Transfer of Training from Virtual Reality Environments

C.J. Hamblin, A. Chaparro, D. McConnell, and F. Toledo

Department of Psychology, College of liberal Arts and Sciences
National Institute for Aviation Research

1. Introduction

One of the most exciting new means of human-computer interaction (HCI) is virtual reality (VR). VR technologies create a sense of “presence” for the user by immersing them into a multi-sensory experience that can provide visual, auditory, haptic, and tactile feedback to the user. Virtual interfaces allow users to move about and interact with virtual objects from a first person perspective which is potentially more engaging than methods afforded by a traditional desktop computer.

One promising application of VR is simulation-based training. VR allows the ability to simulate real world environments which holds promise for training a variety of tasks. In 1995, the American National Research Council published a report regarding the state of VR research and made recommendations for its future development (Durlach & Mavor 1995). The review suggested that Virtual Environments (VEs) have the potential to broaden the application of simulator-based training and provide advantages that are not present in real-world simulators. For example VEs can enhance training by augmenting the training scenario with information not available in a real-world simulator. Darken & Sibert (1996b) used VR to manipulate environmental variables (i.e., furniture, paintings, etc.) to identify cues used for wayfinding strategies. Their study highlighted one of the key advantages that VEs provide in the ability to alter an environment quickly and easily. Others have demonstrated VR’s ability to augment training environments by investigating the effects of transparent and opaque walls on spatial learning (Piller & Sebrechts, 2003). Durlach and Mavor (1995) also suggest that VR training is advantageous because of the ability to replicate real-world environments that are too dangerous or expensive to replicate in the real world (i.e., training firefighters to navigate burning buildings or doctors to perform surgical procedures). Unfortunately, results from studies investigating the effectiveness of virtual training simulators provide mixed results, which create an unclear picture for the application and use of VR as a training tool. There are several explanations for the mixed results but a review of the literature suggests that the variety of technologies used in VR may not be appropriate for certain training tasks. The term “Virtual Reality” is used throughout the literature to describe a wide array of display devices, input devices, and software applications. VR display devices can vary from ordinary desktop monitors to fully immersive stereoscopic head-mounted displays (HMDs). Input devices can include the typical PC mouse, or direct object manipulation devices (i.e., cybergloves and pinchgloves). These devices are mixed and matched throughout the literature; however, each of these devices allows interaction with the VE which affords unique properties that may or may not create an appropriate training environment.

It seems that different devices are more appropriate for training different tasks; however, it has not yet been determined what devices are best to train a complex manual assembly task. For example, studies involving the training of decision making have found success with desktop VEs (Huble et al., 2002; Pleban et al., 2002) while successful training of motor skills have been shown to require fully immersive environments with stereoscopic HMDs (Rose, 2000). The VR technologies required to train a complex assembly task have not been identified. Such a task involves learning procedural steps, specific motor movements, and understanding spatial relationships between parts. Some researchers have explored these concepts individually but few have attempted a complex task that requires all three.

2. Method

Subjects: Forty-eight college students participated in the study. Because of limitations to the HMD, participants assigned to the immersed VE were required to have a minimum of 60/20 uncorrected vision or have 20/20 corrected vision with contact lenses. Each participant was asked to sign an informed consent and confidentiality agreement prior to data collection.

Training Environments. The VEs for this study were created at the Virtual Reality Center at the National Institute for Aviation Research at Wichita State University. The parts and working environment were generated using an SGI Onyx300 equipped with two graphical outputs (IR4 pipes), 8 CPUs and a 8GB Digital Audio graphics card. Motion tracking of the head and hand movements was accomplished using an Ascension Flock of Birds magnetic motion tracking system with 3 sensors (one on each hand and one on the head). Participants assigned to the HMD training environment used an nVisorSX HMD with 1280 x 1024 resolution, 60 degrees of diagonal viewing angle, and a constant screen refresh rate of 30Hz per eye. Object manipulation was accomplished using Fakespace’s pinch gloves equipped with electromagnetic motion transmitters. The VE
allowed the participant to select, manipulate and assemble a virtual model of Lego™. Step by step assembly instructions provided with the Lego™ model were displayed on a digital billboard located within the VE. Participants could advance or review the instructions using prescribed hand gestures. The PC-Based VE (PC) training group viewed the environment on a standard desktop monitor. Participants used a keyboard and three-button mouse to interact with the software. The VE was displayed on a 21” screen at 1280x1024 resolution.

Testing Procedure. Testing occurred after four training sessions each of which required the participant to correctly assemble the forklift one time. All participants performed two tests: a transfer of training test and a transfer of learning test. Transfer of training refers to performing the same task learned in the VE in the real world task. Transfer of learning refers to the application of skills learned in the training task to a new task performed in the real world. The transfer of training test required participants assemble a Lego™ model forklift consisting of 72 parts. Instructions for building the forklift consisted of 35 total steps including 5 subtasks. The transfer of learning test required the participants to build a Lego™ racecar. The racetrack model consisted of the same parts as the forklift assembled in a different order and configuration. Both tests required participants to correctly assemble the model as quickly as possible.

For the tests, individual parts were laid out on a desk in a predetermined arrangement which was same as that used in the virtual environments. The instructions for assembling the model were placed in front of the participant at the beginning of the task but the participant was allowed to move the instructions to a location he or she preferred. The area directly in front of the participant was left clear of any parts to allow enough workspace to assemble the model.

3. Results

In addition to quantifying transfer and learning it is also necessary to determine the efficiency of the training environment. There are two paradigms for measuring transfer. The first is to train all treatment groups to a desired criterion measuring the number of trials necessary to achieve that criterion. The alternative method is to hold the training trials constant and measure the difference in performance after training. When the number of training trials is held constant it may be possible for trainees from different training treatments to achieve equal levels of performance but the amount of time required to achieve equivalent levels may vary. Thus it becomes necessary to determine the efficiency of each training environment as a function of training time.

Results showed a significant effect for Transfer of Training \( F(2, 30) = 18.07, p < .001, \ \eta^2 = .546, \ \beta = .960 \). Post-hoc analysis (t-tests) revealed significant differences between improvement of the virtual training groups and the control group. Interestingly, there were no significant differences in Transfer of Learning between training environments.

Results also showed a significant effect for Training Efficiency training \( F(3, 30) = 44.83, p < .001, \ \eta^2 = .782, \ \beta = .997 \). Post-hoc analysis showed the virtual training groups were significantly less efficient than the real-world training group. Results were similar for Learning Efficiency, \( F(3, 30) = 44.83, p < .001, \ \eta^2 = .782, \ \beta = .997 \). Post-hoc analysis again showed significantly less efficient than the real-world training group.

4. Conclusion

Results from this study show that VEs can be effective training simulators although they are less efficient than real-world training. The results suggest that virtual training is not appropriate for all training scenarios given its lack of efficiency, but rather should be reserved for safety critical tasks that may be too expensive or too dangerous to simulate with other devices.

The lack of efficiency demonstrated by the virtual environments is directly related to the longer training trials required by participants in the virtual training environments. The increase in training time is most likely due to the additional cognitive load of having to learn to navigate and manipulate the VE. This additional learning task increased cognitive load of the learner which increased training time and delayed improvement. This finding suggests that the peripheral devices used to control and display virtual environments have a direct affect on the trainee’s ability to learn. As such, instructors must be aware of the physical requirements of the task to be trained and consider the appropriate peripheral devices.