TRAINING IN A VIRTUAL STEREOSCOPIC ENVIRONMENT

Ronald R. Mourant and Lily Parsi
Virtual Environments Laboratory
334 Snell Engineering Center
Northeastern University
Boston, MA 02115

This study investigated transfer-of-training for a pick-and-place task in monoscopic, stereoscopic, and real-world environments. Ten training trials were given to 30 subjects in the three environments (10 subjects each). The averages of task completion time in the stereoscopic and real-world environments were less than those in the monoscopic environment. In a post-training real-world trial, there were no differences due to the training environment (including another group of 10 subjects who received no training). Subjects, who had training in the stereoscopic or real-world environments, were more accurate in the placement of cans at near targets than those who received monoscopic or no training. Thus training in a virtual stereoscopic environment was beneficial in terms of task accuracy. The effectiveness of virtual environments may continue to improve as advances in computer hardware enable higher resolution presentations and reduce system lags.

INTRODUCTION

This study focused on the effect of a stereoscopic presentation when investigating transfer-of-training from a virtual to a real environment. Barfield, Hendrix, and Bystrom (1999) found that the time to complete a wire-tracing task in a virtual environment (VE) was significantly reduced when using a stereoscopic display. In general, the use of a stereoscopic presentation improves performance when near spatial judgments are required (Yeh and Silverstein, 1992). The task we selected to use, pick-and-place, requires the ability to make near spatial judgments. Gupta, Sheridan, and Whitney (1997) used a stereoscopic 3D view as part of a multi-modal VE system that included a haptic interface to study part handling and part insertion. They found that the stereoscopic view marginally improved handling time, but the subjects reported the task using stereoscopic 3D was not easier than when using a monoscopic presentation.

Kozar, Hancock, Arthur, and Chrysler (1993) also used a pick-and-place task to study possible transfer-of-training from a VE. However, their VE training was done using a monoscopic display. They found that VE training had no effect on real-world performance and suggested that improvements in VEs are needed to enable positive transfer of training. A stereoscopic presentation may be one such improvement.

Another study (Kenyon and Afenya, 1995) used a difficult pick-and-place task to investigate transfer-of-training from a VE. Although their sophisticated environment, a CAVE, included a stereoscopic presentation, it was subject to large delays that may have offset any benefit of stereo depth cues. They found some subjects showed a small improvement in performance that may be attributed to the VE training.

METHODOLOGY

Participants

Thirty subjects ranged in age between 22 and 40 years old and were students or staff at Northeastern University. They had normal visual acuity (either corrected or uncorrected) and were paid ten dollars for their participation. All subjects completed the study.

Design

Our method to estimate transfer-of-training was to use a training phase of ten trials followed by a testing phase of one trial in the real world. In the training phase there were three groups (Monoscopic, Stereoscopic, and Real-World) of ten subjects each. The task of the subjects was to move six colored cans from near targets to far targets and back again. This task was similar to that used by Kozar, et.al. The order of can movements is shown in Figure 1. Subjects were instructed to do this as quickly and accurately as possible.

The distance between the near row and the far row was 46 centimeters. Participants in the Stereoscopic Group wore CrystalEyes shutter glasses that were synched with the output of a 19-inch stereo capable monitor. Subjects in the Stereoscopic and Monoscopic groups used the middle button of the mouse for can selection and movement.

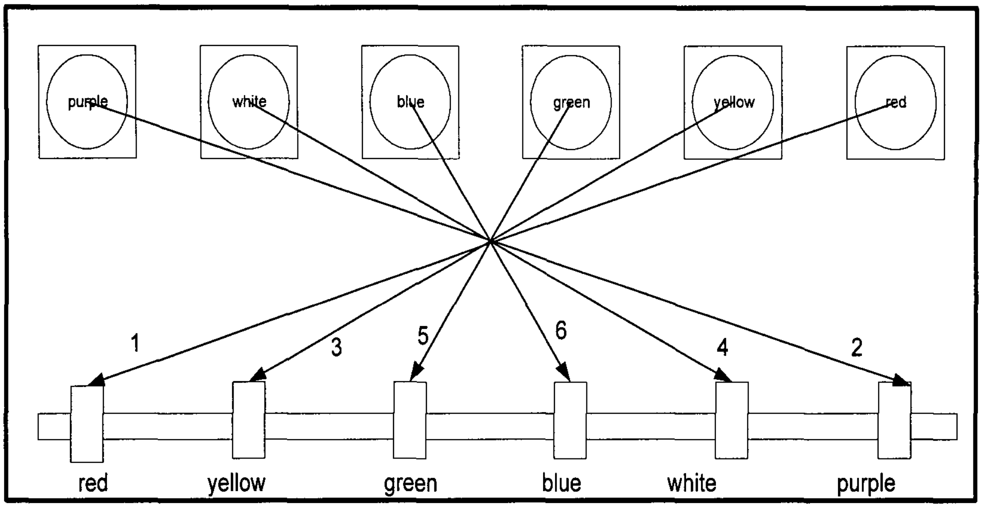

Figure 1. The order of moving cans to and from far targets.

The following performance measures were recorded: 1) time to move the cans from the near row to the far row and vice-versa, 2) absolute deviation of can centers from target centers in the X direction (left/right), and 3) absolute deviation of can centers from target centers in the Z direction (near/far). The test phase was one real-world trial (moving the cans to the far targets and back to the near targets) for the above three groups, and for a fourth group of ten subjects (No-Training group) who did not receive any training.

RESULTS

Training Phase

Means of completion time were computed over the ten training trials for the Monoscopic, Stereoscopic, and Real-World groups and are presented in Figure 2.

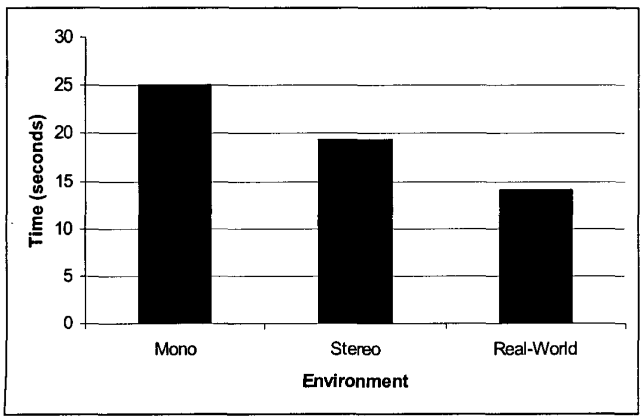

Figure 2. Average trial completion times by environments during training.

An ANOVA found the main effect of Environment (groups) highly significant at $p < .001$. Bonferroni post-hoc tests showed that the average completion time for both the Real-World group (14.1 sec, $p<.001$) and the Stereoscopic group (19.3 sec, $p<.05$) was significantly less than that of the Monoscopic group (25.0 sec). The difference between the mean completion time for the Stereoscopic and Real-World groups was not statistically significant.

Figure 3 shows the average absolute error along the X-axis (left/right) and the average absolute error along the Z-axis (near/far) when the cans were placed on the targets.

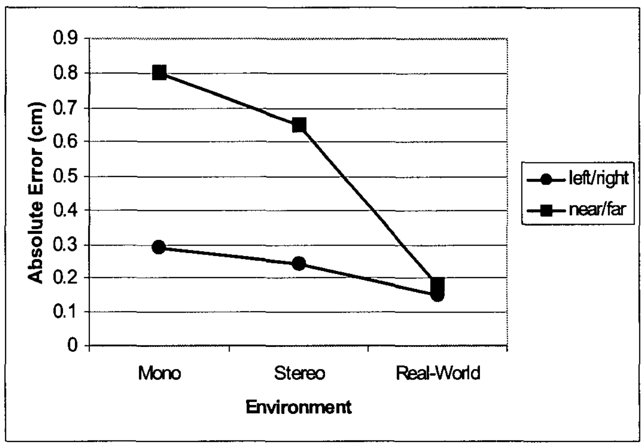

Figure 3. Average absolute errors by environments during training.

Placement errors were measured to millimeter accuracy, but the group averages shown in Figures 3, 4 and 5 are to sub millimeter accuracy. For both left/right and near/far absolute errors, the differences between the Monoscopic group and the Real-World group were statistically significant ($p<.001$). Differences between the Stereoscopic and Real-World groups were also statistically significant at $p<.05$ for the left/right errors and at $p<.001$ for the near/far errors. Differences between the Monoscopic and Stereoscopic groups in terms of placement errors were not statistically significant, indicating that the stereo environment did not improve can placement accuracy during training.

Test Phase

Averages of the real-world test trial completion time were computed for the Monoscopic, Stereoscopic, Real-World, and No-Training groups and are presented in Table 1. An ANOVA showed there were no statistically significant differences between groups.

Table 1
Average Completion Times for the Test Trial

Group	Time(sec)
Monoscopic	14.9
Stereoscopic	13.6
Real-World	13.7
No-Training	14.2

Figure 4 shows the average absolute error along the X-axis (left/right) and the Z-axis (near/far) when the cans were placed on the targets.

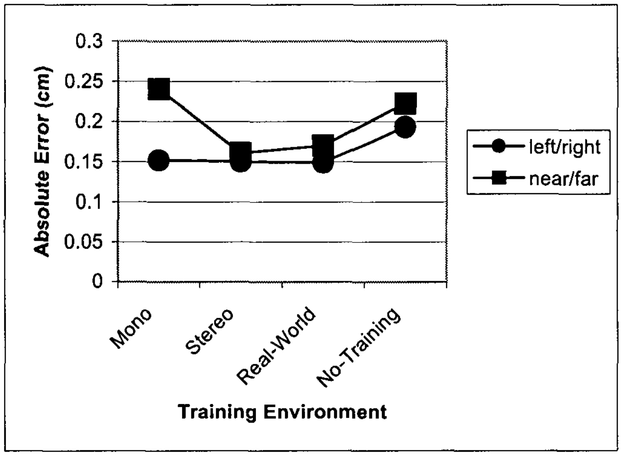

Figure 4. Average absolute error by training environment for the real-world test trial.

There were no significant differences due to the type of training environment. However, there was a significant interaction between training environment and target position (near, far) for the average absolute error on the Z-axis. This is shown in Figure 5.

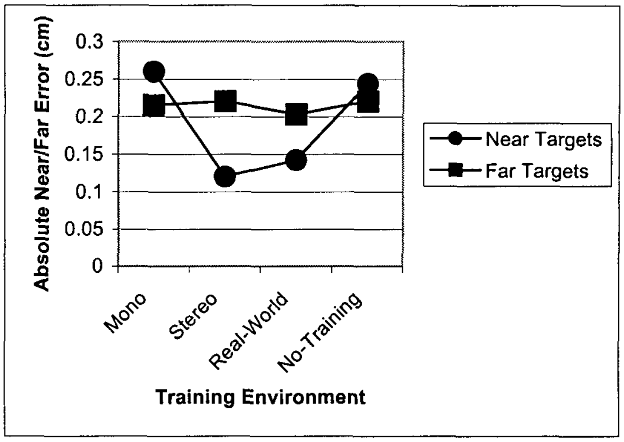

Figure 5. Average near/far absolute error for the training environment by target position interaction for the real-world test trial.

When placing cans on the near targets, the average absolute error along the Z-axis was significantly less ($p<.05$) for those trained in the stereoscopic or real-world environments, than those trained in the monoscopic environment. Thus, training in a stereoscopic environment resulted in more accurate real-world performance than training in a monoscopic environment. The difference between the average for the Stereoscopic group and the No-Training group approached statistical significance ($p=.065$).

DISCUSSION

Past studies have found that the average trial completion times for pick-and-place tasks in VEs have been significantly longer than those in the real-world. Kozar, et. al. (1993) reported mean completion times of 63.45 sec in their VE versus an average of only 5.95 sec for the real-world task. In the Kenyon and Afenya (1995) study, average completion times in the VE were about 20 sec, while those in the real-world were 10 sec. In the present study, the average completion time in the stereo VE was 19.5 sec, and in the real-world 14.3. The difference, 5.2 sec, was not statistically significant. The percent increase in average pick and place task completion time for the Kozar, et.al., Kenyon and Afenya, and present study were 966, 100, and 36 respectively. These large differences may be due to our use of a stereoscopic environment and improvements in virtual environments technology. Our stereo presentation had a high resolution (1024 x 768) and frame rates in excess of 20 per second.

In the training phase (Figure 3) the absolute can placement error in the left/right direction was considerably less than that in the near/far direction for the Monoscopic and Stereoscopic groups, but not for the Real-World group. Apparently, our VE environment did not allow duplication of real-world can placement accuracy along the near/far direction. A possible cause is that subjects' head movements were not tracked, and thus the view of the scene did not change with head displacements and/or rotations. Barfield, Hendrix, and Bystrom (1999) found better performance accuracy in a virtual environment when head tracking was implemented.

In the test phase, the significant interaction between environment groups and the target positions (near and far) highlighted the low absolute error scores along the near/far direction for the Stereoscopic and Real-World groups. This result may be attributed to the training the subjects received in the Stereoscopic or Real-World environment.

The ability to render stereoscopic virtual environments with high frame rates has become considerably less expensive. At the same time, image resolution has increased. For near spatial tasks that could benefit from training, these high resolution stereoscopic environments may provide an effective visual display for a training simulator.

REFERENCES

Barfield, W., Hendrix, C., & Bystrom, K. (1999). Effects of stereopsis and head tracking on performance using desktop virtual environment displays. *Presence*, 8, 237-240.

Gupta, R., Sheridan, T., & Whitney, D. (1997). Experiments using multimodeal virtual environments in design for assembly analysis. *Presence*, 6, 318-338.

Kenyon, R. V., & Afenya, M. B. (1995). Training in virtual and real environments. *Annals of Biomedical Engineering*, 23, 445-455.

Kozak, J. J., Hancock, P. A., Arthur, E. J., & Chrysler, S. T. (1993). Transfer of training from virtual reality. *Ergonomics*, 36, 777-784.

Yeh Y., & Silverstein, L. D. (1992). Spatial judgements with monoscopic and stereoscopic presentation of persptective displays. *Human Factors*, 34, 583-600.