Navigating Virtual Environments: Do Physical Rotations Aid in Orientation?

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Introduction

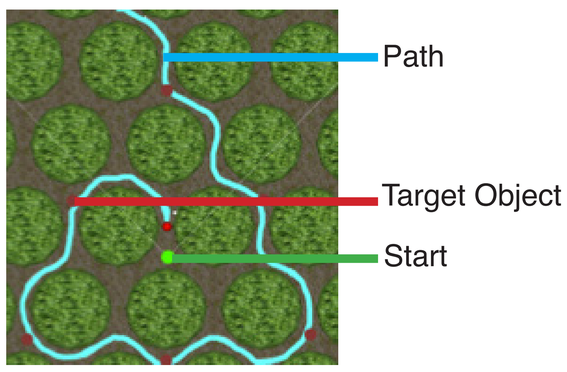
Spatial orientation	Knowing where you are in space is essential for navigation in the real-world and virtual environments (VEs)
Physical locomotion	Might help orientation in VEs compared to only visual information
Drawbacks	High costs and space constraints often make physical movements in VEs difficult to implement
Motion cueing	The body can be tricked into thinking it is actually moving with small, yet effective, movements
Literature gap	How much and what kind of motion is required to significantly increase orientation performance?
Previous work	Physical rotations benefitted men, but not women, in a virtual navigation task compared to visual-only locomotion (Grechkin & Riecke, 2014)
Our approach	Uses a different 360 degree rotating stool combined with a joystick and head mounted display to evaluate spatial orientation

Hypothesis: spatial orientation performance will improve for body-based physical locomotion interfaces

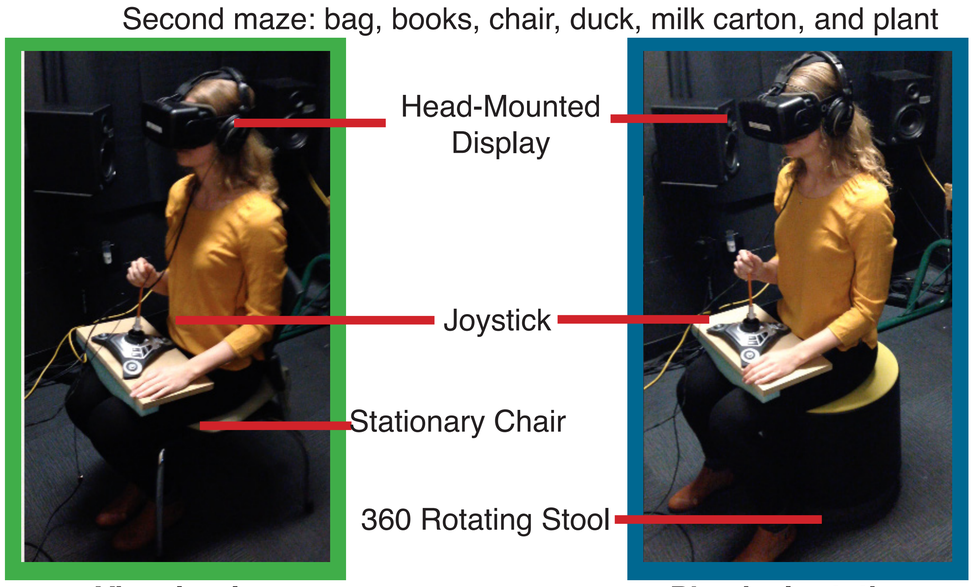
Methods

Pointing Performance assessed in three ways

1. Accuracy: mean absolute pointing error
2. Systematic Bias: absolute ego-orientation error
3. Variability: configuration error



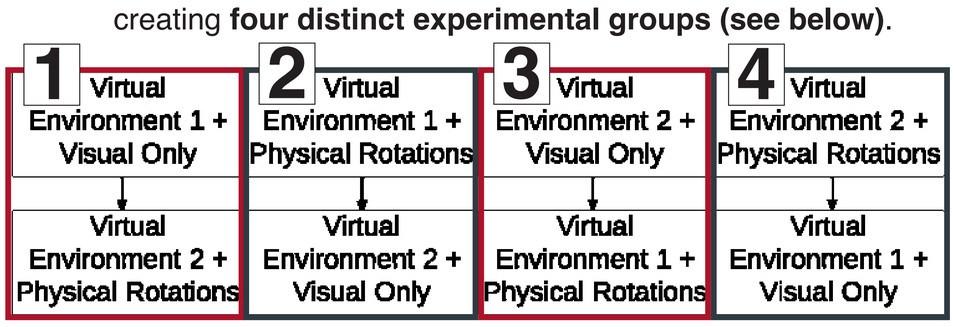
Participants	Fifteen (7 female)
Environment	Virtual hexagonal maze (above), with first-person point of view (left) and top down view (right). Two maze versions (mirror images)
Task	Following a **path** & guided by a red sphere, participants successively learned six target objects; at each **target object** stopped to point to all previous targets and the **starting location** (in random order) as accurately and quickly as possible
Objects	First maze: boot, car, coke bottle, lamp, plane, and train Second maze: bag, books, chair, duck, milk carton, and plant



Visual-only
Non-rotating chair & joystick for both forward movement & rotation

Physical rotations
360° rotating chair for rotations & joystick for forward movement only

Procedure Each participant completed the navigation task twice – first using one and then the other locomotion interface. The order of interfaces and the order of presentations for two variations of VEs were counter-balanced, creating **four distinct experimental groups (see below)**.

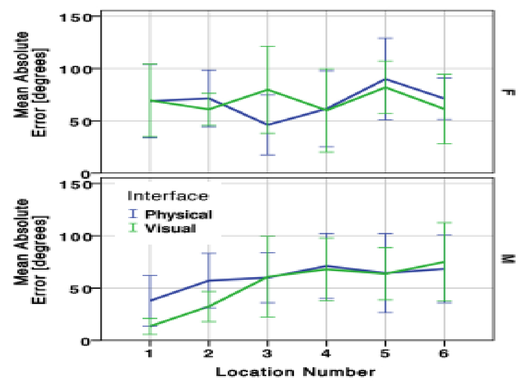


Results

Analysis
Mixed-design 2x2x6 ANOVA
IVs: interfaces (within), gender (between), and location (within)

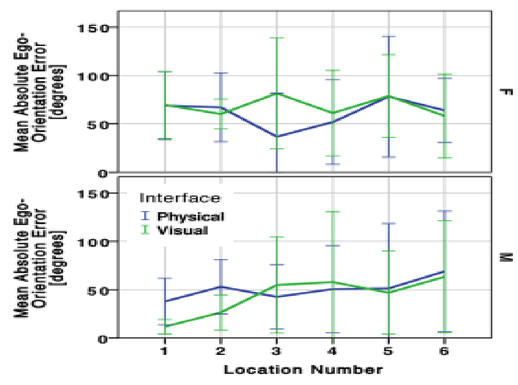
1. Accuracy: Mean Absolute Pointing Error

Accuracy decreases significantly up to the 3rd location in a test of between-subjects effects, $F(5, 59) = 2.812$, $p = .024$, $\eta^2 = .192$.
The remaining effects, main, gender and interface, were non-significant.



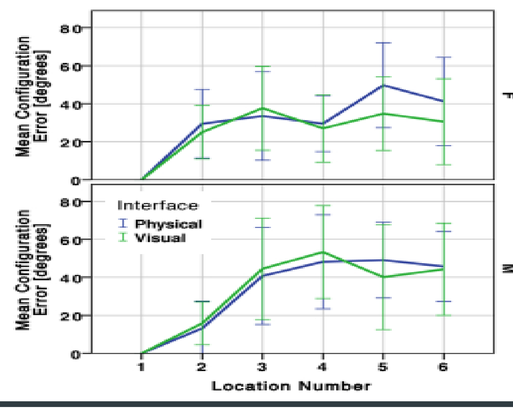
2. Systematic Bias: Absolute Ego-Orientation Error

Females (M = 62.54, SE = 4.60) showed a significantly greater ego-orientation error when pointing than males (M = 46.42, SE = 5.44), $F(1, 60) = 5.110$, $p = .027$, $\eta^2 = .078$.
All other effects, main effects and interactions, were non-significant.



3. Variability: Configuration Error

Visual only condition yielded a lower configuration error (M = 29.04, SE = 2.26) compared to the physical rotation condition (M = 34.47, SE = 2.45), $F(1, 60) = 5.160$, $p = .027$, $\eta^2 = .079$.
Location was a significant between-subjects factor, $F(5, 60) = 12.026$, $p < .001$, $\eta^2 = .501$.
There were no significant interactions.



Discussion and Conclusions

Pointing error increases after three locations

Mean absolute pointing error and configuration error seem to be in agreement.
The task was designed to be difficult, so these results are in keeping with participants' getting disoriented after three locations.

Systematic bias greater in females than in males

Ego-orientation gender effect is consistent with a previous study (Grechkin & Riecke, 2014), which found that men benefitted from using physical rotations versus visual only rotations where women did not; yet, no gender effect for mean absolute pointing error nor configuration error in this study.
Results seem to be consistent with women relying more on landmarks (Lambrey & Berthoz, 2007) (not present in our virtual maze) when navigating, and their performance decreasing when none are present.

Variability minimally affected by the means of locomotion interface

Participants had a higher variability in pointing estimates for the physical rotations condition compared to the visual only condition.

Spatial orientation did not improve for body-based physical locomotion interfaces

Post-experimental debriefing suggests this lack of a benefit from physical rotation might be related to the inconsistency of using body movements only for rotations, but not translations.
We are currently developing the NaviChair based on these findings.

References

Grechkin, T. Y., & Riecke, B. E. (2014). Re-evaluating Benefits of Body-based Rotational Cues for Maintaining Orientation in Virtual Environments: Men Benefit from Real Rotations, Women Don'T. In Proceedings of the ACM Symposium on Applied Perception (pp. 99–102). New York, NY, USA: ACM.
Lambrey, S., & Berthoz, A. (2007). Gender differences in the use of external landmarks versus spatial representations updated by self-motion. Journal of Integrative Neuroscience, 06(03), 379–401.

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