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EGOCENTRIC DISTANCE PERCEPTION IN A VIRTUAL ENVIRONMENT USING A PERCEPTUAL MATCHING TASK

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Objective: To determine whether egocentric distance judgments are accurate in a virtual environment using a perceptual matching task. **Methods**: Observers were immersed within a virtual environment consisting of an L-shaped room with a test object (a column) located down one corridor and a comparison object (a flagpole) located down the other. Perceived distances were measured by having the observers move the comparison object to match the distance to the test object. Textures in each corridor were independently varied, as was the size of the test object. **Results:** Significant effects were found for the texture pattern under the test object and for distance, but not for the texture under the comparison object or column size. Performance was best with a regular (brick) pattern. Overall, observers' judgments overestimated distance to the test object by approximately 7%. **Conclusions:** Egocentric distance judgments were relatively accurate compared to past research. Texture affected performance, with a regular pattern producing highest accuracy.

Introduction

Virtual environments offer a safe and cost effective way to expose people to situations that are inaccessible, dangerous, or simply too costly to otherwise expose them to. As such, their use is highly desirable for many types of training operations. The utility of virtual environment for training is restricted, however, by poor transfer of spatial knowledge from the virtual environment to the real world (Witmer, Bailey, Knerr, and Parsons, 1996; Bliss, Tidwell and Guest, 1997; Waller, Hunt and Knapp, 1998; Darken and Banker, 1998). If virtual environments are to be useful for high risk training scenarios, this problem must be overcome.

One possible cause of this training transfer problem may be the poor distance perception that typically accompanies immersion in a virtual environment. Numerous studies have found observers significantly underestimate egocentric distance judgements while immersed in a virtual environment (Witmer and Kline, 1998; Witmer and Sadowski, 1998; Henry and Furness, 1997; James, and Caird, 1995; Lampton et al., 1995). Real world studies reveal that egocentric distances are also underestimated (compressed) in the depth plane when verbal report measures are used (Gilinsky, 1951; Harway, 1963). However, when egocentric distances are estimated using a visually directed action task such as blindwalking, distance estimations are highly accurate (Thomson, 1983; Steenius and Goodale, 1988; Reiser et al., 1990; Loomis et al., 1992).

Several studies have directly compared distance estimations made in the real world with estimations made in a virtual environment using both verbal report measures and visually directed actions. These studies found distance estimations were significantly shorter in the virtual world compared to the real world, for both a verbal report magnitude estimation task (Witmer and Kline,

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1998; Lampton et al., 1995), and for a blindwalking task (Witmer and Sadowski, 1998). An underestimation of distance in a virtual environment likely distorts the large-scale spatial representation of that space, which in turn may limit the degree to which the large-scale spatial information gained in a virtual environment transfers to the real world.

The goal of the current study is to examine distance perception in a virtual environment paying particular attention to factors that might explain why past research has found distance estimation inaccurate. This study will focus on two possibilities that may account for the inaccurate distance perception found by previous studies. The first possibility is the use of texture, and the second is the method by which distance judgments are made in the virtual environment. Studies in virtual environments have typically failed to show significant effects of texture on distance estimations (James & Caird, 1995; Witmer & Kline, 1998). This is surprising since texture is known to be a strong cue to distance (Gibson, 1986), and the lack of a continuous textured surface has been shown to cause inaccurate distance judgments in the real world (Sinai et al., 1998). The current study will manipulate the texture of the ground surface by comparing high-, medium-, and low-density texture patterns on distance estimations. The task employed will be a perceptual matching task, similar to the one used by Sinai et al., (1998), who found the distance estimates using this task were very similar to estimates using a blindwalking task. Therefore, results using this task may be more accurate because it can be considered a visually directed action rather than a verbal report measure.

The current study focused on the role of textural information on distance perception in a virtual environment using a perceptual matching task. Three texture patterns were tested, each with varying degrees of texture density (low, medium, and high relative density). The low-density pattern consisted of a homogeneous carpet pattern, the medium-density pattern was a red brick pattern, and the high-density pattern was natural grass. It was hypothesized that distance judgments would be more accurate when subjects were immersed in an environment containing a high textural density pattern, compared to a low textural density pattern. Secondly, it was hypothesized that the use of the perceptual matching task itself would result in more accurate distance estimations compared to past studies. To reduce size cues, the comparison object, the column, was of two sizes, neither of which was the same as the size of the flagpole.

Methods

Observers Ten military personnel volunteered for this study. All observers reported having normal or corrected to normal vision. All observers signed consent forms prior to testing.

Apparatus The virtual environment was modeled using Multigen and Vega by Multigen-Paradigm Inc., and rendered on a Silicon Graphics Onyx Reality Engine. The frame rate was fixed at 30 frames/second. Head positions were tracked with a Polhemus 3Space Fastrak electromagnetic tracking system with six degrees of freedom. A V8 HMD manufactured by Virtual Research Systems was used to display the scene. The field of view was 60 degrees diagonal and the resolution was 600 x 480 pixels. Observers manipulated the distance of the comparison object using the joystick and a stop button on a BG Systems Flybox.

Stimulus The virtual environment consisted of an L-shaped room 60 meters long, 30 meters wide, and 3 meters tall. Two rectangular columns were used as target objects, one with the dimensions 1.5 meters high by .61 x .61 meters wide, and the other with the same dimensions except 1.8 meters high. The comparison object was a flagpole, consisting of a cylinder .3 x 2.4 meters high with a red triangle on top (the flag). There were three texture patterns used in the experiment. The high-density texture condition was a digitally imaged patch of grass, the medium-density texture condition was a brick pattern, and the low-density condition was a digitally imaged

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patch of green carpet. The assigning of these texture patterns the labels of high, medium, and low textures was arbitrary, but was based on an informal observation of the average distance between texture elements (i.e. blades of grass vs bricks).

Procedure The experimental setup was as follows: the comparison column was placed at some distance down the middle of the left side of the L-shaped room. The flag was located 15 meters from the observer, down the middle of the right side of the L-shaped room. The observer's task was to view the column, then turn 90 degrees to view the other corridor where the flag was positioned. The observer then moved the flag’s position (by using the joystick) until the distance between the observer and the flag was the same as the distance between the observer and the column. The flag could only be moved along the depth plane. Observers were unable to see both the column and the flag at the same time, but they were free to look back and forth as much as they deemed necessary during each trial. The observer’s position in the virtual environment was always the same, located 15 meters from each wall at the corner of the L. When the observer was satisfied with the flag's position, the observer notified the experimenter to initiate the next trial.

Four distances were tested: 5, 10, 20, and 30 meters with 2 different column sizes. The texture on the floor was varied independently in each corridor of the room. Thus, the column could be placed on a high texture pattern while the flag could be placed on a low texture pattern. Using three textures, there were nine total texture combinations used in the experiment. A completely within-subject design consisting of 3 texture conditions for the ground under the comparison object (column), 3 texture conditions for the ground under the target object (flag), 2 column sizes, and 4 distances (3 x 3 x 2 x 4) was used, resulting in 108 total conditions. Each subject performed each condition once. No feedback was given throughout the experiment.

Results

Mean results for ten observers are shown in Figure 1. Over all conditions, observers tended to overestimate the distance to the comparison object by around 7%.

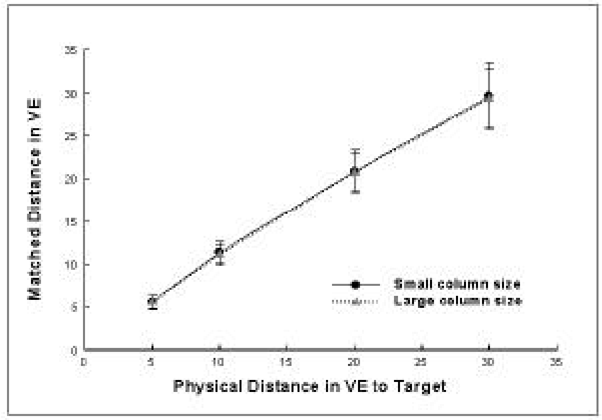

Figure 1. Mean results for ten observers plotted by distance. The values for the 2 column sizes are plotted separately in this graph (see legend). The values for the different texture conditions have been averaged together. The error bars are +/- 1 standard deviation.

A repeated measures ANOVA revealed significant effects for the texture pattern of the ground under the columns ($F_{(2,18)} = 6.62$, $p = .007$), for distance ($F_{(3,27)} = 4.33$, $p = .013$), and for the interaction of the texture of the ground under the columns with distance ($F_{(6,54)} = 3.79$, $p = .0032$). No other effects were significant at an alpha level of .05. The effects of texture can be seen in Figure 2 where the data have been collapsed over column size and distance.

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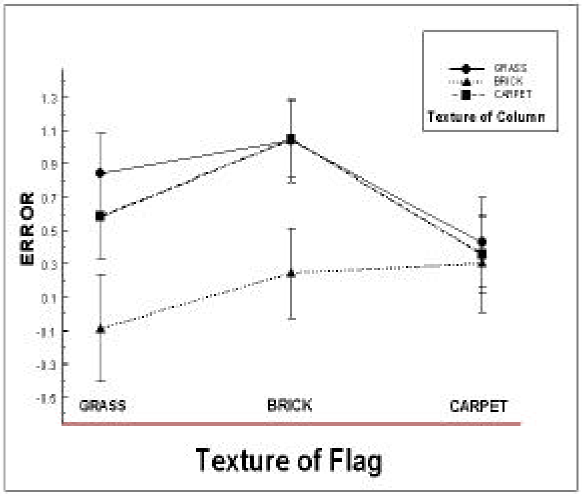

Figure 2. The results shown for the two textured regions, averaged over column size and distance. It can be seen that when the texture of the ground under the column is brick, then mean errors are around zero, while the mean errors for the other conditions are generally slightly higher.

Discussion

This study found that egocentric distance judgments in a virtual environment were relatively accurate compared to past research. Overall, observers tended to overestimate distances by an average of only 7%. This value can be compared to past studies that found observers tend to substantially underestimate distances, sometimes by as much as 47% of the true distance (Witmer and Kline, 1998; Witmer and Sadowski, 1998; Henry and Furness, 1997; James, and Caird, 1995; Lampton et al., 1995). The discrepancy between this study and previous findings may be due to the observer's task. The current study employed a perceptual matching task which in the real world has been shown to achieve similar results as a visually directed action task such as blindwalking (Sinai et al., 1998). Real-world distance perception studies have found that verbal report measures can result in underestimated distance judgments, while visually directed action measures result in highly accurate judgments (Gilinsky, 1951; Harway, 1963; Thomson, 1983; Steenius and Goodale, 1988; Reiser et al., 1990; Loomis et al., 1992). Witmer and Sadowski (1998) measured subjects' VE distance estimates in a visually directed action task while the subject traversed on a treadmill. Witmer and Sadowski found that subjects' distance estimates in the virtual environment were approximately 15% short of the actual distance compared to an 8% underestimate in the real-world control condition. The treadmill may have introduced some methodological problems as other studies have found the use of a treadmill does not improve distance judgments (Witmer and Kline, 1998).

The current study also found significant effects for texture and distance. Although on average observers slightly overestimated distance, for the far column distance observers tended to underestimate the distance. The texture of the ground surface under the column was found to have significant effects on performance, where observers were more accurate when the texture was a brick pattern compared to carpet or grass. This result is contrary to some of the past studies that did not find any effect of texture on distance estimations (Witmer and Kline, 1998; Lampton et al., 1995). Our results show that the symmetrical brick pattern resulted in better performance compared to a relatively low-density pattern of carpet and a relatively high-density pattern of grass. The improved performance with brick may be related to its symmetry, or it may be the case that an optimal amount of density is required for peak performance, where the carpet may have been to low and the grass to high. Further research will be required to test these possibilities.

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