1997

Just which Reality do you Mean? Users' Experiences of Virtual Spaces

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JUST WHICH REALITY DO YOU MEAN?
USERS' EXPERIENCES OF VIRTUAL SPACES

BY

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Submitted in Partial Fulfillment of the Requirements of the Senior Scholars Program

COLBY COLLEGE
1997

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Introduction

Virtual Reality is a relatively new technology in the relatively young field of computer science. The design of Virtual Reality has only recently come into discussion, as well as the implications for this sort of design. I hope to determine how a user can work most efficiently and accurately in a Virtual World. By studying this, I hope to help in the standardization of Virtual Reality design.

Definition of Virtual Reality

In order to discuss Virtual Reality, one must first define the term. Some define Virtual Reality (VR) as simply simulations of the real world. According to Jorge Franchi (1994), "Virtual Reality is a computer-created sensory experience that completely immerses a participant to believe and barely distinguish a "virtual" experience from a real one. It is the use of computer graphics, sounds and images to reproduce an electronic version of real-life situations". However, this definition seems too limited: it is focused simply on VR that tries to imitate the real world. Accordingly, a computer system that immerses the user into some imaginary world in which gravity does not exist would not count as VR.

Franchi (1994) also describes VR as "a technology that uses computerized clothing to synthesize reality". Similarly Eugenia Kolasinski (1996) describes VR as: "a three-dimensional, interactive, realistic, real-time, computer-generated simulation providing direct input to the senses via a head-mounted display (HMD), DataGloves™, or similar devices". By describing VR in this way, Franchi and Kolasinski ignore desktop VR. Desktop VR is a type of Virtual Reality which requires no additional hardware to a computer. The user sits at a normal computer screen and participates in the virtual world without being immersed in it. Examples of this type of VR are many current computer games.

Others disregard the hardware involved and simply define VR by describing what it can do. Furness and Barfield (1995) define a Virtual Environment (VE) as "the representation of a computer model or database which can be interactively experienced and manipulated by the virtual environment participant(s)". This appears to be a better definition because it does not expressly require that the participant physically be immersed in the environment. It also notes that the participants are no longer commanders of actions, but rather, they interact with objects in order to accomplish a task. For example, instead of a user double-clicking a folder icon in the Macintosh Operating System to command the folder to open, in a VE, the user would physically be required to open a folder (or perform the folder opening routine). This represents the user interacting with the folder, instead of commanding it.

VR is sometimes called Artificial Reality. This label is due to its similarity to the field in computer science called Artificial Intelligence. According to Winston (1992) Artificial Intelligence (AI) is "the study of the computations that make it possible to perceive, reason, and act". VR is related to AI in that VR, at times, tries to simulate reality just as AI tries to simulate intelligence. In particular, just as an 'intelligent' thing must know a lot of facts, every object in a virtual world must know its properties. For example, an object in a VW designed to resemble a car must "understand" that if the user walks into it, it should not budge; however, an object designed to be a soccer ball must "know" that if a user walks into it with a certain force, it should move a certain distance. The objects must also "understand" that the user is not the only object in the VW that can interact with it. If the soccer ball is kicked, as it travels, every object it comes into contact with must react to it in some way.

The History of Virtual Reality

The beginning of VR can be seen in Morton Heilig's Sensorama in 1956. Sensorama was an experience similar to modern day theme park rides. The user sat on a seat (which vibrated) and held handlebars (which vibrated) as he or she went through a "virtual" Manhattan. Heilig used three-dimensional graphics, stereo sounds, vibration, wind sensations (the wind strength varied depending on the user's speed), and city smells (such as exhaust and food smells) to evoke a sense of being in Manhattan. These were not computer graphics, but this was the first step toward VR (Kalawsky, 1993; Vince, 1995).

The next step towards Virtual Reality was computer graphics. The "father" of computer graphics, Ivan Sutherland, submitted his doctoral thesis in 1963. It was about the potential of an interactive computer graphics system (SKETCHPAD). In it, he revealed how computers could be used for interactive graphics (Kalawsky, 1993).

Sutherland was also responsible for the next contribution, a display. He believed that a display could provide computer-generated images so realistic that they could not be distinguished from the real thing. In 1965, he designed the Ultimate Display. It was made up of two small CRTs mounted on a head band. It also had a head positioning sensing system. While not as complex as today's Head-Mounted

Displays, for its time the Ultimate Display was an amazing accomplishment (Vince, 1995).

In 1977, Dan Sandin, Richard Sayre and Thomas Defanti made the Sayre Glove at the University of Illinois, Chicago. This glove was bend-sensing, meaning that it could detect when the user's fingers were bent. Thomas Zimmerman contributed to the development of the DataGlove in 1982 with his optical flex sensing glove. This glove had hollow plastic tubes which could conduct light. As the position of the hand and fingers changed inside the glove, different amounts of light traveled through the tubes. By measuring the change in light, the computer could determine the actual position of a finger. Jaron Lanier (who we will see in a moment was the founder of VR) met Zimmerman and suggested putting a sensor device on the glove to determine hand position as well. This was the birth of the DataGlove (Kalawsky, 1993).

In 1983, Myron Krueger published *Artificial Reality*. In this book, he described the mixing of computer graphics and position sensing technology to help control computer systems. He developed Videodesk. In this, the user sits at a desk and places his hands on the desk. Cameras capture the positions of the hands and the computer uses these images to determine what gesture the user is making. The user can use these gestures to control the system (Kalawsky, 1993). This is a form of a present day mouse, except that the mouse in this case is the user's hands.

In 1985, Jaron Lanier and Jean-Jacques Grimaud founded VPL Research, Inc. VPL, who produced the DataGlove, concentrated its research on state-of-the-art computer interfaces. In 1989, less than 10 years ago, Lanier coined the term "Virtual Reality" and, thus, Virtual Reality was born (Vince, 1995).

Uses of VR

Once VR has gained mainstream acceptance, where will it be used? The answer to this is: almost everywhere.

VR is currently a cost-effective training and learning tool. For example, airline companies use VR simulators to realistically imitate the actual look and feel of a commercial airplane cockpit in order to train pilots. By using this technology, the airline does not have to waste money to fuel a plane for a training flight or risk the student pilot crashing one of their expensive jets. They also do not have to "waste" a plane by not having it carry paying passengers. The airlines can also test every situation they would like to test their pilots with. By designing a simulator in which the controls and physical layout are identical to the cockpit it is designed to simulate, pilots can get a relatively accurate feel for what flying the plane is like.

Medicine stands a chance to gain from the use of VR technology. Virtual cadavers can be designed in order to allow physicians and students to examine the inner workings of the human body. Using a specially designed VR input device, a virtual scalpel, the user of the VR system can virtually operate on the virtual cadaver. The input device can simulate resistance to the virtual scalpel, so that the surgeon can "feel" the appropriate pressure necessary to slice different layers of the human anatomy.

VR also has a practical application in academic education as well. For example, instead of students simply reading a textbook with facts about a war they could immerse themselves in a VR representation of the war. Students could also use virtual animal carcasses to practice dissection for a biology practical.

VR has a significant purpose in manufacturing as well. Designing prototypes can include more people and better prototypes can be designed. Instead of trying to use the human imagination to turn a two-dimensional image into a three-dimensional one, VR allows the users to move around the prototype they are designing. They can also see how their product will interact with other existing objects. Caterpillar uses

VR to design new tractors. They use the technology to determine the visibility of the operator of the machine.

Architects have a great deal to gain by using VR. Instead of drawing two-dimensional plans for a building or structure, an architect can build, in VR, a three-dimensional representation of the structure. In addition to its physical appearance, they can also describe the way the structure reacts to different conditions. For example, if the architect was trying to design a building for the San Francisco area, he or she could test the design with different strength earthquakes to determine the practicality of the design. He or she can also use the design to create walkthroughs of the building.

The Department of Defense uses VR to simulate wars. From these simulations, they can determine what are the best strategies for our troops. The Army uses the Close Combat Tactical Trainer (CCTT) to simulate tank warfare. They use the simulator to train and test soldiers. They can simulate everything from different weather conditions to the recoil from firing the tank's cannon to the dust trails left behind a moving tank. Soldiers will not be as unfamiliar with real warfare after training with such a system as compared to training without such a system (Combs, 1996).

Civil engineers have used VR in London to help determine the safety aspects of a building. By designing the building in VR, and populating it with a virtual crowd, they can observe how the crowd will react in different emergency situations. The different people in the crowd react differently. Their behavior comes from psychological studies of emergencies. All types of individuals can be added to the crowd: parents looking for children, handicapped people, slow people, etc.. The engineers can also switch their viewpoint to that of any of the members of the crowd to see how well labeled the exits are from everyone's standpoint (Heichler, 1994).

Current Problems with Virtual Reality

Virtual Reality is a highly-graphically-intensive interface. With the level of detail required to generate VWs, high computational speeds are necessary. Without this speed, the VR system will not be able to generate images in real-time, and the user will not be convinced of the reality. In order to understand this more clearly, we must touch on how VR works.

Virtual Worlds are not simply many images stored and then displayed continuously, like a movie (although, Apple QuickTime VR is an exception). Instead, Virtual Worlds usually require continuous recalculations of the positions of the vertices of polygons. The complexity of VR comes from the number of calculations necessary to regenerate polygons in real-time.

In order for models to adjust in real-time, they must be updated at least ten times per second to appear convincing to the user (Green and Sun 1995). This requires that either the model be geometrically simple, or that the vertex updating algorithm be extremely efficient. Either way, with slow computers, real-time adjustment of the images is not possible. Today, such computational power is available, but at very high costs, literally many hundreds of thousands of dollars.

This problem of speed leads to another problem: motion sickness (Viirre 1996). There is an apparatus in the inner ear, the Vestibular Apparatus, which helps tell the brain how the head is positioned. The brain takes this data and combines it with data received from the eyes to help determine the actual position of the head. If a VR system which immerses the user using a head-mounted display does not update its image quickly enough, the brain will receive mixed signals from the Vestibular Apparatus and the eyes. These mixed signals can lead to motion sickness. However, according to Viirre (1996) , the brain has at least two "states" that it can remember. These states describe to the brain what the appropriate signals from the Vestibular Apparatus should be considering the images received from the eyes. The brain changes between these states based on the input the brain receives from the eyes.

This state changing is similar to wearing a pair of contact lenses. An individual can wear (and be comfortable) with both contact lenses and with glasses because the brain has remembered the two different states. In the first state, the brain receives the visual signals through the contact lenses and in the second state the visual image is coming through the glasses. The brain is able to distinguish, and switch states of the Vestibular Apparatus, between the contact lens setting and the glasses setting. In the beginning, the wearer of the contact lenses will experience some discomfort, but as soon as the brain has "programmed" the new settings, the discomfort will be gone. This observation suggests that if the user uses the VR system long enough, the brain will memorize the settings and the user will no longer experience the motion sickness.

How immersive the system is also adds to the speed problem. VR is not always simply a visual tool, but can be a complete body experience. In order for this to be true, the speed concerns addressed for the visual aspect of VR must also be directed towards other senses, namely touch and smell. If a VW participant grabs an object in the Virtual World, but does not feel the object's pressure against his or her hand until a few moments afterwards, the VW will no longer be convincing to the user.

Another problem is expense. VR can be a fun and efficient way for users to access the information in a computer. Therefore, VR should be designed for every user, not just the wealthy ones. As the costs of VR equipment comes down, it will gain wider acceptance.

Goal of this Research

If Virtual Reality is to be used effectively for real world applications, users should be able to use these systems well. Of particular concern is how efficiently and accurately an individual can do work in a VR system. For instance, if a surgical student is practicing for an operation by using a virtual cadaver, he or she should perform the operation accurately on the virtual cadaver. Therefore, the question that arises is: What properties of a VR system support the user's efficiency and accuracy? By testing two Virtual Worlds, a Literal World and a Dream World, I hope to determine what capabilities will allow users to perform certain tasks more efficiently and accurately

The Literal World will have two restrictions on movement that the Dream World will not have. In the Literal World, users will be restricted to movement at the ground level, while Dream World participants will be allowed to fly. Literal World participants will also have to walk around objects instead of walking through them. Dream

World participants will be allowed to walk through objects, such as a wall.

What Questions do I Hope to Answer?

There are two questions that this research is aiming to answer:

1) Which type of world, Dream World or Literal World, will the user work more efficiently in? Efficiently will be defined in terms of time to complete a task, with a shorter time being more efficient. For example, if a user is asked to move from one place to another, the time it takes the user to do this will represent how efficiently he or she is performing this task.

2) Which type of world, Dream World or Literal World, will the user work more accurately in? Accuracy will be defined by the correctness of a solution. For example, if a user is asked to determine where in the Virtual World he is located, the accuracy measurement will keep track of whether or not he was correct in determining his location.

Predictions

1) Efficiency: The Dream World should prove to be a more efficient environment for the type of tasks that will be performed in this experiment. Since the Dream World participants will be able to go from

one building to another simply by walking through a wall, they will perform the tasks quicker than the Literal World participants. Therefore, I expect the times of the Dream World participants to be faster than the Literal World participants.

2) Accuracy: There should not be a noticeable difference concerning accuracy between the Dream World and the Literal World. Both sets of participants should provide relatively accurate responses to the tasks presented in this experiment.

Method

Subjects

Twenty-six subjects from Colby College volunteered to participate in a Virtual Reality study. Half of these subjects participated in the Dream World (8 women, 5 men) and the other half participated in the Literal World (7 women, 6 men). The participants ranged in age from 18 to 23, with the average age being 20 years old. All subjects were familiar with the layout of academic buildings at Colby College in Waterville, Maine. All subjects had some experience using both a computer and a mouse. All subjects had heard of Virtual Reality.

Apparatus and Stimuli

The experimenting station was made up of a CTX Pentium machine (120 Mhz, 16MB RAM) and the following components; a 15 inch Gateway 2000 Vivitron15 monitor, with resolution of 680x1024; a standard 101-key QWERTY keyboard; a standard 2 button mouse. The monitor was the only form of visual interaction both the user and I had with the system. The monitor was positioned in front of the subject.

The software used to move around the Virtual Worlds was Virtus Corporation's Virtus Voyager (a VR world wide web browser).

Initially, Virtual I-O's i-glasses were to be used as a head mounted display (HMD), but due to incompatibility with the software, it could not be used. A standard personal computer (PC) mouse was used for navigation. By left-clicking the mouse (clicking the left button on the mouse) while the cursor was in the top portion of the screen, a subject could move forward, and by left-clicking the mouse while the cursor was in the right portion of the screen, a subject could turn to the right. Since all the buildings in the Virtual Worlds were four stories, there was an elevator system in each. In order to operate the elevator system, the subject could hold the alt key while left-clicking the mouse on the appropriate button.

World Description

There were two types of worlds designed: Literal Colby and Dream Colby. In Literal Colby, the user had two movement restrictions. The first was a gravitational restriction in that the user was not allowed to fly. The second restriction was a collision restriction, meaning that the user could not walk through objects such as walls. Dream Colby did not have these restrictions. The user could fly and walk through walls.

Both Literal and Dream Colby were intended to represent Colby College's layout (Figure 1). The worlds were 1000 ft x 1000 ft. There were seven buildings in the world (Figure 2). These buildings represented the buildings Arey, Eustis, Keyes, Lovejoy, Miller, Mudd, and Olin on the Colby campus.

Figure 1: Colby College Academic Quad.

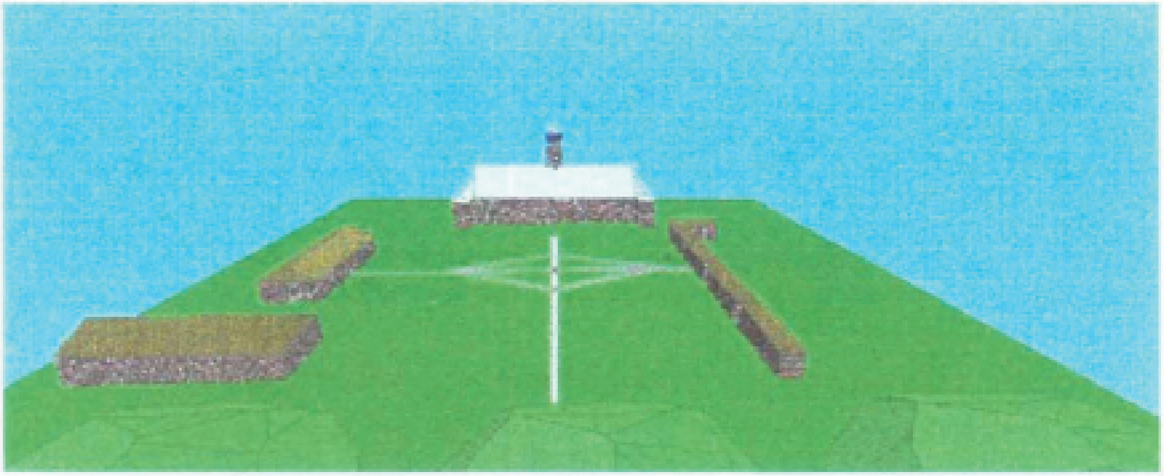

Figure 2: Aerial view of Virtual Colby.

Five of the seven buildings (Arey, Eustis, Keyes, Lovejoy, and Olin) were 50 ft x 210 ft x 60 ft. Mudd was made up of two cubic pieces; one was 50 ft x 210 ft x 60 ft, and the other was 120 ft x 50 ft x 60 ft. Miller was made up of three cubic pieces; one was 660 ft x 275 ft x 80 ft, and the other two were 65 ft x 440 ft x 80 ft. On the side of the world opposite Miller, there was a row of trees (Figure 3). In the middle of the world, there was a flagpole. Outside of Lovejoy, there was a tree. Outside of Mudd and Keyes, there was a tree and two bushes.

The insides of the buildings were all very simple. The interior of all of the buildings were very similar. There were no rooms in the buildings (excluding the third floor of Eustis as noted below) and the interior walls were either gray or light green. The floor was a carpet-like pattern, and there were no windows (Figure 4). These interiors were kept simple because the software did not perform well otherwise. The more objects placed into the world, such as windows, the slower the world got. Therefore, the interiors were all kept quite simple.

There were walkways, with windows, connecting Olin, Arey, Keyes, and Mudd. All the buildings were made up of four floors. There was an elevator system in each building. The elevator was made up of four panels. The one large panel on the left showed what floor the subject was currently on. The three smaller panels on the right represented other floors the subject could go to (Figure 5). Participants of both worlds could use the elevator to change which floor they were on in a building. Dream Colby participants could also fly between floors instead of using the elevator.

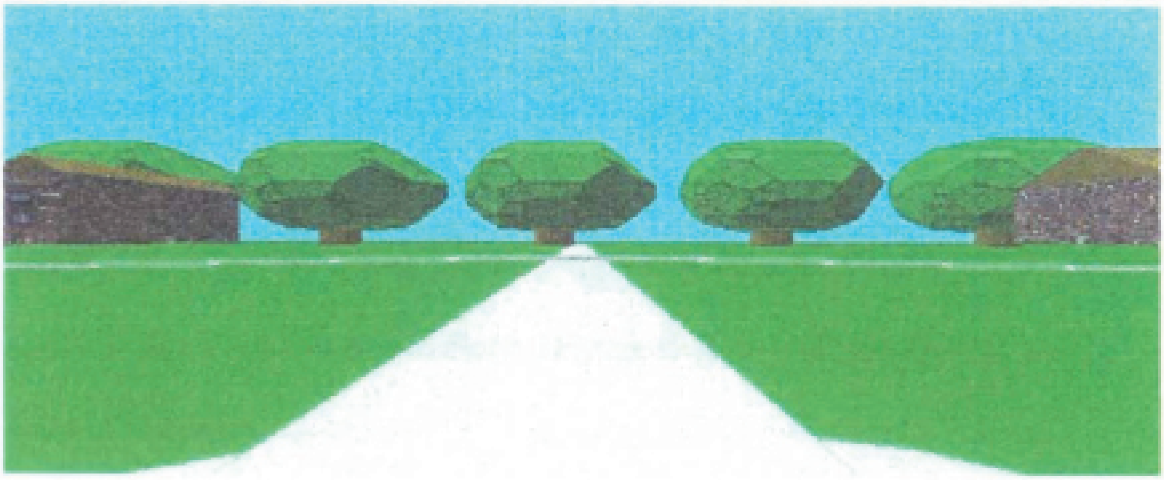

Figure 3: Row of trees.

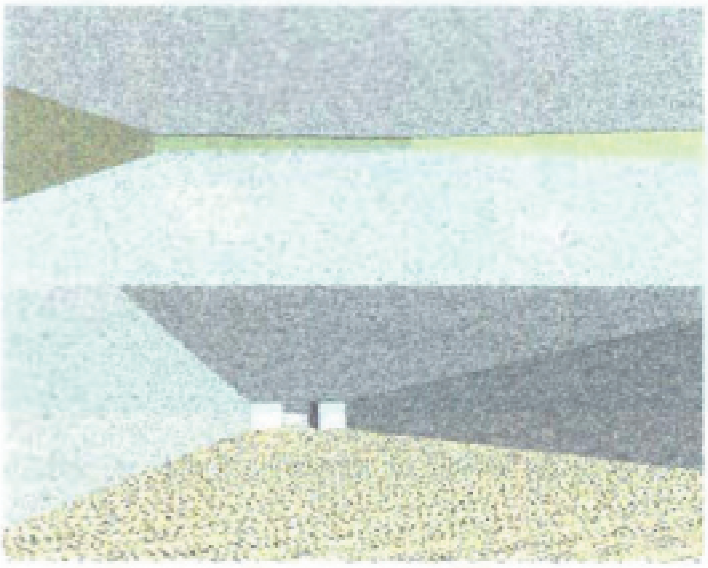

Figure 4: Interior of buildings.

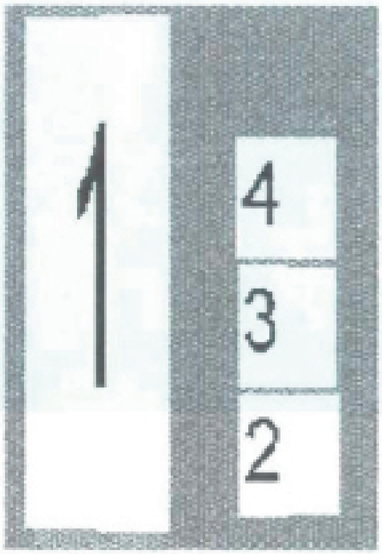

Figure 5: Elevator panel.

The two testing worlds had some additional objects included in them as follows: 1) Eustis third floor was different then the other floors in the other buildings in that it contained a maze. The maze was made up of twelve white walls. At the end of the maze, there was a tent-like object. The other three floors of Eustis were empty. 2) All four floors of Lovejoy and Mudd had three figures each on them. 3) Arey had three figures on the first floor, and two on the second, third, and fourth floor. 4) Keyes had two figures on the first and third floor, and one figure on the fourth floor. Figure 6 shows all the figures that were in the VWs.

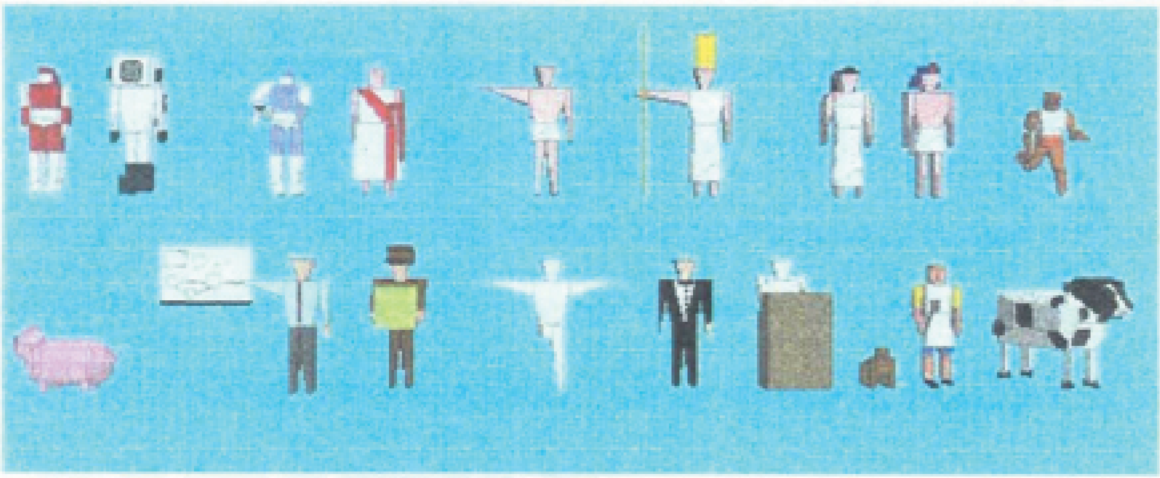

Figure 6: All the figures in the Virtual Worlds.

Training

Dream Colby and Literal Colby each had its own training module. The training module was similar to the actual world in most respects except that it was not populated with figures, such as people. The only objects in the training modules were buildings and trees.

Design

The one independent variable was the type of world the subject was in. This was a between subject design: thirteen of the subjects were in Dream Colby and thirteen were in Literal Colby. Dream Colby participants were not aware of Literal Colby participants and vice versa. Each subject completed an initial questionnaire, five minutes in the training module (so that the user could become comfortable with the controls), nine tasks in the Virtual World and a debriefing interview. Each user took approximately 1 hour to complete the experiment.

The dependent variables were: efficiency (the time to complete a task in seconds); accuracy (the solution to a question i.e. How many cows are in Olin? Answer: Five); method (how a user accomplished a task i.e. The user walked into Mudd, took the elevator to the second floor, and found the object of the task).

Tasks

Every participant was required to complete nine tasks. They were given written and verbal instructions describing the tasks. Appendix A contains a list of the tasks and the measures for each task. Each task was presented separately to the participant on a notecard. The notecard also contained a picture of the object of the task (i.e. a picture of a pig, when the user was supposed to find pigs). Each participant was given the same nine tasks in the same order. This was to ensure that each participant started from the same location to perform each task (i.e. all participants started task four from wherever task three ended).

The tasks themselves were divided into five different types: 1) Find something (e.g. Bob, who is wearing a tuxedo, is somewhere in Mudd. Find him); 2) Completely search a virtual building (e.g. How many cows are in Keyes?); 3) Navigate a maze (e.g. Go to the first floor of Eustis. Using the elevator, go up to the third floor. On this floor is a maze. At the end of the maze is a tent. Find the tent.); 4) Determine the height of a virtual object (e.g. How tall in feet would you guess the flagpole is?); 5) Starting from an unknown location, determine your location in the Virtual World (e.g. I've moved you so that you are facing a wall in one of the buildings. Which building are you in and which floor of that building are you on?).

There were three categories that were observed: efficiency (i.e. time to complete task in seconds); accuracy (i.e. did the participant accomplish the task as intended); and method (how did the participant accomplish the task).

The participant begins the test standing in the Academic Quad facing the flagpole and Miller (Figure 7). Upon hearing a task, the participant begins. The timer also begins when the subject starts the task. When the subject completes a task (i.e., finds Bob) the timer stops. The participant is then given the next task and the timer starts again. This continues until all the tasks have been completed. Throughout this entire time, I took notes regarding how long it took the user to accomplish the task, how accurately the task was accomplished and the method the participant chose to accomplish the task.

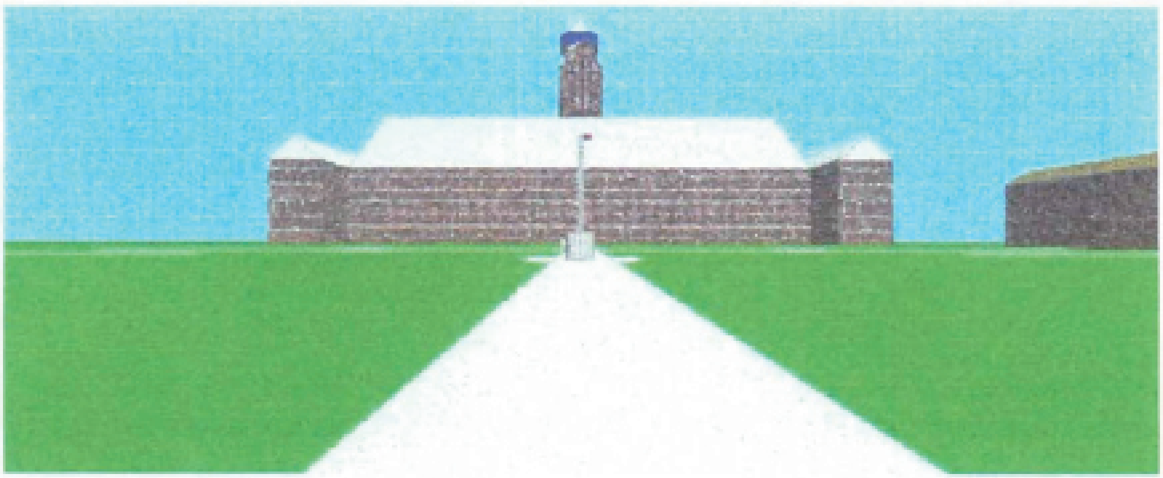

Figure 7: The starting location.

Debriefing Interview

After completing the tasks, the participant answered a twenty-one question questionnaire (Appendix B). The first three questions were a numerical rating on a scale of 1 to 10 (1 = extremely uncomfortable; 10 = extremely comfortable) to assess the participant's level of comfort performing different tasks in the Virtual World (i.e. walking). The next thirteen questions were agree/disagree questions where the participant was asked to state if he or she strongly disagreed, disagreed, was neutral, agreed, or strongly agreed with a statement about the Virtual World. The last four questions were open-ended questions which asked the participant to write a few sentences describing different aspects of their experience with the VW.

Results

Three dependent variables were looked at with this study: time to complete a task, the correctness of a task, and how a task was completed. Time was used to determine how efficiently tasks were being performed in the different worlds. The correctness of the task was used to determine the accuracy of the user in the world. The user's method was used to help understand why one world would be more or less efficient or accurate than the other world.

Efficiency

Of the five task categories, four were looked at to report on accuracy: find something, search a virtual building, navigate a maze, and determine your location. The data is shown graphically in Figure 8. Two of the four categories measured differed minimally in the amount of time taken for the participant to complete a task, namely determining height and figuring out where the user was located. Literal Colby and Dream Colby participants took approximately the same amount of time to guess the height of the flagpole and the bush (average time for the flagpole: Literal Colby 85 seconds; Dream Colby 77 seconds; average time for the bush: Literal Colby 41 seconds; Dream

Colby 53 seconds; average time for determining height overall: Literal Colby 63 seconds; Dream Colby 65 seconds). The same was true for determining where the user was (average time for the user figuring out he or she was in Olin on the second floor: Literal Colby 42 seconds; Dream Colby 38 seconds; average time for the user figuring out he or she was in Miller on the first floor: Literal Colby 34 seconds; Dream Colby 33 seconds; average time for the user figuring out where he or she was located overall: Literal Colby 38 seconds; Dream Colby 36 seconds).

There was a noticeable difference in time for the other four tasks. The Dream Colby participants performed these tasks quicker than the Literal Colby participants. On average, it took Literal Colby participants 355 seconds to find something the first time, while it took Dream Colby participants 217 seconds. The second time the participants had to find something, it took Literal Colby users an average of 187 seconds and Dream Colby users 145 seconds. Literal Colby participants conducted the first all encompassing search of a space with an average time of 326 seconds. Dream Colby participants conducted the same search with an average time of 306 seconds. The second time the users completely searched a virtual building, it took Literal Colby users 354 seconds and Dream Colby users 200 seconds on average. It took Literal Colby participants an average of 315 seconds to complete the maze while it took Dream Colby participants an average of 230 seconds to do the same.

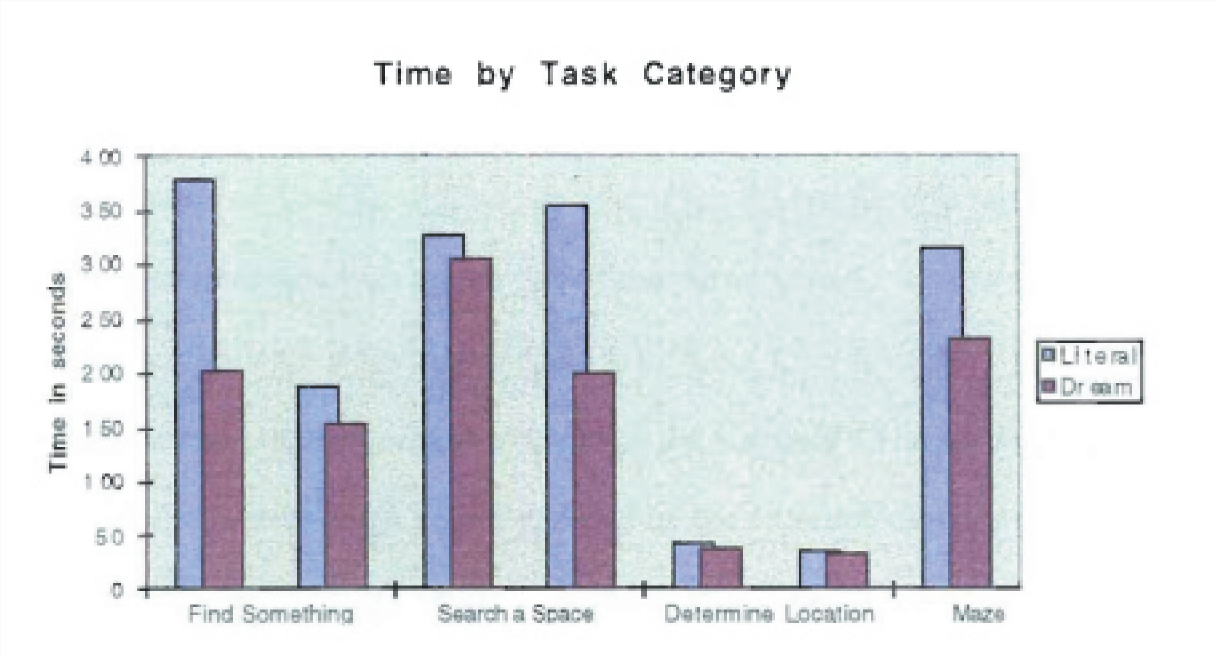

Figure 8: Time by Task Category.

Accuracy

Accuracy was measured in three task categories: search a virtual building, determine height, and determine your location.

Two of the task categories looked at for accuracy did not differ at all. All 26 participants searched a given space completely (i.e. all 26 found 5 cows and 9 pigs) and determined their location correctly (i.e.

all 26 figured out they were on the second floor of Olin and then the first floor of Miller).

Determining height differed slightly for the two sets of participants. The first height determination was to guess the height of the flagpole (an item approximately six times taller than the participants) and the second was to determine the height of a bush (an item approximately half the height of the participants). The Dream Colby participants were more accurate than the Literal Colby participants in determining the height of the flagpole. The actual height was 35 feet; the average height guessed by the Literal Colby participants was 45 feet; the average height guessed by the Dream Colby participants was 36 feet. For the flagpole, if the user guessed a height within 5 feet of the actual height (i.e., between 30 and 40 feet), it was considered accurate. See Figure 9 for the heights guessed by the users. The difference between Dream Colby participants and Literal Colby participants was not as severe for determining the height of the bush. The actual height was 3.5 feet; the average height guessed by the Literal Colby participants was 2.9 feet; the average height guessed by the Dream Colby participants was 2.8 feet. For the bush, if the user guessed a height within 1.5 feet of the actual height (i.e., between 2 and 5 feet), it was considered accurate.

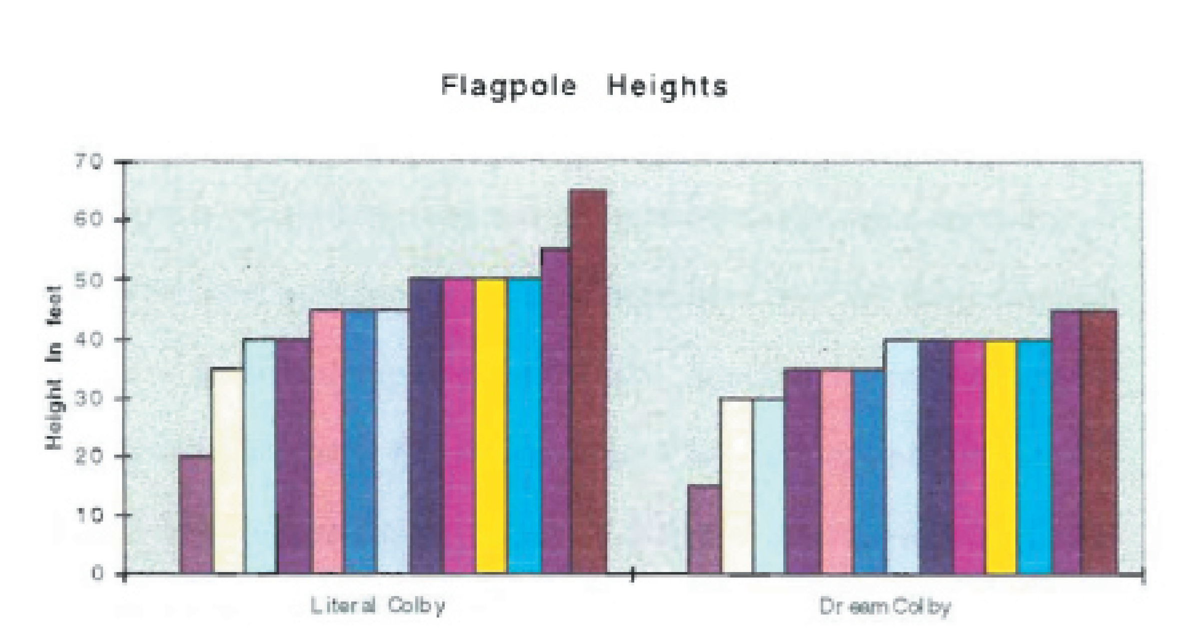

Figure 9: All the flagpole height guesses.

Debriefing Interview

A debriefing interview was administered after the test. Participants of both worlds felt comfortable walking forward (average rating: Literal 8/10; Dream 8/10). Dream Colby participants felt a little more comfortable walking backwards than Literal Colby participants (average rating: Literal 6/10; Dream 7/10). Literal Colby participants were much more comfortable using the elevator than the Dream Colby participants (average rating: Literal 10/10; Dream 5/10).

The next 13 questions asked the participant if he agreed or disagreed with a statement (e.g. The Virtual World was more like a game than the "real world": Strongly Disagree; Disagree; Neutral;

Agree; Strongly Agree). These questions attempted to figure out what the user thought of the experience in the Virtual World. Answers from both Literal Colby and Dream Colby participants varied very little. All participants generally agreed and disagreed with the same questions.

The next question was used to determine how tall the participant felt he or she was represented in the VW. It asked the participant to specify what height he or she was in the VW and it gave five ranges to choose from (e.g. 0-2 feet, 3-4 feet, 4-7 feet, 7-10 feet, 10+ feet). All 26 participants selected the 4-7 foot range.

Two other important categories were examined: what was frustrating, and what was disorienting. Of the 13 Literal Colby participants, four felt that the controls of movement (namely the mouse) was not a very precise system and they found it very frustrating, while two of the 13 Dream Colby participants felt this way. Two of the Literal Colby participants believed that a virtual representation of reality should eliminate tedious tasks that we must perform in real life: "If it is virtual, we shouldn't have to waste our time moving so slowly from building to building, or through doors"; another said: "It would have been nice to be able to jump from one building to another without having to walk, like we do in real life".

The most disorienting part of the VW, according to the Literal Colby participants, was the fact that the buildings were not very unique inside. Seven of the 13 Literal Colby participants felt this way. Four of the Dream Colby participants felt this way. Complaints include "The maze was really disorienting because the walls all looked the same and if you took your eyes off it for a second, you couldn't figure out where you were", and "...the buildings all looked the same inside, so you couldn't tell where you where unless you went outside".

Eight of the Literal Colby participants felt that their experience in the VW was fun. Seven of the Dream Colby participants also felt this way.

Discussion

Efficiency

By looking at the data concerning efficiency overall, it appears that Dream Colby participants were more efficient performing their tasks in almost all cases. Out of the seven tasks performed to judge efficiency, Dream Colby individuals completed six quicker than Literal Colby participants. In the case that the Dream Colby participants weren't necessarily more efficient, they were at least as efficient as the Literal Colby participants (see Figure 10).

These results were expected because Dream Colby participants didn't have to wait for the elevators when they wanted to change floors, they just had to fly up or down. One interesting observation that was not expected concerned the maze. As expected Dream Colby participants completed the maze more efficiently than the Literal Colby participants. In order to explain this difference, the methods need to be looked at. I would have expected that the Dream Colby participants would simply walk through the walls in the maze to complete it, instead of walking around the walls. However, this expectation was incorrect. It turned out, of the 13 Dream Colby participants, only 4 walked through walls. The other 9 completed the maze in a similar fashion to the Literal Colby people. The next interesting observation from this comes when you remove those 4 individuals from the Dream Colby data pool (see Figure 11). The 9 Dream Colby participants who completed the maze in a similar fashion to the Literal Colby participants, were still faster than the Literal Colby participants. Two possible reasons for this are: 1) Poor observational techniques. Potentially, while I was writing down that the user was not walking through walls, the user accidentally did go through a wall. 2) With the software used for this experiment, the farther away the user clicked from the center of the screen, the faster the user moved. Potentially, Dream Colby participants generally clicked farther away so that they would be able to move faster.

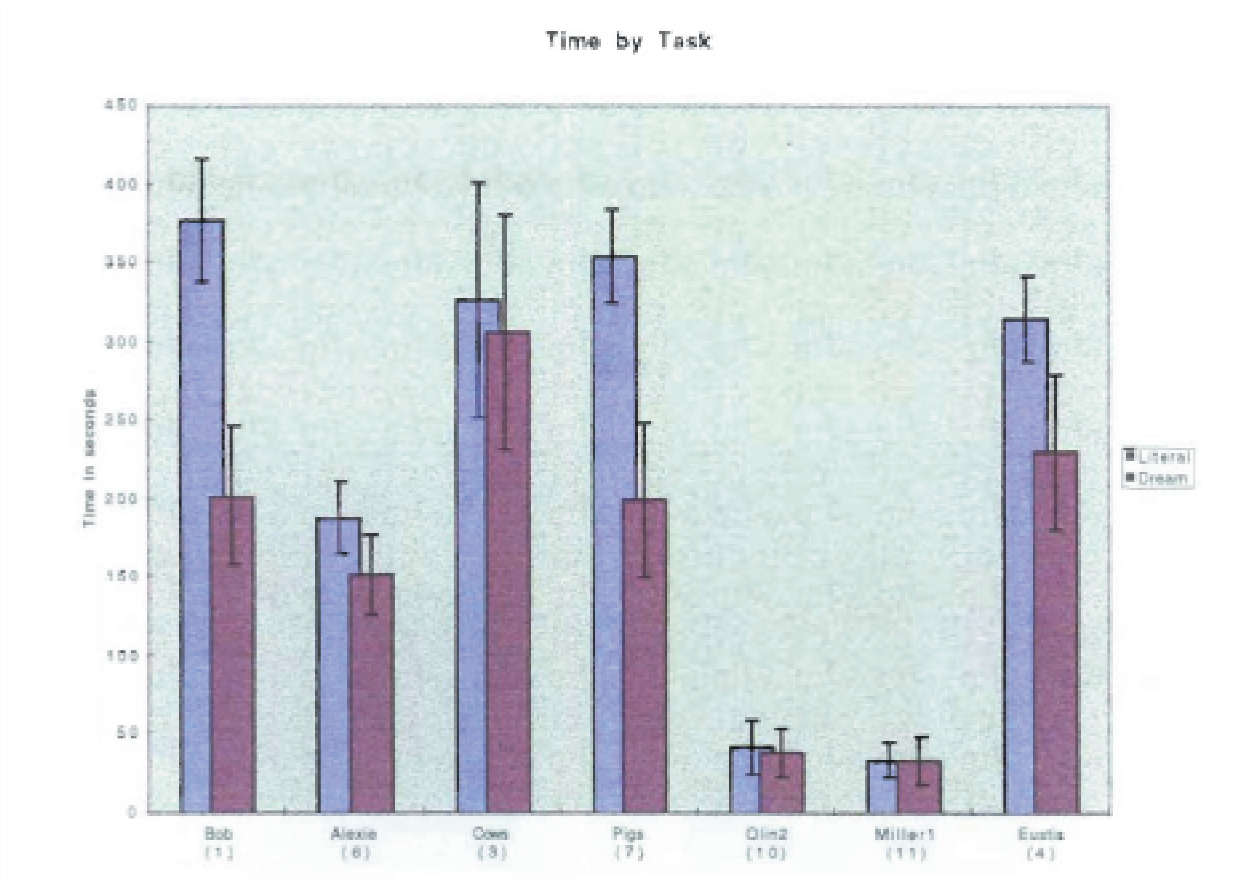

Figure 10: Efficiency with standard deviation.

As predicted, it turned out Dream Colby participants were more efficient than Literal Colby participants. This was because the Dream Colby participants had access to better methods for performing tasks. When Literal Colby participants had to go from one building to another, they were required to find a door and then go through the door to travel to the other building. Dream Colby participants could simply walk through a wall towards the other building. Literal Colby participants were also at a disadvantage because they had to wait for an elevator when they wanted to go to a different floor in a building. Dream Colby users just had to fly up or down if they wanted to change floors, which saved a lot of time.

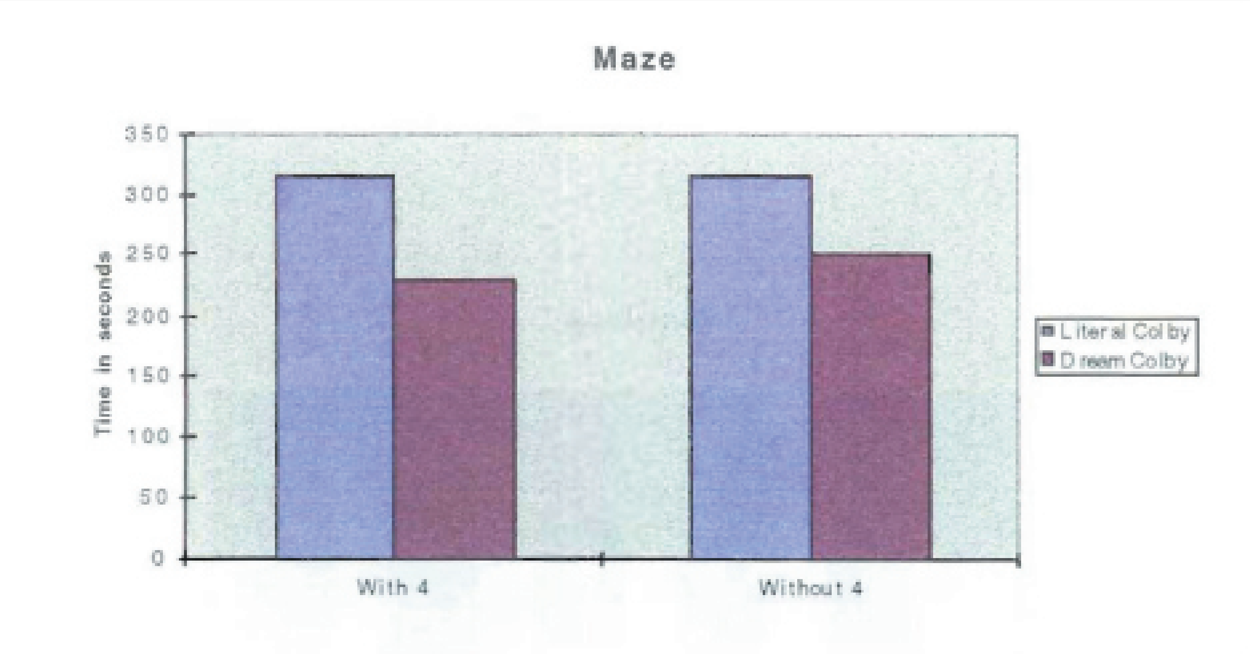

Figure 11: Dream Colby participants and the maze.

I predicted that there would not be a difference in the level of accuracy from one world to another. It turned out that Dream Colby was more accurate than Literal Colby. Again, this is due to the fact that Dream Colby participants had access to better methods for performing certain tasks.

Accuracy

By looking at the data concerning accuracy, it appears that Dream Colby and Literal Colby participants were equally as accurate in almost all cases. In the cases where one set of participants was more accurate than the other, it was always the Dream Colby participants who were more accurate (see Figure 12).

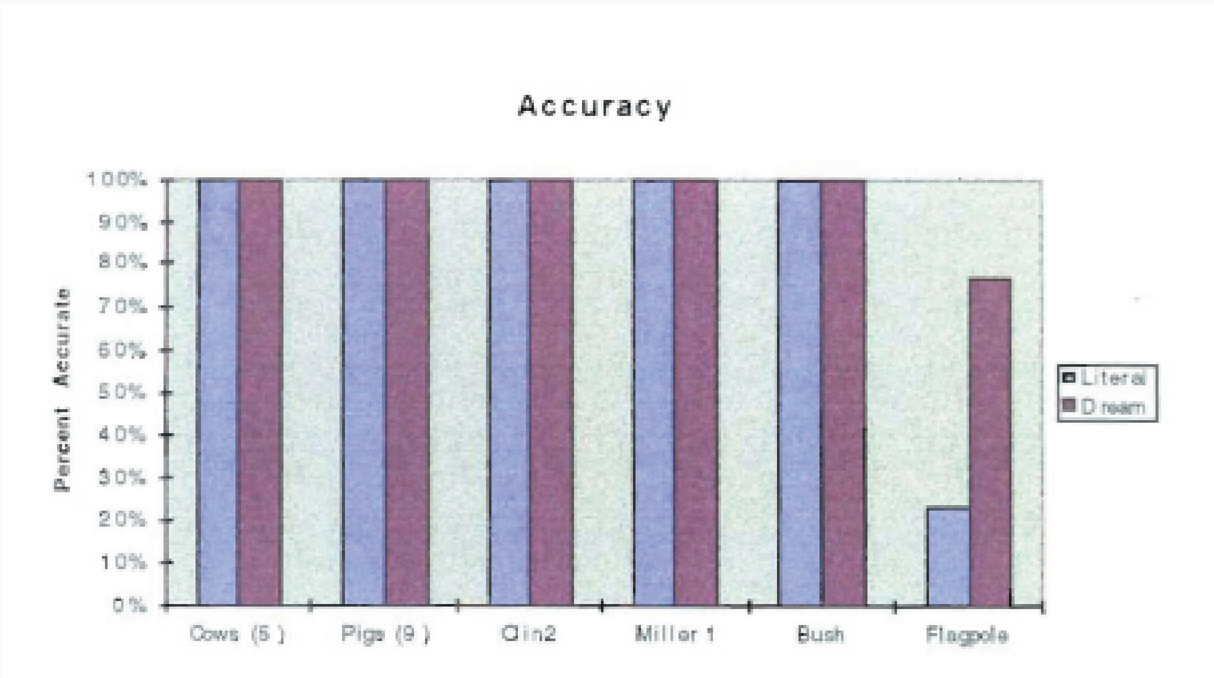

Figure 12: Accuracy.

77% of Dream Colby participants were accurate in determining the height of the flagpole, while only 23% of Literal Colby participants were accurate. This can be explained by looking at the methods used by both sets. The 13 Literal Colby participants had no other option than to stand in the quad and look at the flagpole to make a guess. All 13 of the Dream Colby participants, however, had access to, and used a better method. They all flew up to the height of the flag (the top of the flagpole) and then compared their location with other landmarks in the world, such as buildings. Some of the Dream Colby participants even flew at that height into a building to see what floor they were on to determine their height

Conclusions

Dream Colby was a better design for the type of tasks performed for this experiment with regards to efficiency and accuracy. This was because the Dream Colby users had access to better methods to complete a task. This does not mean that Dream Colby will always be a better design. However, a designer of Virtual Worlds, who is designing a world in which tasks similar to those presented in this experiment will be performed in that world, should allow the user the freedom of movements allowed in this study if he or she would like to capitalize on increased efficiency and accuracy.

Further research on this subject would not only be interesting, it would be appropriate. If I had more time, an in depth analysis as to why Dream Colby participants navigated the maze quicker than Literal Colby participants would be interesting. I would retest that task with a new subject pool. During this test, I would try to determine why Dream Colby users were able to complete the maze quicker, even though they were not walking through walls.

Another area of this research that would be interesting to look at deeper is the fact that these Virtual Worlds were desktop Virtual Reality, meaning that the user experienced them in the same way a user experiences computer systems today, through a monitor. It would be interesting to see how these results differ if the worlds were immersive (having the user wear a headset, for instance). By having the user wear a headset, the world would be more immersive and the user would hopefully get a better sense of his or her surroundings. Would this change result in Literal Colby users being more efficient and accurate than Dream Colby users? Would there be a certain level of discomfort associated with either world, or both?

Another possible direction this research could go is within the worlds themselves. Currently, nothing in the worlds, besides the user, can move. It would be interesting to design these worlds so that the user could actually interact with objects (e.g. a user would be able to pick up a book and do something with it). Would this portray a better image of reality to the user? Would this give the user any advantages over the worlds as they are designed now?

A Virtual World designed to maximize efficiency and accuracy should do just that. This research has touched the surface as to what factors may contribute to such a world. Through further research and investigation, a more comprehensive list of such factors could be produced. This is only the first step in the journey of finding such a list.

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Appendix A

DATA:	TASKS
Time:	Bob, who is wearing a tuxedo, is somewhere in Mudd. Find him.
Time: How many?	How many cows are in Keyes?
Time:	Go to the first floor of Eustis. Using the elevator, go up to the third floor. On this floor is a maze. At the end of the maze is a tent. Find it.
Time:	Alexie is running in Lovejoy. Find her.
Time: How many?	How many pigs are in Arey?
Time: Height?	How tall would you guess the flagpole is?
Time: Height?	How tall is the bush in front of Keyes?
Time: Time:	Now I will start you off in different locations, tell me where you are.

Appendix B

Please rate your level of comfort on a scale of 1 to 10, with 10 being extremely comfortable and 1 being extremely uncomfortable.	**Rating**
Movement	
Walking Forward	
Walking Backwards	
Using the elevators	

Please circle whether you agree or disagree with the following statements.

This virtual world was more like a game than the "real world".	strongly disagree • disagree • neutral • agree • strongly agree
I felt like I was actually visiting around Colby.	strongly disagree • disagree • neutral • agree • strongly agree
I found the lack of interior walls in the buildings very confusing.	strongly disagree • disagree • neutral • agree • strongly agree
In the beginning, I found it very easy to get lost.	strongly disagree • disagree • neutral • agree • strongly agree
At the end, I found it very easy to get lost.	strongly disagree • disagree • neutral • agree • strongly agree
I would have liked to have been able to walk through walls.	strongly disagree • disagree • neutral • agree • strongly agree
I would have liked to have been able to fly.	strongly disagree • disagree • neutral • agree • strongly agree
When I was moving, I felt like I was walking.	strongly disagree • disagree • neutral • agree • strongly agree
The elevators were too slow	strongly disagree • disagree • neutral • agree • strongly agree
Using the mouse for navigation was confusing.	strongly disagree • disagree • neutral • agree • strongly agree
I wish there had been stairs instead of an elevator.	strongly disagree • disagree • neutral • agree • strongly agree
The inside of the buildings all looked the same.	strongly disagree • disagree • neutral • agree • strongly agree

Appendix B (cont.)

Please answer the following questions.	
Roughly, what height did you associate with yourself?	0-2feet • 3-4feet • 4-7feet • 7-10feet • 10+feet
How tall are you in real life?	
What did you find frustrating about this experience?	
What did you find disorientating about this experience?	

Please describe below your feelings on your experience in the virtual world.