Effect of Physical Rotation and Gender for Navigational Performance in Virtual Environments

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Introduction

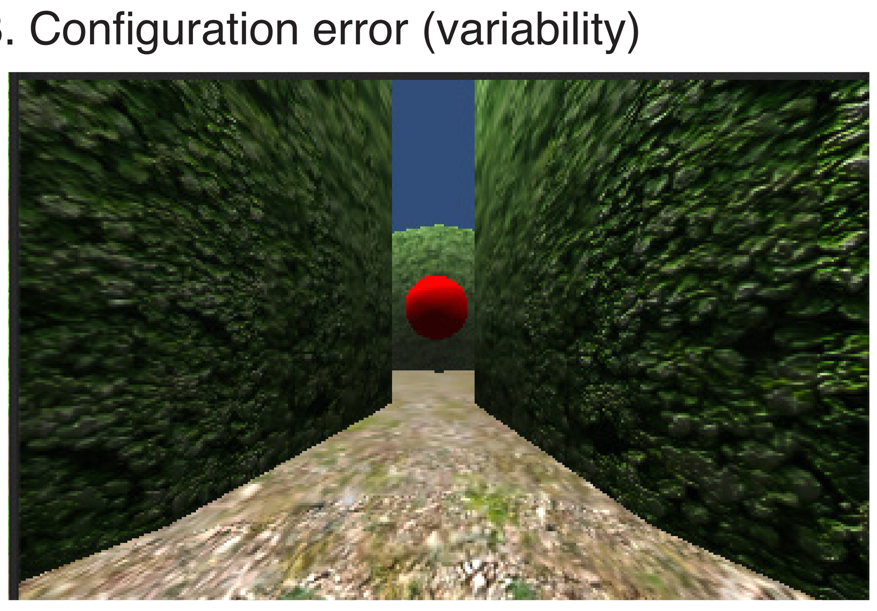
Knowing where you are in space is essential for navigation; this is true for real-world as well as virtual environments. It seems like physical locomotion will better the experience of virtual environments, but high costs and space constraints often make physical movements in virtual environments difficult to implement. However, the body can be tricked into thinking it is actually moving with small, yet effective, movements.

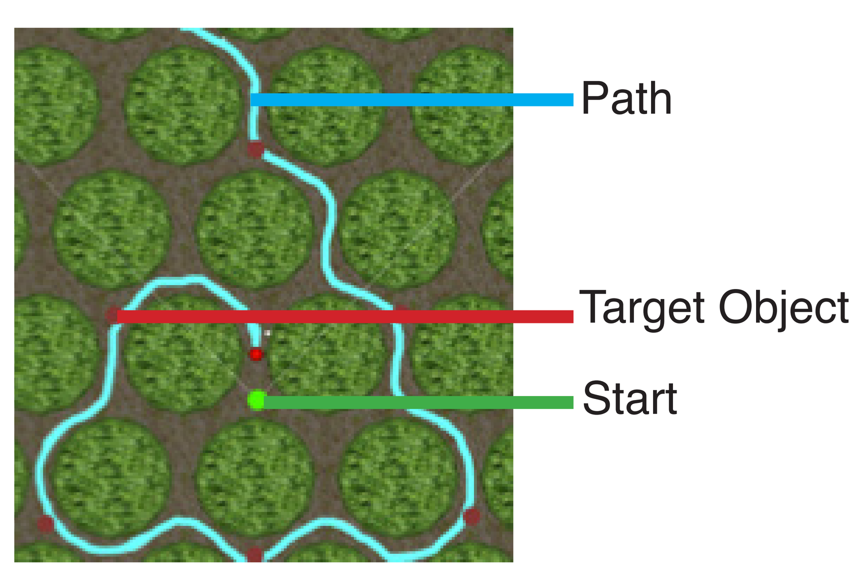
Physical motions may help orientation in virtual environments compared to only visual information. However, it remains unclear how much and what kind of motion is required to significantly increase orientation performance. A recent study found that physical rotations benefitted men, but not women, in a virtual navigation task compared to visual-only locomotion (Grechkin & Riecke, 2014). In this study, we use a different 360 degree rotating stool combined with a joystick and head mounted display to evaluate spatial orientation.

We hypothesize **spatial orientation performance will improve for body-based physical locomotion interfaces**.

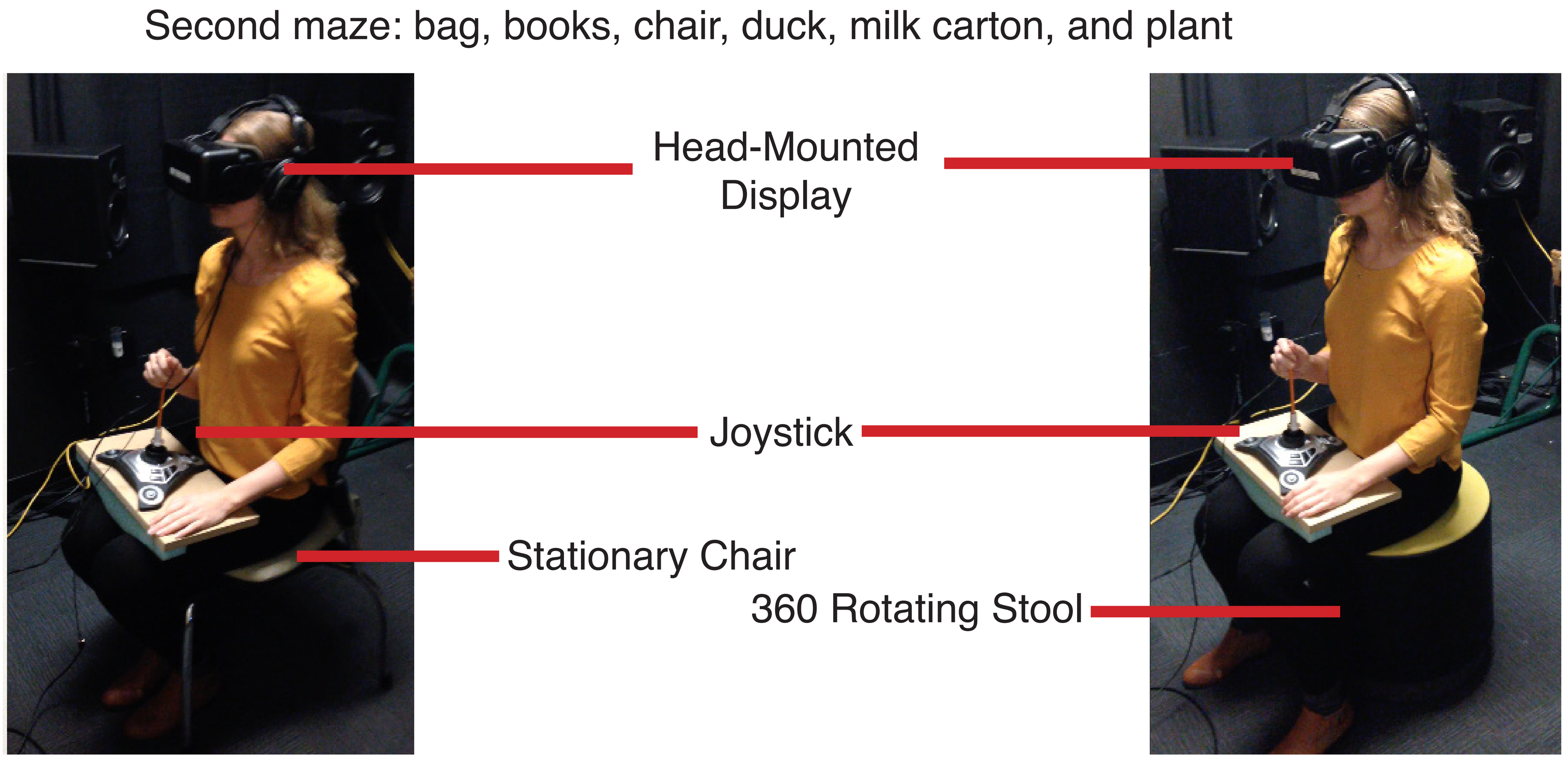
Methods

Participants: Fifteen (7 female)
Pointing performance assessed in three ways:
1. Mean absolute pointing error (accuracy)
2. Absolute ego-orientation error (systematic bias)
3. Configuration error (variability)





Environment: Virtual hexagonal maze (above), with first-person point of view (left) and top down view (right). There were two maze versions, which were mirror images.
Task: Guided by a red sphere, participants successively learned one target object after another (6 total), and 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



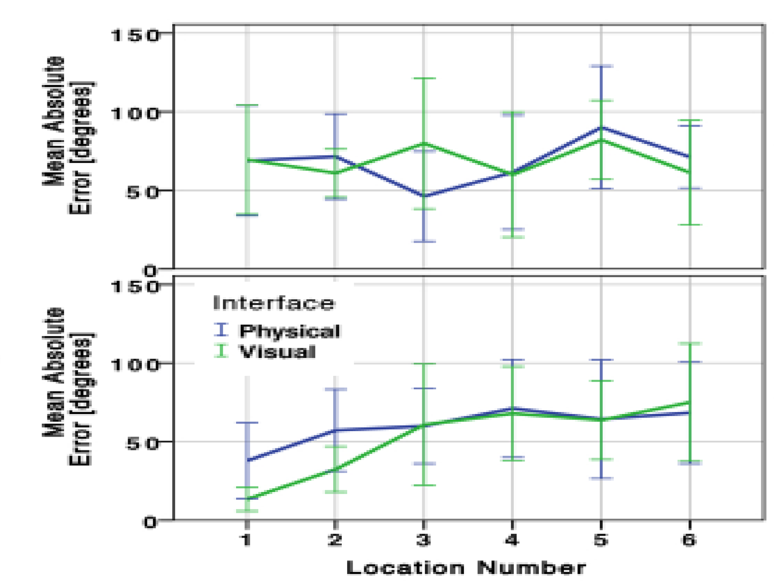
Compared two locomotion interfaces (above):
1. Visual-only (left): non-rotating chair and joystick used for both forward movement and rotation
2. Physical rotations (right): 360 chair and joystick used for forward movement only

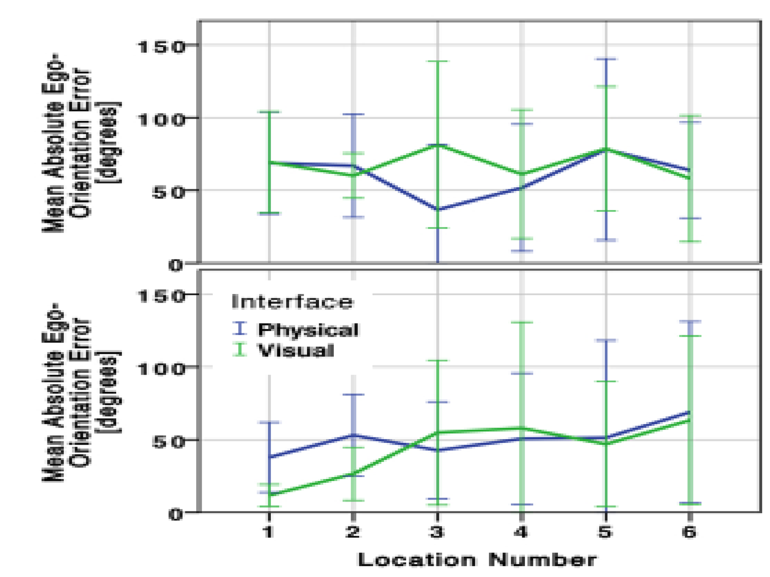
Virtual Environment 1 + Visual Only	Virtual Environment 1 + Physical Rotations	Virtual Environment 2 + Visual Only	Virtual Environment 2 + Physical Rotations
Virtual Environment 2 + Physical Rotations	Virtual Environment 2 + Visual Only	Virtual Environment 1 + Physical Rotations	Virtual Environment 1 + Visual Only

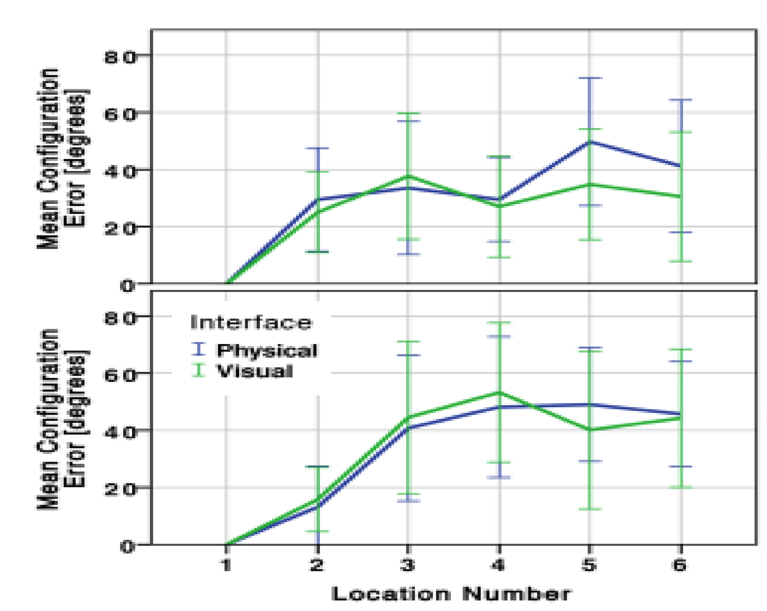
Procedure: Each participant completed the navigation task twice – first using one and then the other locomotion interface. The order of interfaces and the order of presentations for two variations of virtual environments were counter-balanced, creating four distinct experimental groups (see above).

Results

Analysis: We performed a mixed-design 2x2x6 ANOVA. The independent variables were interfaces (within), gender (between), and location (within).
Mean absolute pointing error (top):
A test of between-subjects effects revealed location to be a significant factor, $F(5, 59) = 2.812$, $p = .024$, $\eta^2 = .192$, indicating that mean absolute pointing error was significantly different depending on the which object location the observer was at, i.e., whether they were first, second, third, etc. The effect size is medium, accounting for 19.2% of the variance. The remaining effects, main, gender and interface, were non-significant.
Absolute ego-orientation error (middle):
Females ($M = 62.54$, $SE = 4.60$) howed a significantly greater ego-orientation error when pointing than males ($M = 46.42$, $SE = 5.44$), $F(1, 60) = 5.110$, $p = .027$, $\eta^2 = .078$. The effect size is very small, indicating a negligible effect. All other effects, main effects and interactions, were non-significant.
Configuration error (bottom):
The visual only condition yielded a lower configuration errors ($M = 29.04$, $SE = 2.26$) compared to the physical rotation condition ($M = 34.47$, $SE = 2.45$), $F(1, 60) = 5.160$, $p = .027$, $\eta^2 = .079$. A small effect size was observed. Location was a significant between-subjects factor, $F(5, 60) = 12.026$, $p < .001$, $\eta^2 = .501$, signifying that the effect of location on configuration error was medium to substantive. There were no significant interactions.







Discussion and Conclusions

Consistent with our predictions, all three measures seem to indicate different factors having an influence on pointing performance.

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

Absolute ego-orientation error appears to be greater in females than in males. Our result of 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. However, this study did not find the gender effect for mean absolute pointing error nor configuration error. Our results also 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.

Finally, **configuration error was minimally affected by the means of locomotion interface**. Meaning that participants had a higher variability in pointing estimates for the physical rotations condition compared to the visual only condition.

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. This suggests that **embodied interfaces should include at least some physical translation or translational motion cueing**, like the NaviChair we are currently developing 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. doi:10.1145/2628257.2628275
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. http://doi.org/10.1142/S021963520700157X

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