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Link Foundation Fellowship Report
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1. Narrative

Introduction

In this report we summarize the results for three experiments completed during the Link Fellowship period. The aim of the first and second experiments were to test the efficacy of a novel assessment procedure for determining visual acuity and quantifying depth errors of observers wearing an optical see-through prototype head-mounted display. If successful, the assessments could provide an optimization procedure capable of discerning limitations attributed to separate components of the VE system or to the system as a whole.

The second experiment explored the feasibility of utilizing mixed reality (a mix of real and virtual items) environments for the study of brain injury. More specifically, we hypothesized that providing natural spatial and geographical cues to a person with anterograde amnesia would lead to better transfer of training of therapy to their home environment. Taken together, these experiments provide the foundation for further testing ego and exocentric relationships of objects within VEs as they pertain to cognitive rehabilitation protocols for different populations of persons with acquired brain injury (e.g., spatial neglect).

Results

The results from the first experiment appear in the special issue of Presence on the topic of Immersive Projection Technology ((Fidopiastis, Fuhrman, Meyer, & Rolland, 2005). In this paper we presented a methodology for testing user's visual acuity while wearing a prototype optical see-through head-mounted display designed in the Optics, Diagnostics, and Applications Laboratory at the University of Central Florida. We used a computerized Landolt C test to determine the user's resolution visual acuity or their ability to resolve small visual angles over different lighting conditions and while viewing different types of retroreflective material. In addition, we varied the contrast of the test stimuli to determine which retroreflective material would provide the best viewing conditions for targets or images of low contrast.

The results from this experiment showed that user's were able to attain the visual resolution set by the field of view and resolution of the display, which was 4.1 arc minutes, under any lighting condition. However, when viewing a low contrast target on the retroreflective material that was less efficient at directing light to the user's eyes, there was significant drop in the observers' visual acuity. Thus, we were able to show that the visual acuity test could point out technology within the VE system which is not optimal when designing environments where low contrast targets may be required (e.g., military applications). In a second experiment, we extended the above work to include a test for determining visual depth errors.

In this experiment, users performed a virtual dolman depth perception test while wearing a multi-depth plane optical see-through head mounted display. This prototype display is capable of displaying computer generated 3D stimuli at image plane distances of either 0.8, 1.5 or 3.0 meters. Although the data is still in the analysis phase, we had an unexpected outcome from the first use of the virtual dolman task.

The Howard Dolman peg test is a classic test for determining depth perception in real space. The participants' task is to align two pegs of the same size viewed through the window of the Dolman apparatus. The goal of such a device is to minimize the effects of monocular depth cues (e.g., size) and emphasize the depth cue of stereopsis or the difference in object position as seen by each eye. We adapted this task to be viewed in virtual space whereby the observer aligns two virtual objects, an octahedron and a column, within virtual space. This work is an extension of Rolland, Meyer, Arthur, & Rinalducci (2002).

Interestingly, when we first tested participants while wearing the prototype display, they were unable to fuse the image. The participants described that there was a perceptual mismatch between the actual image plane and that projected by the computer graphics. Further, the participants reported a tilting of the virtual objects with respect to one another. Analysis of the resulting depth errors were well beyond those predicted by the parameters of the head-mounted display. The results of the virtual dolman test suggested that that one or both of the lenses within the head-mounted display were tilted with respect to the image plane.

We were able to test this prediction by measuring the parallax error between both eyes when participants viewed a stationary target from each of the respective depth plane distances. The results of the parallax test showed that when the image pane was set to .8 meters there was a 5 cm (3.57 degrees) error between the projected focus target and the perceived image. Additionally, the perceived image was shifted to the left of the target suggesting that one lens was tilting inward while the other lens remained parallel. These results were repeated over the 1.5 and 3.0 meter depth planes thereby confirming the misalignment of the two lenses. This procedure provided a solution to the issue of lens tilt raised by Azuma (1997) who suggested that optical see-through head-mounted displays should be tested for lens tilt prior to running experiments.

The results of the last experiment discussed were presented at the International Workshop for Virtual Reality and Rehabilitation (IWVR) in September, 2005. A results summary will also appear in a special issue of CyberPscyhology and Behavior in 2006. In this pilot study a cross-disciplinary team from the University of Central Florida including the Media Convergence Laboratory, the Communicative Disorders Clinic, and the Institute for Simulation and Training created a mixed reality kitchen based upon the actual kitchen of a person with anterograde amnesia (i.e., the inability to remember new information).

Although the participant had lived in his home for three years, after his acquired brain injury (ABI) he was unable to remember where items for making meals such as breakfast were kept. These items could be silverware or food items (e.g., cereal). To test whether providing natural spatial and geographic cues would facilitate transfer of learning to the home, we replicated the participant's kitchen using a physical reconstruction of the real kitchen space made of plywood that matched the same dimensions and location. We then created a graphical overlay of textures and nontarget appliances (e.g., the stove). Thus, the participant interacted with real opening cupboards, drawers, and refrigerator while viewing a computer graphics overlay of his real kitchen.

The results showed that after 5 training sessions within the mixed reality environment, the participant improved his cereal making time from the 4 minutes single baseline measured at home to 2.5 minutes post measurement at home. There are two interesting aspects of this research: 1) we developed a novel method to capture tracker data of the participant's movement while performing the task and 2) we showed evidence that the participant, although amnesic, can form assistive schema action plans as a result of training.

The Tracker Review, a Java based software program capturing tracker data, allowed for data analysis of location errors, time on task, and movement efficiency. The tracker data allowed us to show that the participant was creating an unscripted retrieval pattern that was leading to his improvement in locating kitchen items needed to complete the task. This successful retrieval pattern was repeated in the home after training. Although more true experiments are needed, these results along with the methodology are encouraging.

Significance and Impact

The results of the first two studies suggest that a formalized visual assessment battery will assist in pinpointing VE system problems that may inhibit successful implementation of VE based training scenarios. The added value of such tests is that they are easy to implement and allow for optimization prior to executing experiments or training protocols. Optimization of the VE environment is key to eliminating confounds when testing participants with ABI. Visual perceptual errors within the VE have the potential to distort experimental results, including those obtained from brain imaging. By pretesting participants utilizing the assessment battery for resolution visual acuity and the virtual Dolman task, these perceptual issues can be minimized.

The third experiment has great implications for retraining persons with different types of memory impairment. The results suggest that the mixed reality kitchen provided a safe, yet controlled environment to explore aspects of learning and transfer.

Additionally, the mixed reality paradigm allows for both applied research within the cognitive rehabilitation domain, as well as basic research pertaining to how we perceive the space, depth, and locations of objects.

Where this might lead?

As a rehabilitation-training tool, VE must demonstrate that participants can demonstrate of general and specific transfer along with generalization of learning to one's home and possibly work once training is complete. By optimizing the VE system, we are better able to separate VE system limitations from those of the participant with ABI. Further, we will assist in systematizing VE design allowing for replicability of results across different research sites. Replicability will allow more rapid confirmation of best practices when applying VE rehabilitation protocols, thus improving patient outcomes.

2. List of Journal Publications acknowledging the Link

Fidopiastis, C.M., Stapleton, C.B., Whiteside, J.D., Hughes, C.E., Fiore, S.M., Martin, G.A., Rolland, J.P. & Smith E.M. (2006), Human Experience Modeler: Narrative Threads and Context Driven Cognitive Retraining. *Cyberpsychology and Behavior: SI IWVR* (in press).

Fidopiastis, C.M., Fuhrman, C., Meyer, C. & Rolland, J. P. (2005, October), Methodology for iterative evaluation of prototype head-mounted displays in virtual environments: visual metrics. *Presence: SI Immersive Projection Technology*, 14(5), 550-562.

Fidopiastis, C.M., Stapleton, C.B., Whiteside, J.D., Hughes, C.E., Fiore, S.M., Martin, G.A., Rolland, J.P. & Smith E.M. (2005, September), Human experience modeler: Context driven cognitive retraining to facilitate transfer of training. *Fourth Int. Workshop on Virtual Rehabilitation (IWVR '05), September 19-21, 2005, Catalina Island, CA.*

3. Expenditure of Discretionary Funds

A laptop was purchased to allow for mobility to participant testing sites. Other monies were spent on tracker equipment and materials to construct experimental setups.

4. How did this Fellowship make a difference?

The fellowship allowed me the time and financial resources to pursue a novel line of research that will eventually impact the design and implementation of virtual environments as they are used for cognitive rehabilitation of person with head injury. I have been dreaming of the experiment that I helped perform with the mixed reality kitchen for 10 years. I have not had the resources to undertake such a study. The Fellowship allowed me to achieve a milestone in my career. The experiment not only confirmed my initial support of VE as a training tool for cognitive retraining, it solidified the choices that I made academically to pursue this line of research. I am now poised to extend this research to elucidate depth perception as it pertains to egocentric and exocentric depth relationships. I am ever closer to studying neglect syndromes utilizing VE, which is my ultimate goal.