.37, or 1.52 meters; and the angle was 22.5, 45, 67.5, 90, 112.5, or 135 degrees to the left or to the right.

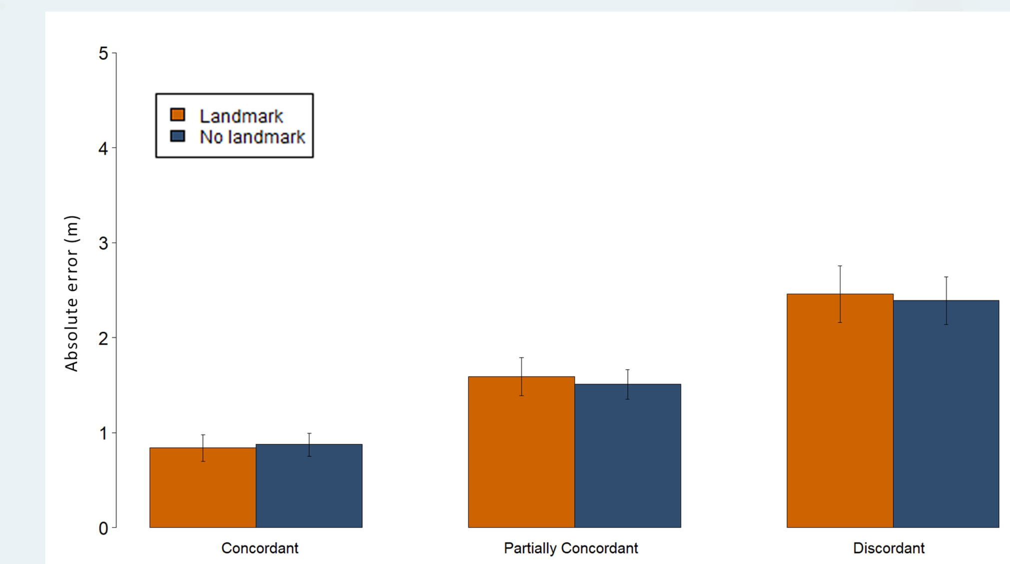
Responses



Confidence Ellipses — Scatter plots of x and y error in responses. Ellipses are based on 95% confidence intervals.

Results

An ANOVA test revealed a significant effect of interface ($F(2,20) = 34.659$, $p < 0.001$). Further contrast tests revealed that performance in the **Concordant** condition was significantly better than in the **Partially Concordant** condition ($F(1,10) = 29.514$, $p < 0.001$), and performance in the **Partially Concordant** condition was significantly better than in the **Discordant** condition ($F(1,10) = 16.036$, $p < 0 .005$).



Absolute distance error across interfaces
A comparison of error (the distance between the participant's response and the actual start position) separated by navigation interface and environment. Error bars represent 95% confidence intervals.

Conclusions

Results suggest the following:

- As predicted, body-based cues affect spatial updating, regardless of environment.
- Contrary to the second prediction, landmarks did not reduce errors.

Discussion

Walking and turning with the body were both important predictors of navigation success. Body rotation was better than no body rotation, and body rotation plus walking was better than body rotation only. It is unclear why landmarks did not reduce errors, but it is possible that landmarks placed within the navigation space would prove more helpful.

This suggests that although physical space constraints often dictate navigation interface decisions, body movement should be concordant with movement through the VE whenever possible to enable more successful navigation in virtual environments.

Future work can examine the effects of landmarks on VE navigation, using different landmark placements. Additionally, researchers can see whether some people benefit more from body-based cues than others, for instance if people who are of lower spatial ability might be more adversely affected by discordant interfaces.