Lack of 'Presence' May be a Factor in the Underestimation of Distances in Immersive Virtual Environments

Victoria Interrante[1], Lee Anderson[2] and Brian Ries[1]   [1]Department of Computer Science and Engineering   [2]Department of Architecture   University of Minnesota

Motivation

Numerous researchers have reported evidence of a significant compression of perceived egocentric distance in immersive virtual environments (IVEs) presented via head-mounted displays (HMDs). However, the factors that contribute to this phenomenon remain to be fully elucidated. In this study we investigated the possibility that observers' judgments of egocentric distance in immersive virtual environments may be affected by the cognitive discordance in 'presence' that occurs as a result of their being visually immersed in a virtual environment that is not the same place as the actual physical environment in which they are situated.

Methods

Using direct blind walking, we assessed participants' estimates of egocentric distance under two cognitively different immersion conditions: one in which the presented virtual environment was unambiguously known to be a perfectly registered, high fidelity 3D model of the same space in which the user was physically located (the *room* environment), and one in which the presented virtual environment was unambiguously known to be a high fidelity 3D model of a different real space (the *hallway* environment).

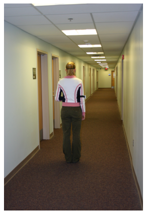
We used a mixed design with three independent variables. The within-subjects variable was *technology*: whether the distance judgments were made in the real world, or in a virtual model of the same real world space, presented via a head mounted display. We did this as a within-subjects measure in order to establish a control level of performance for each individual, as well as for each environment. The two between-subjects variables were: *place* (room or hallway), and *exposure* (whether the distance judgments were made in the real world first or in the virtual world first).

Twenty participants were recruited from the University of Minnesota and the Minneapolis community for this experiment. Each participant was arbitrarily assigned to one of four place/exposure conditions: real room then virtual room, virtual room then real room, real hall then virtual hall, or virtual hall then real hall. Each participant completed 30 trials of blind walking: 10 in the real environment and 20 in the virtual environment. The distance interval used for each trial was determined randomly and constrained to be in the range 8-25'. Participants underwent no training, and received no feedback about their performance at any time.

All virtual environment testing physically took place in our lab, a room, shown in the images to the right, which houses a large curved screen display along one wall, and has approximate dimensions of 30' long by 25' wide in the center, tapering down to 16.5' wide at the edges. Real world testing took place either in the lab (for those who experienced the 'room' condition) or in a long hallway located on the 4th floor of the same building. All participants had a chance to see (but not to walk around in) the lab space before donning the head mounted display.

To create the virtual environments, also shown in the images to the right, we built high fidelity 3D models of the real room and hallway spaces using the architectural system SketchUp and textured them with high resolution photographs of the corresponding surfaces. The virtual environments were presented via an nVisor SX head mounted display, which offers separate 1280x1024 resolution images to each eye over a 60° diagonal monocular field of view (about 2.2 arc minutes per pixel), with 100% stereo overlap. This HMD weighs approximately 1 kg, and is attached by a set of 15' cables to a video control unit, which was mounted on a short wheeled cart that could be pulled around by tugging on the cables. An assistant managed the cables at all times during testing, making their presence transparent to the participant. The position of the viewpoint used for image generation was updated at a rate of 500Hz using a HiBall 3000 optical ceiling tracker.



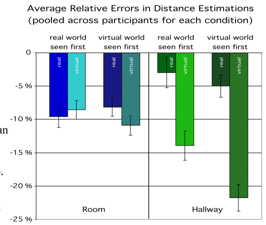
Photographs of the real environments used our study: Above: the room; Right: the hallway.




Screen captured images of the high fidelity virtual environments used in our study. Left pair: room; Right pair: hallway.

Findings

Our most important finding is that a significantly greater amount of distance under-estimation was observed in the non-co-located virtual environment (virtual hallway, relative to the real hallway), than was observed in the co-located virtual environment (virtual room, relative to the real room).

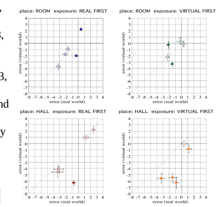


Average relative errors in distance estimates, pooled across all participants who experienced the same experimental conditions. The error bars represent ± 1 standard error of the means in each case.

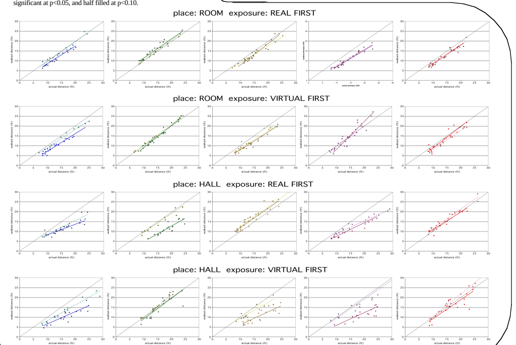
A three-way mixed analysis of variance of the errors across *place* (room vs. hall), *exposure* (real world first vs. virtual world first), and *technology* (trials done in the real environment vs. trials in the virtual environment) found a significant main effect of technology {F(1,392)=18.05, p<0.001} and a significant two-way interaction between technology and place {F(1,392)=20.28, p<0.01}.

A two-way ANOVA over technology x exposure for the room data alone found no significant main effect of either technology {F(1,196)=0.06, p=0.80} or exposure {F(1,196)=0.41, p=0.52}. However, looking at the hallway data alone, this two-way ANOVA found a significant main effect of technology {F(1,196)=25.98, p<0.0001} but not of exposure {F(1,196)=2.55, p=0.11}.

A two-way ANOVA over place x exposure for real world data alone found a marginally significant main effect of place {F(1,196)=2.73, p<0.1}, and no significant main effect of exposure {F(1,196)=0.03, p=0.85}. Looking at the virtual world data alone, this ANOVA also found a significant main effect of place {F(1,196)=19.02, p<0.001}, but not of exposure {F(1,196)=2.02, p=0.16}, and a marginally significant two-way interaction between place and exposure {F(1,196)=2.90, p<0.1}.



Average errors (ft) in real world vs. virtual world distance estimates made by each participant. The error bars represent ± 1 standard error of the means in each case. The circles are fully filled when the difference is significant at p<0.05, and half filled at p<0.10.



Plots showing all of the individual distance judgments made by each participant. Estimates made in the virtual environment are shown as filled points; outlined points represent estimates made in the real world. Solid line shows best linear fit to the virtual world data; dashed line shows best linear fit to the real world data.

Conclusions

Through this study, we have provided some insight into one possible factor contributing to the widely reported phenomenon of apparent distance compression in virtual environments, namely the cognitive discordance in presence that may be associated with the awareness that one is visually immersed in a virtual environment that is not the same place as the occupied real environment. Notwithstanding the difficulties of quantifying 'presence', it stands to reason that if a person does not believe himself to be actually physically 'present' in the visually presented virtual environment, his actions in that environment may not be truly indicative of the actions that he might make under similar circumstances in the real world. Although for most practical applications involving immersive virtual environments, it is not desirable to have the IVE represent the same space that the participant occupies in reality, knowing that nearly veridical judgments of egocentric distance can be achieved in such an IVE mayhelp elucidate the question of how better to enable participants to accurately perceive distances in other IVEs.

This work was supported by the National Science Foundation through grants CCR-0313226, EIA-0323471 and ACI-9875368, by the University of Minnesota through a Digital Technology Center seed grant, and by the Linda and Ted Johnson Digital Design Consortium Endowment and Lab Set-up Funds.