A little unreality in a realistic replica environment degrades distance estimation accuracy

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ABSTRACT

Users of IVEs typically underestimate distances during blind walking tasks, even though they are accurate at this task in the real world. The cause of this underestimation is still not known. Our previous work found an exception to this effect: When the virtual environment was a realistic, co-located replica of the concurrently occupied real environment, users did not significantly underestimate distances. However, when the replica was rendered in an NPR style, we found that users underestimated distances. In this study we explore whether the inaccuracy in distance estimation could be due to lack of size and distance cues in our NPR IVE, or if it could be due to a lack of presence. We ran blind walking trials in a new replica IVE that combined features of the previous two IVEs. Participants significantly underestimated distances in this environment.

1 INTRODUCTION AND PREVIOUS WORK

Immersive virtual environments (IVEs) have the potential to become important tools in architecture and design. In object design, they allow the designer a first-person view of his or her creation at full scale without the expense of building a physical model. In architectural design, they can free the designer from the constraints imposed by the computer screen or the drafting board, which can have an unintended effect of framing the design, leading the user to design an object for the context of that two-dimensional frame. Since perception of space is so important in architectural design objects, we need to understand how humans perceive space in virtual environments if they are to be effectively used for this purpose.

Typically an IVE is used to display a model that was created somewhere else, but we feel there is great promise in using IVEs from the earliest steps in the design process, including sketching out initial concepts. NPR is an appropriate technique in this situation. Because NPR can be used to show only the important details, it is good for rendering designs where some details have yet to be specified. NPR can also render designs in a sketch-like style, which signals to the viewer that the design is unfinished. Customers who view a realistic early rendering will be less willing to offer opinions about the design or ask for changes, which leaves them less happy with the finished product [6].

Klein et al. [4] were the first to consider NPR virtual environments. They solved many technical issues in creating painterly-rendered environments. Gooch and Willemsen [2] and Thompson et al. [7] compared blind walking performance in environments of differing quality, including an NPR wireframe environment, and found that participants estimated distances poorly in all the environments, leading them to conclude that the quality of graphics does not have an effect on distance estimates.

Most studies find that users underestimate distances on blind walking tasks in virtual environments; however, our previous work found that participants in a high-fidelity virtual replica that is co-located with the real environment that it replicates (i.e. participants come into the lab, put on the HMD, and then see the same lab) do not significantly underestimate distances [3]. The replica had been created by mapping photographic textures onto the walls of the model. Since the previous NPR studies did not consider replica environments, we repeated our experiment with an NPR replica, which we created by swapping line drawings in place of the photographic textures, giving the IVE a wireframe effect where the lines were registered with the major edges in the room. In this NPR environment participants were no longer accurate, they walked short [5].

We suggested that users walked accurately in the realistic replica because they felt present, as if virtual environment was really the world they were occupying, and that they underestimated in the NPR environment because their surroundings were so unreal that, even though they knew it was the same room, they no longer felt present and were no longer drawn to behave as they would in the real world. An alternate explanation is that participants took cues from the realistic textures that helped them judge distances, but our NPR textures removed too many of those cues.

2 EXPERIMENT

The experiment was conducted in our virtual reality lab, which is a 30' by 16.5' room that widens to 25' in the middle due to a curved, panoramic display along one wall. The HMD was an nVis nVisor SX, which has two 1280 x 1024 displays with 100% stereo overlap and a 60° field of view, as specified by the manufacturer. Head tracking was provided by a 3rdTech Hiball 3000 that was mounted on the ceiling. The virtual environment was rendered in real time by the OGRE game engine.

In the original high-fidelity replica, texture maps were created for the model from photographs taken of the interior of the lab. For the later NPR study, we used an image editing program to trace over the major edges of the photographs with black lines and then put those lines on a white background. For the study reported here we created a new virtual replica environment by taking the black lines from the NPR textures and overlaying them over the photographic textures. These new textures contained the fine detail of the original photographic textures, but included an additional element of unrealism by superimposing dark lines on the major edges in the environment. (Figure 1.)

Ten participants were recruited from our university's staff and student population, were screened for normal stereo vision, and were compensated with a gift card. Participants entered the lab and were given written instructions. They put on the HMD and then performed 20 direct blind walking trials. In each trial participants sighted a virtual piece of tape on the floor. Then they closed their eyes, notified the experimenter, who recorded their position and blanked the screen, and then walked to where they thought the tape was. The experimenter recorded the participant's position, and then an assistant directed the subject to the edge of the room and turned them around to perform the next trial in the opposite direction. The distances to the target tape were randomly generated. After completing the trials in the virtual environment, the participants performed 10 blind walks in the real environment. Participants had

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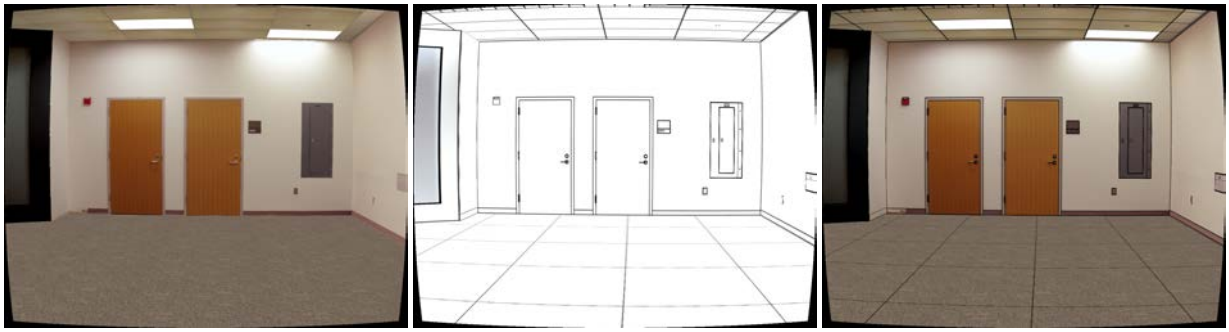
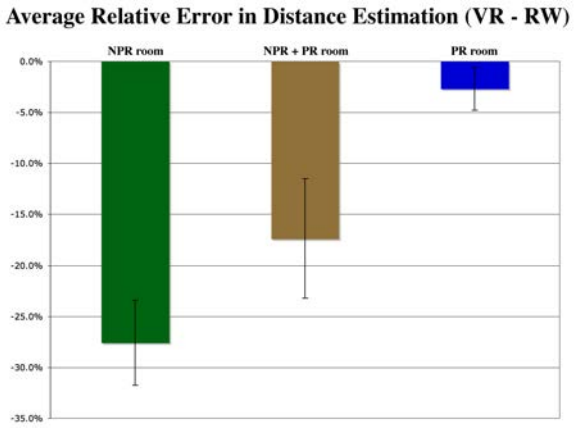


Figure 1: High-fidelity, NPR, and enhanced-NPR replicas of our lab.

a blindfold to cover their eyes and strips of cloth were used as the targets. Participants were not given feedback on their performance during the experiment.

2.1 Results and Discussion

Participants who saw the enhanced NPR environment underestimated distances by 17.36% on average, compared to their performance in the real world, while participants in the realistic environment underestimated by 2.68%, and participants in the original NPR environment underestimated by 27.57%. The difference between the errors in the enhanced NPR environment and the realistic environment is significant $F(1,18) = 5.348$, $p = 0.033$, but the difference between the enhanced NPR and the original NPR environments is not statistically significant $F(1,16) = 1.756$, $p = 0.204$. (Figure 2.1.) Readers should be aware that these comparisons are between experiments conducted at three different times, but using the identical protocol.



Participants underestimate distances in the enhanced NPR environment significantly more than participants in the high-fidelity environment. Since the enhanced NPR textures contain nearly the same amount of detail as the the original photograph, we feel the lack of detail was not the main cause of participants' underestimation in the original NPR environment. We suggest that the unrealism of the thick outlines in the enhanced NPR textures was sufficient to degrade participants' sense of presence in the virtual environment, interfering with their interpretation of its affordances for action.

3 Future Work

In the original realistic environment, it is easy to overlook the fact that most of the detail comes from two-dimensional photographs. Our subjective experience of the NPR and enhanced textures is that they look much more flat than the photographs. Doors and other fixtures in the walls appear more like big decals than their real-world counterparts. In future work we plan to move from our textured box to a more geometrically-detailed model.

We think that presence may be more readily achieved in NPR virtual environments if the user is encouraged to interpret the view through the HMD as not images of an artificial place, but rather as a view through a pair of magic glasses that translate the real world into a different style. The fact that visitors to our lab often mistake the realistic replica for live video, suggests an experiment: A dual camera video see-through augmented reality system could be used in conjuction with software to process the video and render it in an NPR style, as demonstrated for single camera images by Fisher et al.[1].

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