Interfaces for Navigation and Familiarity Training

Michael Eckmann, Li Yu, Terrance E. Boult, G. Drew Kessler

[mie3, liy3, tboult, dkessler] @eecs.lehigh.edu

Lehigh University, Bethlehem, PA

Abstract

Search and rescue operations can greatly benefit from the training provided by familiarity with the situation area and from practice navigating the area. Often it is difficult, dangerous and expensive to train people in the actual environment in which they will be working. For example, training firefighters in a burning building is dangerous and very costly (a building is destroyed). Therefore, it would be advantageous to perform training in a less dangerous and less costly environment.

We describe and compare four different interfaces for navigation and general familiarity training of an office environment, approximately 160 feet by 27 feet (the sixth floor of Packard Laboratory on Lehigh University's campus, referred to as the "sixth floor" throughout this document.) These interfaces are Immersive Remote Reality (IRR) (see [Boult, et. al.]), Virtual Environment (VE), Enhanced Blueprint (EBP) and Traditional Blueprint (BP). We compare these interfaces against each other. The dangers in using the interfaces are minimal and the costs are relatively low. However, the most obvious disadvantage of the interfaces compared to the actual environment is that they model the environment with varying levels of realism.

We give a description of an experiment we designed and performed to test familiarity and navigation skills. The subjects, who were required to be unfamiliar with the sixth floor environment, were assigned randomly to train using one of the four interfaces. Subjects were given a task in the real environment after training and their navigation time and wrong turns were recorded. Subjects also completed Witmer's & Singer's Presence Questionnaire [Witmer and Singer, 1998] for each training environment.

Introduction

Because of the complexity and importance of search and rescue operations, it would be beneficial to have efficient and cost-effective ways of navigation and familiarity training. This paper explores several novel interfaces for this type of training.

There has been considerable research in training environments (for navigation training in particular.) Satalich's Master's thesis [Satalich, 1995] provides excellent background on navigation and wayfinding research. Satalich quotes Gluck, ([Gluck, 1990] defined wayfinding as "the process used to orient and navigate. The overall goal of wayfinding is to accurately relocate from one place to another in a large-scale space.") In addition, Satalich summarizes other wayfinding ideas such as those by [Downs and Stea, 1973], who state the importance of landmarks in navigating.

Landmarks potentially play a great role in successful navigation. Locations of landmarks can help people determine where they are, choose the proper route and figure out where the destination is. However, a traditional blueprint does not provide a good way for users to learn about landmarks in an unfamiliar environment. Therefore, in addition to blueprints and virtual environments, we propose two other interfaces for navigation training -- Immersive Remote Reality and Enhanced Blueprint. These training interfaces give more information on landmarks and 3D structure than do blueprints.

Much research has been done in the area of training for navigation and effectiveness of transfer from the virtual environment (VE) to the real world. [Bliss, et. al., 1997] and [Bliss, et. al., 1995] compare the training effectiveness of VE, blueprint and non-training. [Rose, et. al., 2000] measure and evaluate what is transferred from training a simple sensorimotor task in a VE to real world performance. [Regian, 1996] discusses transfer of training effects in VR and other training environments. There are countless other papers in this area as well.

Other papers, such as [Darken and Banker, 1998]'s work and [Clawson, 1998]'s work, focus on what characteristics of the training environment are beneficial to training. For example, Clawson found that transparent walls in a virtual world were beneficial. Also, Darken's study which compared maps to virtual environments and real world conditions, suggests that the training method is not as important as navigation ability. Our experiment deals with many of the same issues. The four interfaces we compare all have different usability and we want to find out what interface properties have a beneficial effect on training.

In many real world situations the best path is not known ahead of time. For example, firefighters and rescue workers do not always know what the best path is to make their rescues because the victims' whereabouts may be unknown until they arrive on the scene. They need to have a general understanding of the layout of the area to be able to make on the spot decisions regarding their mission. Therefore, we did not train a specific path in any of the training environments. Instead, we hoped to teach a general understanding of the layout of the sixth floor during training to help the subjects achieve their task in the real environment.

In general, the subjects in our experiment had no prior bias towards any of the training environments, whereas in the Firefighter paper [Bliss, et. al., 1997], the subjects were firefighters who had extensive prior experience with blueprints. Interestingly, in both [Bliss, et. al., 1997]'s and [Philbin, et. al., 1998]'s studies, the paper map (or blueprint) navigation training achieved better results than VE training.

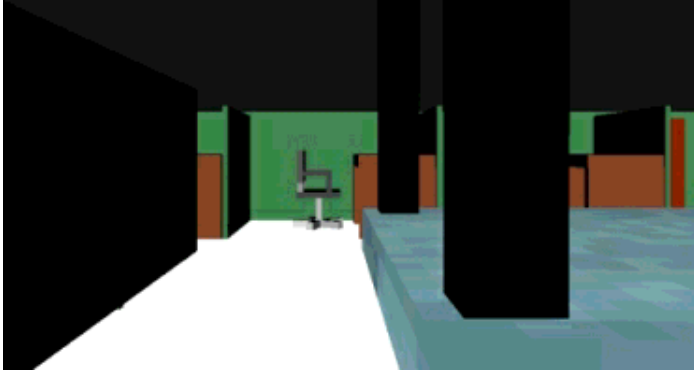# The Interfaces

Virtual Environment (VE)

Figure 1: Perspective view within the VE.

To build the VE, measurements of the actual sixth floor were made as well as images taken for texture maps. Using this information, a 3D model of the sixth floor was created using Ray Dream studio which is exported as a VRML model. A VE program, which uses the VRML model as input, was written utilizing the Simple Virtual Environment (SVE) (see [Kessler, et. al., 1997]) library.

To use the VE of the sixth floor, subjects stand and wear a Head Mounted Display (HMD) equipped with a head tracker and hold a hand-held stylus input device. A perspective view (see the picture in Figure 1) of the environment is displayed in the HMD, based on the user's position and direction of view. The user may travel in any direction and look around the entire environment. Travel may be done at varying speeds and the user may stop to look around. The user may also travel through walls, which provides some advantages, but also may lead to problems.

Overall, the VE provides a semi-realistic 3D view of environment. The immersive nature of the VE allows the user to feel present in the VE. When the model is viewed from above (a bird's eye view) the user gets a non-immersive view similar to that of a blueprint without measurement information.

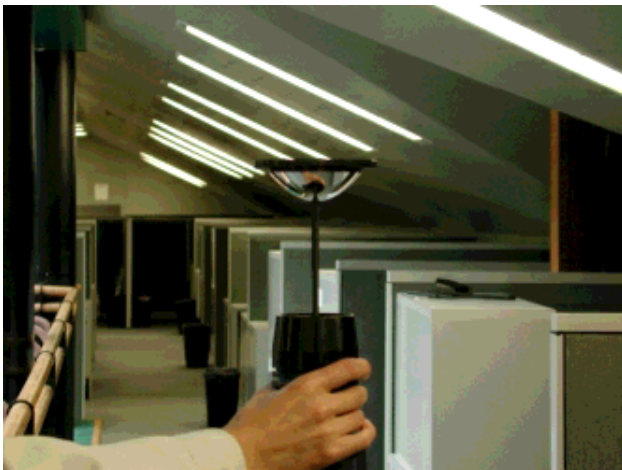## Immersive Remote Reality (IRR)

Figure 2: Omnidirectional mirror and video camera used to build the Immersive Remote Reality environment.

An Immersive Remote Reality (IRR) environment is created using a video camera equipped with an omnidirectional mirror (see Figure 2). Video is taken while walking at a normal pace through the environment. Each frame of video contains an approximately 360 degree horizontal view and 210 degree vertical view. (See Figure 4 for an example frame.) This video is input to software that perspectively unwarps views based on the subject's position and orientation. IRR is similar to Virtual Reality (VR), but with two significant differences. First, the scenery generally looks more realistic because it is actual video (not models.) Second, the IRR user must follow the path of the video while the VR user is not restricted in this way. To reduce this restriction, future work could be done to record the video to an indexed CD which would allow a user to "jump" to a specific place in the environment. In both VR and IRR, the user may look around while moving or stop and look around.

To use the IRR of the sixth floor, the subjects sit or stand and wear a Head Mounted Display (HMD) equipped with a head tracker. A perspective view (similar to image in Figure 5) of the environment is displayed in the HMD based on the user's position and direction of view. The user must travel in the direction in which the video was recorded, but may look in any direction within the imaged hemisphere.

Travel may be done at varying speeds by controlling the video with a remote control. The subject also has the ability to stop (pause) the video and look around.

Traditional Blueprint (BP)

Usually, traditional blueprints (BP) are available and therefore do not need to be (re)created. The BP provides a good general overview of the environment, with measurement information. Another possible advantage is that those who know how to read a blueprint can do so efficiently (see [Bliss, et. al., 1997]) Other advantages are that they are easily transportable and inexpensive.
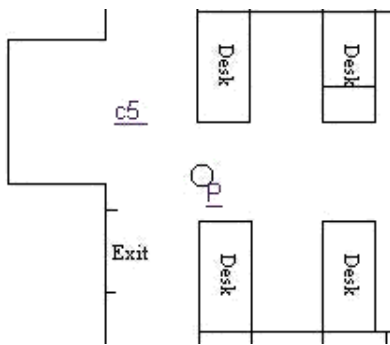
Enhanced Blueprint (EBP)

Figure 3: A part of the blueprint. P specifies the location that the trainee wants to see (selected by clicking the mouse on the blueprint.) c5 is the location of the camera.
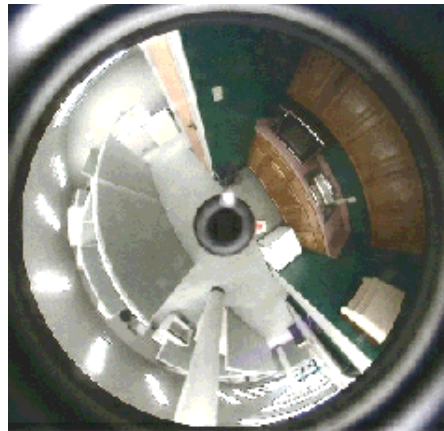
Figure 4: The omni-image taken by camera c5. This image is not shown to the user.

Figure 5: This image is the perspectively unwarped view from the omni-image, generated and displayed when the user clicks at location P, which is at the center of this image.

While a traditional 2D blueprint (top-view map) provides a good view of the whole site, it is not able to "tell" trainees what objects are like in the real world. An enhanced blueprint (EBP) takes advantage of the positive aspects of a 2D blueprint as well as make up its shortcomings by providing images of the scene. Basically, an EBP is an interactive BP featuring many omnidirectional images available for viewing.

To build an EBP, a 2D blueprint must be drawn (or acquired), and several omnidirectional images (omni-images -- see Figure 4) must be taken in different specific locations and registered with the blueprint. A web-based application was developed and used to calibrate a camera using a 2D blueprint and the omni-image taken by that camera. The user can choose a camera to view a location (but by default, the nearest camera is chosen.) This allows a location to be viewed from different angles. Furthermore, the interface allows trainees to navigate through the environment (click and drag on the image to pan and tilt around the immersive scene, zoom in and out to 'walk' forward or backward.) The EBP utilizes the ParaShot(tm) Viewer to unwarp an omni-image. The omni-images we use have a resolution of 1600 by 1200 pixels, 24-bit true color, and a zoom of 38mm. The interface of our application was developed using javascript. While this application can be used in different systems, it currently runs on Netscape Communicator 4.61 for Microsoft Windows.

Comparison of Interfaces

Naturally, the actual environment as a training interface has the advantage of being the most realistic. However, there are many advantages to the other interfaces over the actual environment (safer, less expensive, and more controlled, etc.) The main disadvantage is their varying accuracy.

Here we compare the interfaces on four issues. We ranked the interfaces and assigned values to them from best (4) to worst (1).

	Immersive Remote Reality (IRR)	Virtual Environment (VE)	Enhanced Blueprint (EBP)	Traditional Blueprint (BP)
Overview provided by interface	1	3	4	4
Navigation	3 (user can walk through the whole environment and look around, but must follow the route contained in the video.)	4 (user has most freedom of movement, can walk anywhere, even through walls, and can stop to look around.)	2 (user can navigate through one image at a time with the functions of pan, tilt, and zoom.)	1 (user can "navigate" only by tracing a path with his eyes on the blueprint.)
Model creation & update time*	3 (quick to build, less than an hour to take video and an hour to edit video if necessary.)	1 (took approx. four weeks for the sixth floor -- most of this time was spent on building the model.)	2 (took approx. one week for the sixth floor.)	4 (took approx. two days for the sixth floor, could take no time if the BP is already available.)
Fatigue**	1 (user may experience some fatigue.)	1 (user may experience some fatigue.)	3	4

Table 1: Comparison of interfaces on four issues.

* Note that for large buildings and environments, the time it takes to build an EBP and a VE could increase dramatically. IRR for a large building or environment can essentially be built in little more than the time it takes to walk (or drive) through the environment.

** The values for fatigue in the table are predicted --- we did not measure fatigue.

Motivation / Goal of Research

We believe that Immersive Remote Reality and Enhanced Blueprints have a high potential to be used as training tools as alternatives to Virtual Environments or more traditional training environments. Our goals in this research are to do the following. First, we want to introduce the concept of Immersive Remote Reality and the Enhanced Blueprint to the Presence and Virtual Environment community,

especially for those interested in novel training environments. Second, we want to compare the four interfaces in terms of training ability and presence felt. To these ends, we designed and conducted an experiment to compare a VE, IRR, EBP and traditional BP for navigation training. Our experimental procedure was designed to be a good unbiased one for testing training.

We expected of course that VE, IRR and EBP would provide more feelings of presence than BP. We also thought that IRR would yield higher values than other interfaces for PQ questions pertaining to Visual Sensory factors, due to the higher visual realism (due to actual video) combined with the HMD. We did not have a prediction on which interfaces would be better for training. We wanted to basically find out the advantages and disadvantages of each, through subject comment feedback, as well as training ability by comparing navigation times and wrong turns. We also want to know the relationship between levels of presence and training effectiveness in our experiment.

Experimental Method (including Training and Testing procedures)

Participants were divided into four training groups (Virtual Environment, Immersive Remote Reality, Enhanced Blueprint, or a Traditional Blueprint.) The experimental method and training and testing procedures are outlined below.

For each subject:
1) a) Subject is asked to sign a consent form.
    b) Before training in any of the environments, the experiment is explained to the subjects and the four interfaces are briefly explained.
    c) Subject is told that he will be assigned one of the interfaces for training, then after the experiment on the Sixth Floor, will use the other interfaces if willing to spend the time.

2) Subject is assigned one of the four training interface (called the primary training interface.)
3) Subject is shown and told how to use the interface and given seven minutes to train with it.
4) Subject is asked to fill out a web version of Witmer and Singer's PQ with regard to the training interface.
5) Subject is trained in use of a wheelchair (about 1-2 mins.) The reason a wheelchair is used is explained later in this section.
6) Subject is given their task to read. The task the subjects were given to read appears later in this section.
7) Subject performs the task during which he is followed by an investigator -- wrong turns are noted (but not told to subject) and navigation time is recorded.

If subject is willing, he could participate in the following post-training steps for each of the three remaining interfaces.
8) Subject is shown and told how to use one of the other three interfaces and given five minutes to use it.

9) Subject is asked to fill out a web version of Witmer and Singer's PQ with regard to the interface just used.

10) After the experiment is over, the subject is expected to answer Witmer's and Winger's Immersive

Tendencies Questionnaire at their convenience, on the web, within the next 24 hours.

Note: Subject is not asked to use the BP as a post-training interface because we are not interested in the PQ answers for BP. However, when BP is assigned as the primary training interface, for consistency, the PQ is required to be answered for it. Additionally, subjects who have some familiarity with the sixth floor environment can participate by only using each interface as a post-training interface. They do not perform the task on the actual sixth floor. Basically they do steps 1a, 1b, then 8-10 (all for VE, EBP and IRR (not BP.))

Note: the presence questionnaires answered about the primary training interface are kept separate from those answered about the post-training interfaces. The primary training interface questionnaires are collectively referred to as PQ1's. The post-training interface questionnaires are collectively referred to as PQ2's.

Each subject spends approximately 55 minutes on this experiment. A wheelchair is used to lower the eye level of subjects below the cubicle walls present in the actual environment. This is done to require the subjects to rely on their training to recall the floor layout. If they walk upright, then they can assess quickly the layout of the sixth floor by looking over the cubicle walls, thereby diminishing their reliance on their training. Also, the use of a wheelchair slows navigation time, which artificially increases the size of the environment.

The subjects were given the following to read which explained the task they were to perform on the actual sixth floor. "An empty box is in the North East corner of the sixth floor. You must go from the entrance to the sixth floor to the North East corner and pick up the box. Then you must bring it to the conference room, located in the South Center of the sixth floor, and place it on the table inside. Then you must come back to the door where you started. Your time will be recorded, so do this as safely, accurately and as quickly as you can." Before starting this task, the subjects were shown an identical box to the one there were to find. The experiment is structured not to give bias towards any of the four training environments. The correct path to be taken during the experiment in the real environment is never told to the subject and especially not during the training.

We feel that this type of training is fair to all the four interfaces. We want the subjects to get a general understanding of the layout of the sixth floor and then be able to transfer this learned information to perform an unknown task on the sixth floor. In contrast, the firefighter [Bliss, et. al., 1997] paper was biased because they compared "no training" to those who were trained on the correct route to take. The "no training" group was required to find the victim using an exhaustive search, whereas the other two training groups were told the correct path.

In addition, we did not want to give unfair advantage to the Immersive Remote Reality system by videotaping the path to be taken for the task, because the other three systems did not have the ability easily to show a prerecorded path. (For the blueprint, the path could have been drawn on it but extra programming would be involved to show a prerecorded path in EBP and VE, which is certainly possible, but was not done for our experiment.)

We want to test if the user can get generally familiar with the sixth floor using these interfaces, not whether they can remember a path shown to them during the training. The navigation skills are tested by measuring the time for task completion and the number of wrong turns. How well they navigate is related to how well they could understand directions and descriptions in the task based on what they

learned in the training environments (not how well they follow a path that they are told.)

We believe this type of experiment is fair to the four interfaces. It is fair in the sense that the task was *not* told to the subjects during the training. Furthermore, the training was consistent among all four interfaces. So that we could accurately compare the four interfaces, the task was only told to the subject after training (and even after answering a questionnaire.)

Steps 3, 8, and 10 are explained further (i.e. "shown and told how to use" is expanded on below for each of the interfaces.)

Traditional Blueprint training procedure.

1. The subject is instructed that they are being shown a blueprint of the Sixth Floor of Packard Lab.
2. While pointing to the entrance on the BP, the subject is instructed that this is a door and upon entering the door he is traveling SOUTH. If he immediately turns right he is traveling WEST and if he had turned left he would be traveling EAST. (All this is done while pointing and making hand motion directions.)
3. The legend containing a compass pointed out, as is the distance legend.
4. The subject is informed that his task is to learn the layout and get generally familiar with the Sixth Floor.
5. Timer is started.

Enhanced Blueprint training procedure.

1. The subject is instructed that they are being shown a blueprint of the Sixth Floor of Packard Lab with embedded images.
2. While pointing to the entrance on the screen with the EBP, the subject is instructed that this is a door and upon entering the door he is traveling SOUTH. If he immediately turns right he is traveling WEST and if he had turned left he would be traveling EAST. (All this is done while pointing and making hand motion directions.)
3. The legend containing a compass is pointed out, as is the distance legend.
4. The subject is informed that his task is to learn the layout and get generally familiar with the Sixth Floor.
5. The subject is shown how to select images and how to use the various functions (click and drag the image to see different areas of the room, and zoom in and out)
6. The subject is asked to use the interface. They are observed using the Enhanced Blueprint and when it is determined that they know how to use it, the timer is started.

Immersive Remote training procedure.

1. The subject is told that he is about to see a video taken with a special Omni directional video camera that captures a full 360 degree view horizontally and 180 vertically.
2. The subject is told that he may use the remote control to Pause, Play, FF and Rewind the video.
3. Subject is asked to wear the HMD and the video is paused so that he sees a stationary scene in the display. He is instructed to look in the direction that shows the entrance of the sixth floor and is instructed that this direction is SOUTH. He is asked to turn right and is instructed that this direction is WEST. He is asked to turn all the way to the left and that this direction is EAST.
4. If the subject asks how they can control their direction of travel (only then are they told that this is

not possible.)

5. They are told that they can look around as the video is moving as well as when they pause the video. They are asked to try this.
6. They are asked if they understand and when they say yes, they press play and watch the video. They are told that the video clip is 4 minutes long so they should feel free to pause it when they want to.
7. The subject is informed that his task is to learn the layout and get generally familiar with the Sixth Floor.
8. Timer is started.

Virtual Environment training procedure.

1. The subject is told that he is about to see a 3D model of the sixth floor of Packard.
2. The subject is instructed on how to travel --- press button on stylus to travel in the direction they are looking (gaze.) They are told they may look up, down, left, right, etc. and that they may travel in these directions as well. They are told they can go through walls.
3. They are instructed to look in the direction that shows the entrance of the sixth floor and they are instructed that this direction is SOUTH. They are asked to turn right and are instructed that this direction is WEST. They are asked to turn all the way to the left and that this direction is EAST.
4. The subject is informed that his task is to learn the layout and get generally familiar with the Sixth Floor.
5. They are asked if they understand and when they say yes, the timer is started.

Participants

Participants were gathered for this study by sending out email to all Electrical Engineering and Computer Science Sophomores, Juniors, Seniors and graduate students as well as faculty and staff in the EECS department of Lehigh University. Additionally, 8.5 by 11 notices were placed in high traffic areas around campus including the University Center. Advertisements (email and paper) lured the subjects by the novelty of the technology and 5 USD. Participants are required to have no prior knowledge of the sixth floor of Packard Laboratory.

Materials

The following materials were used in the Virtual Environment interface.

- Head Mounted Display (HMD) is a Virtual Research Systems V8 Head Mount Display
- Tracker is a Polhemus FASTRAK system and stylus.
- Computer is a Dell Workstation PWS 330 with 4 Pentium III processors and 500 MB RAM.
- Software library for the VE is the Simple Virtual Environment library [Kessler, et. al., 1997].

Figure 6: Virtual Environment equipment. HMD,
stylus and tracker (on top of HMD) are visible in
photograph.

It is worth noting that for the VE, a ceiling was not part of the model. Also the whole north wall was absent from the model as well. These omissions were done intentionally. The ceiling not being present can be thought of as a feature to allow the subject to travel up above the room and look down to get a good overview of the environment. An enhancement would be to create a ceiling and give the user the option of making it transparent (useful when looking down from above.)

The following materials were used in the Immersive Remote Reality interface.

- Head Mounted Display is a Glasstron, Sony Personal LCD Monitor PLM-S700E mounted to a one-size fits all baseball cap.
- Tracker is an Intersense IS-300 Precision Motion Tracker.
- Camera used to play the video is a Canon Optura Mini DV camera.
- Remote control for Camera is a Canon Wireless Controller WL-D71 (small hand-held remote control with typical controls such as Rew, FF, Pause, etc.)
- Computer is an AMD 300 MHz machine with 128MB RAM, running Red Hat Linux 6.2, running in-house unwarping software for the omni-video.
- Video capture card is the Hauppauge! WinTV-GO model 190 with the Brooktree BT878 chipset.

Figure 7: Immersive Remote Reality equipment. HMD, video camera, remote control and tracker (on top of HMD) are visible in photograph.

The following materials were used in the Enhanced Blueprint interface.

- Monitor is a 19" Trinitron monitor, with 1024x768 resolution.
- Mouse is a Logitech M-S48.
- Special software for Enhanced Blueprint is the Cyclovision Parashot web system, Agfa Photowise and Netscape Communicator 4.61, with Javascript and Java enabled.

Figure 8: Enhanced Blueprint equipment. Computer monitor (displaying the EBP) and mouse are visible in photograph.

Readers may visit http://www.eecs.lehigh.edu/~liy3/Blueprint.html to try the enhanced blueprint on the

web.

The Traditional Blueprint interface only utilized a piece of paper approximately 2 feet by 6 inches, containing the blueprint of the sixth floor.

The following materials were used in the experimental task.

- A small cardboard box (dimensions: 11" x 8" x 4".)
- An 18" Merits standard manual wheelchair, with the following specifications. Overall Height/Width is 36" * 23", 200 lb. capacity with foot rests.

Note that the hallway widths on the sixth floor (the hallways that the wheelchair was required to travel down were at least 40" wide.) The dimensions of the sixth floor are approx. 160 feet by 27 feet.

Questionnaires

Examples of the questionnaires that were used can be found at:

http://www.eecs.lehigh.edu/~mie3/VR/pq1_example.html
http://www.eecs.lehigh.edu/~mie3/VR/pq2_example.html
http://www.eecs.lehigh.edu/~mie3/VR/itq_example.html

A portion of one of the questionnaires is below.

Please enter the ID number assigned to you by the investigator of the experiment.

Using the scale below, please complete the following form as accurately as possible with respect to the environment in which you trained.

7 6 5 4 3 2 1 (7 = very,   4 = moderately,   1 = not)

1) How much were you able to control events?

2) How responsive was the environment to actions that you initiated (or performed)?

3) How natural did your interactions with the environment seem?

4) How completely were all of your senses engaged?

Results / Conclusion / Discussion

Due to bureaucratic problems with Lehigh's Institutional Review Board (IRB), the experimental data that was taken in May 2001, and the conclusions drawn from those experiments are sequestered until further notice. This committee was to have met in June 2001 to decide the fate of the data but not enough members attended to vote on this so another meeting is in the process of being scheduled for late July or early August, 2001. If the data already taken is deemed allowed for use, then this data, results, and conclusions will be available at http://www.eecs.lehigh.edu/~mie3/VR/results.html immediately upon receiving notification from IRB. If they vote that the data must be destroyed, then new

experiments will be performed and new data will be reported on the page above as soon as it is available. If the reader would like to receive email when this results web page is updated, please send a request to Michael Eckmann at mie3@lehigh.edu.)

Future work

There are many improvements that can be made to the interfaces, such as adding sound to VE and IRR, better graphics for VE, more accurate model for VE, usability enhancements to VE, IRR and EBP, etc. An interesting challenge to Virtual Environment training researchers would be to compare IRR and EBP to their VE training implementations. Further improvements to the interfaces should be made based on the comments from the subjects of the experiment.

Acknowledgments

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