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Peripheral Visual Information and Its Effect on the Perception of Egocentric Depth in Virtual and Augmented Environments

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Abstract

A frequently observed problem in virtual environments is the underestimation of egocentric depth. This problem has been described numerous times and with widely varying degrees of severity. Though there has been considerable progress made in modifying observer behavior to compensate for these misperceptions, the question of why these errors exist is still an open issue.

The study detailed in this document presents the preliminary findings of a large, between-subjects experiment (N=98) that attempts to identify and quantify the source of a pattern of adaptation and improved accuracy in the absence of explicit feedback found in Jones et al. [1].

Keywords: depth perception, augmented reality, virtual reality, perceptual adaptation

Introduction

Underestimation of depth in virtual environments is a well studied phenomenon. However, the degree by which underestimation occurs varies widely from one study to the next, with some studies reporting as much as 68% underestimation in distance and others with as little as 6% (Jones et al. [2]). Jones et al. [1] reported an interesting pattern of improved judgment of depth in both virtual and augmented environments as exposure continued over an approximately 20 minute period of performing visually directed blind walking. Generally speaking, adaptation with continued experience performing a given task in a virtual environment is not uncommon when observers are provided with feedback (e.g., Richardson and Waller [3]). However, the adaptation seen in Jones et al. [1] occurred in the absence of explicit feedback. This implies that observers were receiving corrective information from some uncontrolled aspect of the experiment. The experiments reported here attempt to identify this source of inexplicit feedback and quantify its effects.

Experiment 1

After careful examination of the experimental procedures used in Jones et al. [1], no sources of feedback indicative of the observers' performance could be found. This seems to indicate that the source of feedback is not correcting the observers' behavior in the environment but is correcting the observers' perception of the environment itself. Two possible sources were identified: proprioceptive feedback from the blind walking task itself and peripheral visual information available via a small gap between the HMD and the observer's face. Experiment 1 attempts to identify which of these potential sources of feedback could be influencing observers' perception of the virtual environment.

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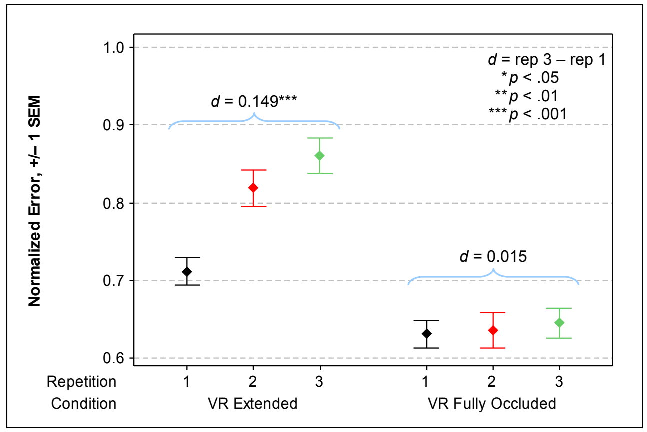

Figure 1: Normalized error in the extended walking and fully occluded periphery conditions separated by task repetition. As indicated, d, a measure of effect size, is the difference between the third and first repetition. An asterisk(s) indicates a significant difference of repetition for the condition (ANOVA).

This experiment compared two conditions: extended walking and fully occluded periphery. A detailed description of the experimental conditions is given in the Appendix. The extended walking condition was intended to ambiguate any proprioceptive feedback by forcing observers to perform their return from a randomly selected distance further than their judgment distance. The fully occluded periphery condition involved blocking all gaps between the HMD and the observer to prevent exposure to any peripheral visual information. These conditions were tested only in a completely virtual environment as this environment exhibited the strongest adaptation effect in Jones et al. [1].

Experiment 2

Experiment 2 attempted to quantify the effect of peripheral visual information. This experiment compared four conditions that systematically varied the availability and position of visual information available on the return walk portion of the blind walking task. These include fully occluded periphery, partially occluded periphery, restricted field-of-view, and the unmodified condition from the previously described study in Jones et al. [1], which will henceforth be referred to as the "standard" condition. A detailed description of the experimental conditions is given in the Appendix. These conditions were tested in both augmented and virtual environments.

Results

Experiment 1 aimed to determine if the source of uncontrolled feedback was proprioceptive information gained by walking the judged distance twice (once during the judgment walk and again during the return walk) or peripheral visual information, such as optical flow. By systematically removing these sources of feedback, one would expect no adaptation to occur in the suspect condition. Figure 1 clearly shows that observers in the extended walking con-

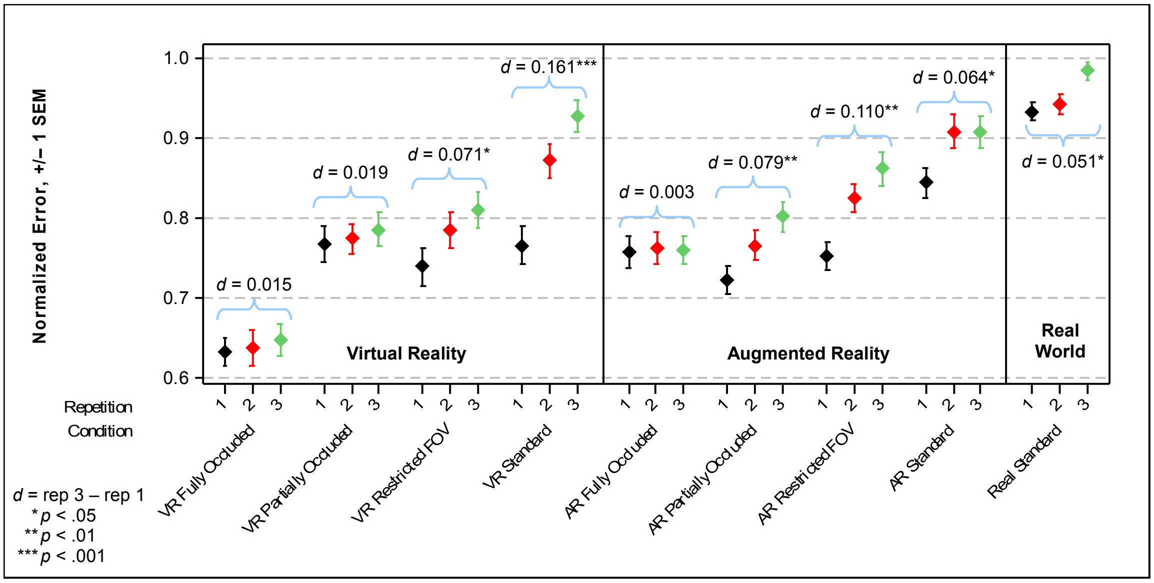

Figure 2: Normalized error in the peripheral restriction conditions in virtual reality, augmented reality, and the real world.

dition exhibited significant adaptation, indicating that proprioception is an unlikely source of feedback. However, observers in the fully occluded periphery condition exhibited no significant change in performance. This seems to indicate a relationship between the observed adaptation and the presence of peripheral visual information.

The results of Experiment 2, depicted in Figure 2, revealed that in both augmented and virtual environments observers significantly improved their performance over time in all experimental conditions except the fully occluded periphery condition, as indicated in the results of Experiment 1. The strongest effects of adaptation were seen in the standard, restricted field-of-view, and partially occluded periphery conditions respectively. This ordering also matches the general availability of visual information in each respective condition. This could imply that simply providing observers with a forward view of their surroundings may not be sufficient to fully convey an accurate sense of depth in either an augmented or virtual environment.

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References

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Appendix: Experimental Conditions

Experiment 1

Extended Walking: The observers perform a standard blind walking task. Once the judgment walk is completed, the observers are asked to blindly walk forward until instructed to stop by the experimenter. The observers then perform a standard return walk to the their original starting position.

Fully Occluded Periphery: The observers' peripheral view is occluded by a fully opaque veil that wraps completely around the bottom and sides of the HMD. The observers' forward view through the HMD window is also covered by a rigid, fully opaque occluder. The observers otherwise perform a standard blind walking task.

Experiment 2

Standard: This is the standard blind walking task as described in Jones et al. [2] and Jones et al. [1].

Partially Occluded Periphery: The observers' peripheral view is partially occluded by a semi-opaque veil that wraps completely around the bottom and sides of the HMD. Through the veil observers can see hue and luminance changes, but are unable to see defined shapes or patterns. The observers' forward view through the HMD window is covered by a rigid, fully opaque occluder. Observers otherwise perform a standard blind walking task.

Restricted Field-of-View: The observers' peripheral view is occluded by a fully opaque veil that wraps completely around the bottom and sides of the HMD. The observers' forward view of the real-world surroundings is left unoccluded during the return walk portion of the blind walking task. Observers otherwise perform a standard blind walking task.