# Virtual Confined Space Experiment

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## ABSTRACT

The purpose of this document is to explain the procedure and reason behind the Virtual Confined Space Experiment. I worked with this project at The Pennsylvania State University Applied Research Laboratory with the SEALAB team. This document will detail the designing, method, and the factors tested and the results of that testing.

### Keywords

Virtual, Virtual Reality, Virtual Confined Space,

## INTRODUCTION

The Virtual Confined Space Experiment in a general sense is the study of a persons' acceptability to a virtual environment. This experiment was put together to try and find out what factors came into play when a person is immersed in a virtual environment. Testing was done using a virtual environment that was based on a real environment. For this experiment a vending room was chosen as the environment.

## RESOURCES

This experiment was preformed at The Pennsylvania State University Applied Research Laboratory. The computers used in the development of virtual environments are the SGI Octane, Tezro, and 330 computer systems. The software that was used to modify the virtual vending room was MultiGen Paradigm's Creator and Vega Prime. The system used to display the virtual environments is the CAVE (Cave Automatic Virtual Environment) by FakeSpace [3].

## WHAT IS A VIRTUAL CONFINED SPACE?

A computer science definition of the word virtual is: Created, simulated, or carried on by means of a computer or computer network [1]. Along with the word confined meaning: to in close [1] give a good idea of a virtual confined space. It means and in closed virtual environment where the user is immersed meaning: to plunge into anything that surrounds or covers [1]. The CAVE is designed to enclose the user inside four walls which stereographic images are projected on. Using a special pair of glasses and a tracking system the images are combined to give the appearance of three dimensional spaces. Using this system a virtual mock up of a vending room was created to scale of an actual vending room.

### Virtual Vending Room

Modeling of the vending room was done first by taking measurements of the actual vending room to get as close to an accurate replica in the virtual world. The original model was done by Kylie Nash. During the first phase of testing the model was to look as close as possible to the real vending room. The room was modeled using photos of the room and the measurements to make a 1:1 scale room and texture mapping on the surfaces to give the room as close to a real look as possible in a virtual environment. This model can be seen in figure 1 with a picture of the actual room. Using this model as a base the virtual room was modified to make it a color model representation of the room instead of a realistic representation. To do this the texture mapping of images was removed and a color based system was used to represent objects within the room. The room consists of a drink machine, snack machine, trash can, book shelf, chair, and 2 coat racks.


**Figure 1: Real (left) and Virtual (right) vending room.**

*The Color System*

The color system that is used in the updated model is a color scheme used to represent types of structures within a virtual environment. This color scheme is commonly used when visualizing CAD (Computer Aided Design) data within the virtual environment. Here are the colors and

what they represent. Green - machinery, Purple – electrical, Red – structures.

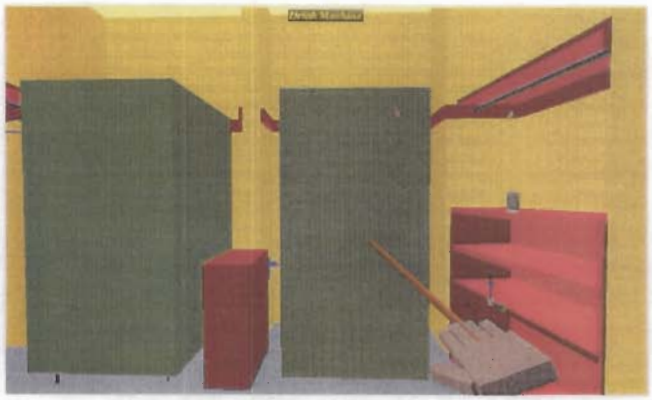

Figure 2: Virtual False Color Model

### Other Modifications

Along with the color changes the virtual vending room was modified to make the objects with in the room moveable. In the first model objects with in the environment were static and unmovable. Making movable objects within the environment gave way to the possibility of more involving tests with more complex tasks which would attempt to increase the involvement of the user within the environment. Simulated lighting and material gave the environment a solid look in the absence of image textures.

## WHY TEST USERS EXPERIENCE?

Testing the experience of users within the virtual environment must be done to find out what effects such environments have on the human body and mind. Since virtual reality is still not as common place as the television testing can be done to refine the technology before it becomes widely used and increasingly difficult to improve. This study and other like it are being done to ascertain the practical uses of the virtual environment. The main focus of this study is to improve the user experience inside the virtual environment. Virtual mockups are quickly replacing traditional desktop 3D Computer aided Design (CAD) tools and physical mockups, for visualizing products, because of the time, expense, and the labor boundaries of a physical mockup. [4] By testing various users in the environment over a period of time data and responses will be analyzed to find out what will make the virtual environment as welcome to a wide range of users. These tests also attempt to find flaws in using a virtual environment so that the problems can possibly be worked out. The user input is an important factor in the development of this technology and it is important to try and receive as much of the user input as possible.

## EXPERIMENTATION

The experiment done by Kylie Nash was conducted using the virtual and the real vending room. The goal is to determine if virtual environments can convey spatial information to the user, so they can accurately perceive what the space looks like without actually being in the physical world. [4] There are however limitations in the virtual environment that are not present in the physical world, due to scaling differences. [4] These limitations include the user's perception of size, shape, space, and their body within the virtual mockup. [4] The user was told to complete identical tasks and answer questions. The responses in both environments were compared and scored to give an idea of how the user accepted the virtual mock up as oppose to the real room. Kylie states that "a comparison of the results from the virtual and physical questionnaires is the key" [4] to understanding and eliminating the limitations and questions about virtual environments.

### Testing the test

The first phase of testing was to test the new version of the experiment. Since modifications were made to the virtual environment the new elements had to be tested before selection people to start the experiment. The new movable aspect of the virtual room was the biggest part of this test phase. In order to give accurate instructions to the user about how to move objects tests were done with moving various objects. The problems occurred when trying to move an object and accidentally selecting another object such as the wall itself and turning the whole room. To solve this problem a better object was selected for the interaction test. This testing also presented the opportunity to find flaws in the presence questionnaire. The questionnaire had to be corrected to clearly state objectives.

Figure 3: User moving a virtual hanger within the Virtual Vending Room

### Presence Questionnaire

Kylie devised a brief questionnaire that would attempt to get a feel for the user's acceptability of the virtual room. Her questionnaire was composed of 3 different sections: Navigation and Orientation, Spatial Relationship, and Tasks. After the questions were answered for both the

virtual and real room a score was given based on the comparison of the answers. The PQ or presence questionnaire has been updated, but retains the same tasks and questions as the original with more questions added that are based on Sensory Perception. The new questions have a focus on the reactions of the user's senses in the virtual environment. With these new questions being added a new scoring system was developed to fit the first set of questions with the added ones. The sections were reduced from 3 to 2; tasks and sensory perception.

*Tasks*

The tasks are designed to involve the user in the virtual environment. This interactivity will involve the novice to expert user within the environment. The tasks are simple and easy to do with one complex task. This may seem unbalanced when you the aspect that the novice may have increased difficulty with the tasks where as the season veteran will have no trouble performing the tasks. My attempt to balance this was in the Sensory Perception section of questioning. The tasks included simply navigation though out the virtual environment, interaction with objects with in the environment and a complex task that is suppose to seem possible in the virtual environment when in actuality it is impossible to accomplish. The goal of the tasks is to test the user's ability to navigate in a virtual environment and to test the user's spatial orientation.

*Sensory Perception*

With the tasks being as they are a veteran of the virtual environment will have no trouble completing the tasks, but with the questioning we find out how the senses come into play with the virtual environment. A novice is more likely to have "Awe Factor" when using the CAVE for the first time therefore enhancing his or her experience where as a veteran is acclimated to the environment and is not taken as easily by the visuals. With the sensory perception questioning I attempted to grab the experience of the novice regardless of the difficulty factor of being able to use the CAVE. The question focus on the effects the virtual environment has on the senses of hearing, sight, and equilibrium.

**Scoring**

In the first series of testing the users were scored based on the comparison of their responses to the question and a percentage was given based on how close their responses were. I changed this method to try and score based on how much of the person's senses were positively or negatively affected within the virtual environment. Using the users responses to the question presented in the PQ I assigned a percentage based on the weight of the question relating to the sense that the question is referring too. The scoring system was developed on basis that the percent of presence a person experiences within the virtual environment is related to how much each of the senses are involved in the environment. A person uses 100% of all sense that the person has at all times in the real world. With this in mind a method was devised to try and find out just how much of a person's senses are involved in the environment. In the following example you will see the use of 6 senses. Each sense is balanced equally based on the person. Each sense is weighted equally as a percentage of 100%. The rationale behind this is that at all time in the real world we use all of our senses. All of the senses are balanced because they all contribute to the person's presence in the real world. Even if a person losses one sense the others increase naturally to compensate for the missing one which results in a 100% usage and presence relative to that person. The facilities of touch, taste, and smell were not questioned or gauged in the virtual environment which results in a 0% use of those senses. However they are included in the scoring because the person is still using these senses regardless if the virtual environment stimulates theses senses or not.

*Functional Senses Score*

Information must be obtained regarding the condition of each of the persons senses using hearing, sight, smell, taste, touch, and equilibrium a score is given based upon the individual's ability to use each sense. A fully working sense would yield a score of 1 and a no working one would yield 0. Partially is 0.5. Here are a few examples of obtaining the score:

- Person 1 has fully functional senses

  Hearing = 1
  Sight = 1
  Smell = 1
  Taste = 1
  Touch = 1
  Equilibrium = 1

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  Functional Senses score = 6

- Person 2 is blind

  Hearing = 1
  Sight = 0
  Smell = 1
  Taste = 1
  Touch = 1
  Equilibrium = 1

Functional Senses score = 5

- Person 3 has a slight vision problem, but is not wearing any corrective eyewear

Hearing = 1

Sight = .5

Smell = 1

Taste = 1

Touch = 1

Equilibrium = 1

Functional Senses score = 5.5

*Use and Perception score*

The use and perception score (UPS) is calculated for each individual sense. Each sense is scored by using the following formula:

- ((((1/FSS) * 100) * PoP)/ 100) * FSS = 1 sense use and perception score

FSS is the Functional Senses score from above and the PoP is the percent of perception which is base upon the answer obtain in the PQ. After each sense is calculated the UPS for each sense is calculated by adding all the UPS scores obtained.

*Perception Score*

The total and final score is calculated by the use of the following formula:

- (Total UPS/FSS) * 100 = Total Percentage of Presence

*Example of scoring process*

Using the questions a person is gauged based on the senses used during the experiment. The senses of smell and taste are not gauged by questioning since the virtual environment used has no way of stimulating these senses; although they are not excluded from the calculation since the person is still using these senses. The FSS is assumed to be 6.

- Each sense is broken down into a smaller percent of the whole

(1 / FSS) * 100 = sense%

(1 / 6) * 100 = 16.7% (rounded up)

Sight – 16.7%

Hearing – 16.7%

Taste – 16.7%

Touch – 16.7%

Smell – 16.7%

Equilibrium – 16.7%

- Let's assume the subject answers the questions relating to sight by giving a rating of 1 using the Likert scale. Then the PoP of sight is 100%. Then we use the following equation

((sense% * PoP) / 100) * FSS = UPS

((**16.7 * 1**) / 100) * 6 = 1.002

- The answer is a perception score to be added with the results from the other senses as so

Sight = 1.002

Hearing = 0.3507 (using 35%)

Taste = 0

Touch = 0.3507 (using 35%)

Smell = 0

Equilibrium = .2004 (using 20%)

Total UPS = 1.9038

To find the percent of presence experienced

(Total UPS / FSS) * 100 = Total Percentage of Presence

(1.9038 / 6) * 100 = 31.73 % of presence

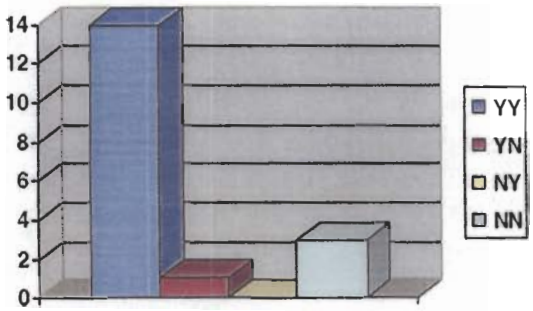
**Orientation**

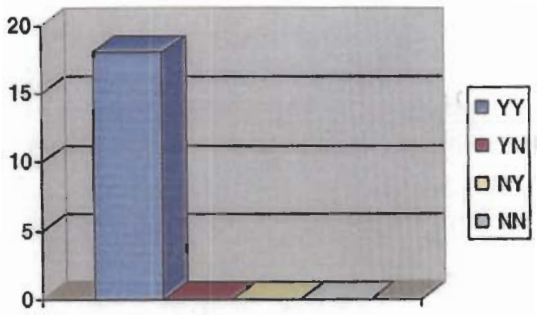
The decision to use a short orientation session of the virtual environment was made as an equalizing element between the experience user and the novice user. After a few test runs with users before the orientation was implemented a few observation were made. The increased difficulty that the new user experienced greatly affected the performance and scoring of the user. The brief orientation was a program designed to show how the immersive display system itself works and to allow the user to navigate for a brief moment before the experiment began. The program was no more than a display of the projection system of the CAVE system. The user was allowed to move around and see how the projections on the 4 wall system were created. This gave a new user the answers to "What is this?" and "How do I use this thing?" in a short time. Comments of users experience contributed to the

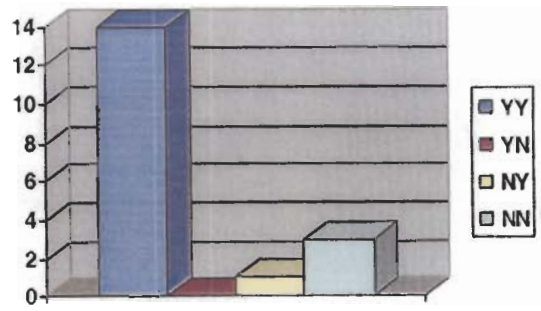
need of the orientation session. A new user was not able to function in a manner that would allow the subject to effectively complete the experiment.

## DATA ANALYSIS

Data analysis was preformed on a pool of 18 of the completed test. Tasks that were preformed in the experiment were scored an analyzed using two methods. The user was given tasks to complete which would yield a Yes or No answer. A comparison chart was made to find out how many users gave Yes and No in the Real and Virtual rooms. The Chart has the order of Real to Virtual. An example of the symbols are YY = Yes(real)Yes(virtual) and YN = Yes(real)No(virtual). The following are charts showing the results of these tasks. The tasks that we used this analysis on were 1, 5, 6, and 7.



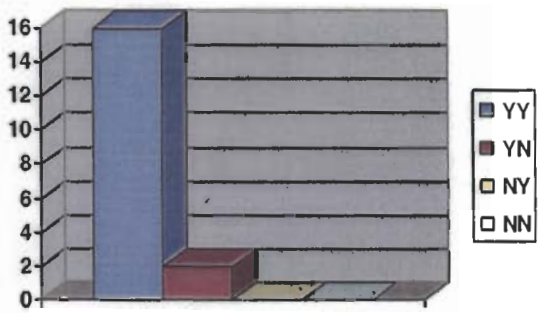
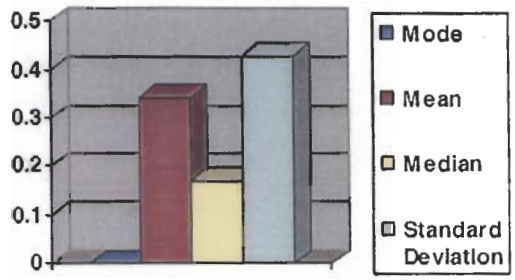
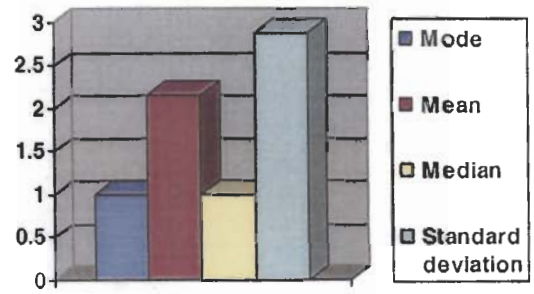
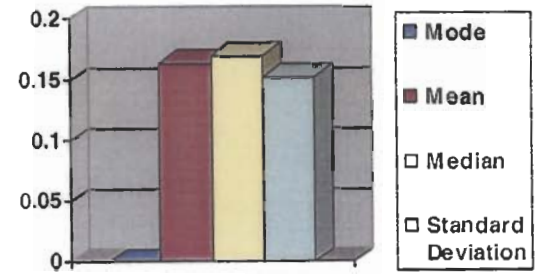




Figure 4 a-d: Charts of Tasks 1, 5, 6, and 7

Each person that was tested gave estimates in feet and inches. These values were converted to a decimal and compared. From this comparison the mean, mode, median, and standard deviation were calculated. This method was used on tasks 2, 3, and 4.



## CONCLUSION

Out of the 24 subjects tested up to this we found a few interesting observations. A key observation I noticed was that if the interaction within the virtual environment is to simplistic or difficult the person has a decreased sense of presence. With increased difficulty the user feels excluded and lost, and with great ease the user feels he/she is included in the environment. Another observation that was made was that the background of a user plays an important role in the presence. Using the comments and the observed reactions the conclusion that presence is unique to individuals based on what they relate the environment to. Some users referred to the environment as a being like a video game. Further research is needed to find the common groups that will provided a virtual environment to target a certain group of individuals. From the tests a discovery was made that one subject had Multiple Sclerosis and that balance and equilibrium was an issue in her daily life. The subject said that within the virtual environment there was no difficulty in maintaining balance. Some research could branch to find out if virtual environments could be used to treat persons with illnesses that impair balance and equilibrium.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