A Comparative Study of Presence in Virtual Reality vs. Presence in the Real World

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ABSTRACT

The primary purpose of this research was to study and compare the relationship between the sense of presence in the virtual environment and the sense of presence in the physical world while experiencing the virtual world. There were two parts to the study, each consisting of thirty-five subjects. A moderately simple virtual plane environment was experienced while using a 6D head-tracking system and display. Participants were given a questionnaire after completing fifteen minutes in the simulation. Using simple averaging, The Part I data indicated that participants felt almost equally present in the real word simultaneously with the virtual world. Sense of presence was slightly higher in the virtual world than the real world. Using a scale of 0-10, the total combined average of sense of presence was eleven. In Part II, sense of presence was again slightly higher than presence in the real world, and the total combined average sense of presence was thirteen. The Part I results lead to a preliminary and interesting theory that a person's overall sense of the world actually increases slightly when put into a virtual environment. The Part II data supports the findings of Part I. Advances into virtual reality research allow the development of technologies that enhance and optimize human abilities and efficiencies; human interaction and learning; and sensory and cognitive capabilities. Research in these areas enhances opportunities for the discovery and generation of new knowledge, which in turn advances the efficiency and effectiveness of man and machine interaction.

Keywords

Sense of Presence, Virtual Environments, Virtual Reality

1. INTRODUCTION

A well-known aspect of virtual reality is the sense of presence in the virtual environment. It is often thought of as the sense of "being there." In the 1990's, a few theoretical research articles were published in the journal of *Presence, Teleoperators and Virtual Environments*, published by the Massachusetts Institute of Technology (MIT) [2, 4, 8, 9, 12, 13]. However, a limited number of research articles have been published in this area and appear to lack much needed experimentation. As North wrote in a recent article, "there is a great need to develop a scientific body of knowledge or a theory to assist researchers in the development of efficient virtual environment applications," and within this to "rigorously investigate the sense of presence" [3].

In-depth studies into the sense of presence are currently being thoroughly investigated, but because of the complex nature of this subject, they have been very focused and have left some small gaps. This study expands on one such gap. Topics being discussed and very relative to this study are: What is presence exactly? What factors contribute to your sense of presence in an environment, either virtual or real? What is the best method for measuring presence? This study had to consider each of these topics carefully, so a literature review of these topics is included in this paper.

So, how is presence defined? Simplistically, presence is the sense of being in an environment, either real or virtual. Although this definition is intuitive, it is actually quite vague. To begin with, what does it mean to be present somewhere? Is it a function of the body or the mind? The traditional way of thinking of presence stems from the writings of Rene Descartes and the German philosopher Emmanuel Kant. They make a clear distinction between objects located in the mind and objects located outside of the mind [7]. One of the first theoretical articles on presence describes it as the feeling of "realness, vividness, and feeling very much alive" [2]. There was also a proposed division of the definition of presence, separating it into subjective presence (conscious state-of-mind) and behavioral presence (non-conscious state-of-mind) [10]. However, there is another recent view of presence that fits well with virtual reality: the concept of estimation. Thomas Sheridan presents this concept using three defining points. "1. 'Real' reality can never be known but, because of sensory and action constraints, only estimated." This makes all perception virtual reality to some extent. "2. This estimate takes the form of an internal action-sensation model mapping." Thus, the constantly reassessed environment can be changed through "action upon the environment, sensing the result, and refinement of the model to get a better prediction." And "3. The action and sensing are not random, but are condition by the action and sensory filters. For this reason, and because of time limitations, the model will fit only that subset of reality which has been experienced" [6]. So, using the concept of estimation, reality is determined by constantly evaluating the given input and changing your perception of reality based on the results. In a VR simulation, much of what is sensed is the visual VR, but much is also felt and heard in the lab. So which is reality? Where are you actually present? Understanding more about the nature of presence helped to define the purpose and methodology of this study. It has yet to be determined exactly how much presence is necessary to determine a reality, but studying the quantitative factors involved in sense of presence is another area of study.

There are many factors that contribute to one's sense of presence, or how much one feels immersed in an environment. Many studies have been conducted, but one in particular from Sheridan at MIT summarizes and gives some additional enlightenment on the subject. Sheridan proposes that there are four categories of variables that affect a person's immersion in an environment. The first is the amount of "information quantity" that gets through to the participant. This depends on whether the participant is paying attention, any visual distractions, noise variances, etc. The second is "sensor position/orientation," which deals with the head-tracking devices and the degree of corresponding visual feedback. The third is the "change of relative location of objects" in response to both static feedback, such as gravity, and direct manipulation commands [6]. For example, a study by Slater indicated that naïve subjects in an immersive virtual environment experience a higher subjective sense of presence when they locomote by walking-in-place than when they push-button-fly [11]. The last variable to be considered is "the active imagination in suppressing disbelief." This factor is the most difficult to control and generally relies on a large enough participant base to even out differences. Because there was no direct manipulation in the plane simulation, the third variable Sheridan lists was not used. However, care was taken to keep a standard across participants so that the other variables introduced above, especially sound, visual distractions and the head-tracking device, were constants for the data sample.

Sheridan focused predominately on environmental factors, while another study focusing on therapy through virtual reality focused much more on the psychological factors effecting immersion. Psotka found that "immersion was most affected by how claustrophobic one is. The more claustrophobic you are the more often you think about the other person(s) in the real world with you there…. How immersed one feels appears to be determined by a complex set of physical components and affordances of the environment, as well as psychological processes that as yet are poorly understood" [5]. This study did not take into account any atypical psychological issues, but rather relied on averaging to represent the majority. This complex set of factors, both environmental and psychological, is what makes typical subjective measures of presence studies hard to work with. Because this study was not measuring sense of presence in order to study the variables, as long as the variables were turned into constants as much as possible, the data sample was considered representative of the average.

And lastly, there has been some discussion on the best way to measure presence. A study headed by Dillon out of New Cross London discussed some of the issues that arise when attempting to measure presence. Recently, physiological measures of presence have been proposed to be the most accurate and objective possible measurement. Dillon notes that the "unifying idea behind this approach is that as presence within a displayed environment increases, physiological reaction will tend towards those that would be observed in a real environment…. Alternatively, these objective, continuous measures could provide additional information about viewing experiences which are not tapped by post-test subjective rating scales, which may be prone to demand characteristics and memory biases." [1] However, such measures may not be appropriate in cases when even a high amount of presence does not physically stimulate the subject, such as moving a chair in a virtual environment. After an in-depth study that compared heart-rate monitoring, skin-conductance monitoring, and survey methods, Dillon concluded, "physiological measures are an addition to, not a replacement for, subjective presence measures." [1] Because this experiment was a simulation of sitting in a plane, it was determined that physiological measures would not be very beneficial, though a heart-rate monitoring system and other physiological measurement devices were available in the laboratory. It was also determined that because this study only compared sense of presence in two environments, it is the difference in the measurements that is most important to us. Since the relatively large sample size provides a good indication of the actual average, there was no need to have these additional measurements.

This brief review attests to the fact that there is a great need to develop a scientific body of knowledge or theories of sense of presence to assist researchers in the development of efficient virtual environment applications. This study has been designed and implemented to extensively study the sense of presence and its relationship in the real and virtual environments.

2. RESEARCH METHODOLOGY

2.1 Experiment - Part I

2.1.1 Participants

Thirty-five volunteered subjects (24 male and 11 female) participated in this part of the study. They were all undergraduate Kennesaw State University Computer Science and Information Systems students ranging in age from twenty to forty-eight years old. The average was twenty-eight years old.

2.1.2 Apparatus

The virtual reality system for this study was installed and operated in the Virtual Reality Technology Laboratory in the Computer Science and Information Systems department. The system consisted of a Pentium-based computer using a 6D head-tracking system and display. The virtual environments were created using the Sense8™ Virtual Reality Development Software Package and Libraries. Each session was executed using the Virtual I-O Glasses with a head-tracking device. The virtual environment scene used was a moderately simple rendition of a window-seat passenger's view of a plane taking off and flying during bad weather. The simulated plane was a commercial 767 airliner.

2.1.3 Procedure

The subject was seated in a chair equipped with vibration capabilities, which corresponded to the engine noise and vibration. The subject could partially view their body (which was set to correspond to their sex). They also listened to sounds such as the flight attendant speaking, engine noises, and noises due to turbulence. The only control the participants had over the simulation was through the head-mounted tracking system that responded to their head movements by correspondingly moving the view in the virtual world (Figure 1). Participants experienced fifteen minutes in the plane simulation, and responded to a sense-of-presence questionnaire immediately afterward. The questionnaire consisted of only two questions, with a definition of presence given beforehand. The definition of presence given was “the sense of being there,” where “there” meant the particular environment referenced. Each participant rated the question quantitatively on a scale of 0 to 10, with zero being equal to no sense of presence and ten being equal to complete immersion in the environment. There were no other rules imposed on how they could score their sense of presence.

2.1.4 Sense of Presence Questionnaire

This survey attempts to measure your sense of presence (your sense of being there, in the specified environment), with 10 being the highest presence and 0 being the lowest.

1. Rate your sense of presence in the virtual world during the experiment.
2. Rate your sense of presence in the real world while experiencing the virtual world.

Figure 1. A subject is wearing a head-mounted display and head-tracking device and is immersed in the virtual

2.1.5 Problems with Part I

During the collection of data in Part I, care was taken to offer a constant experience to each participant, but a few unanticipated problems arose. As addressed in the literature review, there are many factors that contribute to sense of presence. The problems listed below are factors that are acknowledged to affect sense of presence. Taken together, these problems could lead to inaccurate results. These problems were: 1. The participant’s ability to swivel the chair allowed rotation of the entire body quite unlike what is possible in a real airplane chair; 2. Possible misalignment of participant’s actual physical position and their perceived position in the plane due to incorrect mounting of the head display; and, 3. Misinterpretation of the two critical survey questions.

Problem 1 could cause an error that would cause virtual presence to be higher due to increased interactivity. However, it could also have caused decreased sense of presence due to the unrealistic nature of the motion causing a conscious comparison with the real world. Problem 2 was recognized afterwards to have happened to some of the participants, but the actual number of affected participants is unknown. This in itself causes a variation in the procedure that could effect results. If the alignment between the users movement and the head tracking devise was out of phase, it would cause disorientation to the participant. This would most likely lead to a systematically lower rating for the virtual sense of presence question.

Problem 3 was different from the others since the actual occurrence of Problem 3 is difficult to determine. It was necessary to offer a definition of “presence” on the survey so that the participants could adequately understand the questions in order to answer them appropriately. In an effort to provide understanding while being simplistic and using non-technical terms, the definition given was “your sense of being there, in the specified environment” (see page 8). However, when one person answered a one for sense of presence in each environment simultaneously, there appeared to be some lack of understanding. If understood, it would indicate that the subject’s mind was entirely occupied with other matters, so that there was little immersion in either the virtual or real environment. Now this was a possibility, but the participant was observed and they did appear to be actively involved in looking around the environment, so the data given did not concur with the observations. However, there is no way to know for sure the subject’s intentions since the subject was not questioned. It could have been a misunderstanding about the survey. If this happened once, other participants could also have been confused and answered the questions inconsistent to their real feelings. Problem 3 may not have been a problem at all, but the questions could probably be improved upon to minimize this occurrence. Part II of this study attempts to correct all of these problems to provide the most valid data.

2.2 Experiment - Part II

2.2.1 Participants

Thirty-five volunteered subjects (25 male and 10 female) participated in this part of the study. They were all undergraduate Kennesaw State University Computer Science and Information Systems students ranging in age from nineteen to fifty-one years old. The average was thirty years old.

2.2.2 Apparatus

The virtual reality system for this part of the study was the same as in the first part of the study.

2.2.3 Procedure

There were three differences in this part of the study from the previous part. First, this part of the study replaced the chair with the vibration capabilities. To simulate more accurately an airplane chair and its features, this part of the study used a flex-backed padded chair that did not swivel. The second difference was that any misalignment between the head-tracking device and the computer was eliminated. The third difference was with the survey. In order to keep the data samples comparable, the two critical survey questions were kept the same. However, the definition of presence changed to “your depth of immersion.” Also, eight other questions were given before the critical two. They were designed to make the participants think more about their experience and more about the sense of presence before answering the two questions that would be studied. The questions were also designed to have either a negative or positive connotation which evened out so as not to affect the participant's feelings about their sense of presence in either direction (see page 12). The questions were taken from a survey designed by Psotka [5].

2.2.4 Sense of Presence Questionnaire

This survey attempts to measure your sense of presence (your depth of immersion) in the virtual world using a similar scale as Part I.

1. When you removed the head mounted display, how surprised were you at the direction you were facing?
2. During the immersion, how aware were you of the direction you faced in the real world?
3. How often did you think of the other person(s) in the real world with you?
4. How much more enjoyable would it have been to have the immersion experience with no one else in the room?
5. When you turned your back on an object in the virtual environment, was it still there?
6. How flat and missing in depth did the virtual reality world appear?
7. How exhilarated did you feel after the experience?
8. How disoriented did you feel after the experience?
9. Rate your sense of presence in the virtual world during the experiment (using both scales).
10. Rate your sense of presence in the real world while experiencing the virtual world (using both scales).

3. ANALYSIS AND DISCUSSION

3.1 Part I

Looking at averages in the data, the average sense of presence in the virtual world was 6.0 while the average sense of presence in the real world was 5.0. So on average, presence in the virtual world was felt more strongly. However, these averages are not the best indication of difference because they do not take into account the matched pairs of data, so further analysis follows.

The Matched Pair T-Test showed very strong evidence ($p = .01$) that the mean absolute difference in sense of presence is greater than two, and good evidence ($p = .06$) that the mean absolute difference was greater than 3. When calculated, the mean absolute difference is 2.7 with standard deviation 2.7. The box plot in Figure 4 shows the absolute difference of the matched pairs in graphical format. The differences ranged from zero to ten, with the average being about three, and the quartiles defined by the vertical separations.

If the only indication of difference was the difference between the averages of the environments, it would be misleading. The average for the virtual world is 6.0 and the average for the real world is 5.0, giving a difference of one. However, the results using matched pair averages give more accurate analysis of each individual's sense of presence, which came to a difference of 2.7. This difference indicates incongruence between the two environments. Participants did not tend to feel equally immersed in each environment, but rather showed a tendency to gravitate towards sensing one environment much more strongly than the other.

There were eleven choices (numbers 0 through 10), presented to the participants to rate their sense of presence in each environment simultaneously, but the sum of those possible combinations could be ten maximally (0+10=10) assuming opposing answers (i.e. 0 and 10, 1 and 9, 2 and 8, etc). However, the T-Test showed that there was very strong evidence that this was not true ($p = .028$ that the sum does not equal ten). When each score pair was taken individually, the totals ranged from two to as high as seventeen, with the average total sense of presence being 10.8.

So, while subjects were given no rules or guidelines regarding their two sense of presence ratings, it was expected that most subjects would divide their ratings between the two conditions so that the total of the two scores would be at or near ten. This expectation was met for most subjects, with twenty-five participants (71.4%) giving total sense of presence ratings from eight through twelve. Only one subject (2.9%) gave total ratings below eight, and that subject's rating of was only one for each condition. Perhaps the most interesting subjects were the nine (25.7%) who gave total ratings higher than twelve. However, in light of the problems with the procedure previously discussed, the validity of these results should be based on further evidence collected with a more stringent procedure, as Part II attempts to accomplish.

3.2 Part II

When looking at the averages of the sense of presence scores, the average sense of presence in the virtual environment was 6.4, while the average sense of presence in the real world was 6.1, giving an average difference of only .3 in favor of more presence in the virtual environment. However, looking at the absolute value of the matched pair difference gives a more accurate picture of what each felt for sense of presence because it keeps the data paired. Using the box plot for the Part II data (Figure 5), 50% of the participants felt between zero and three units difference between the two environments, with an average of one unit of difference, rather than the .7 units that simple averaging suggests.

Though the participants did not rate much difference in their scores, their sense of presence was high for each environment. In the Part II data, two participants (5.7%) had a total sense of presence below eight. Seventeen participants (48.6%) had totals from eight through twelve, and sixteen participants (45.7%) had totals above twelve. The average sense of presence rating felt for the total sense of presence came to 12.5.

The data collected in Part II of the study supports the data found in Part I of the study. The Part II data is similar to the Part I data, and it follows the trends set in Part I. In both studies, the sense of presence in the virtual environment was felt more strongly on average than the sense of presence of the real world, and the total sense of presence score was greater than ten for both parts of the experiment. This leads to the conclusion that the problems identified with the procedure in Part I must not have significantly effected results. They may have averaged out, since only Problem 2 seemed to cause a systematic bias in reporting. Problem 2 could be the reason that the Part I data results in a slightly lower (.4) average score for sense of presence in the virtual environment, though this difference is almost negligible. Similarly, the sense of presence in the real world was 1.1 units higher for Part II than for Part I, an almost negligible amount given the nature of subjective surveys.

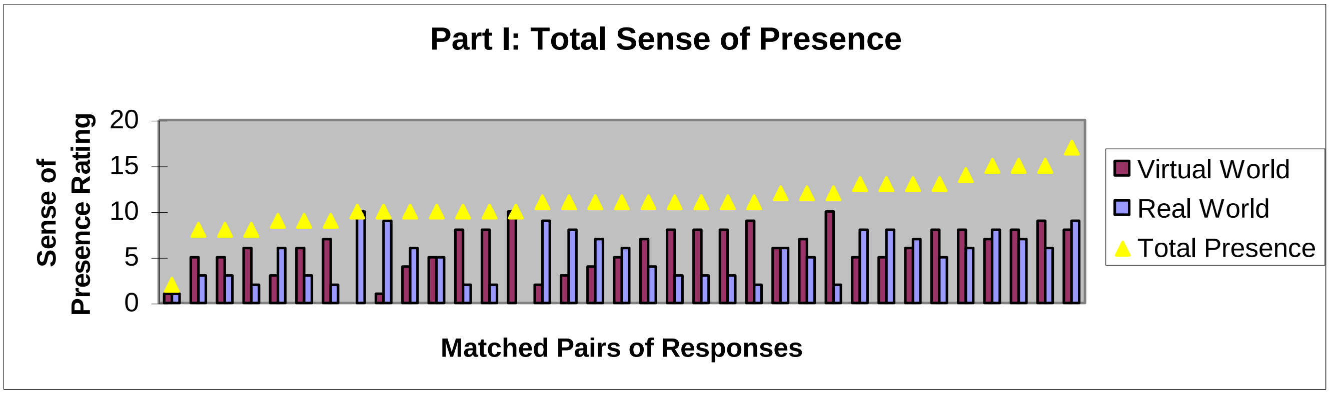

Figure 2. **A graph of total sense of presence scores combination of virtual and real environments for each participant that ranges from 2 to 17 out of 10 possible score in Part I.**

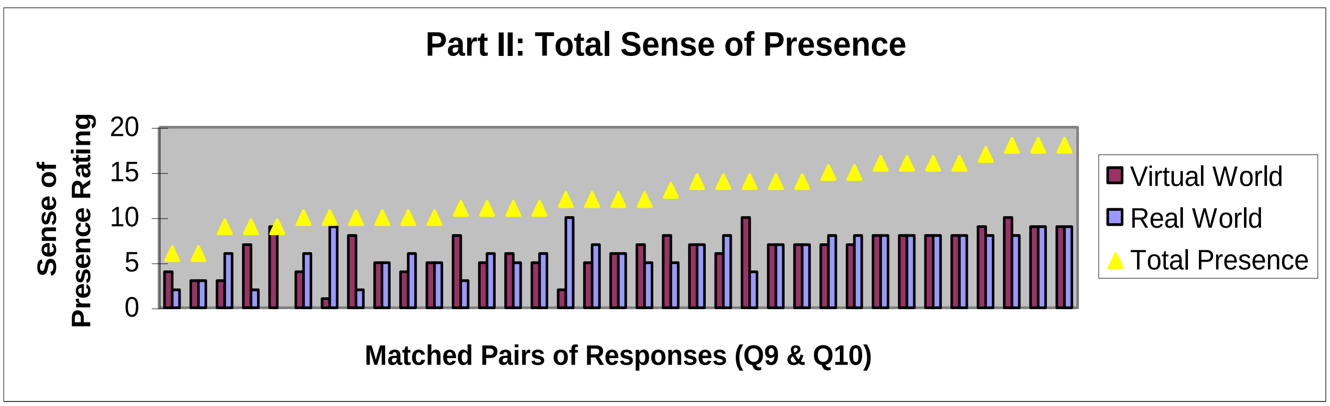

Figure 3. **A graph of total sense of presence scores combination of virtual and real environments for each participant that ranges from 6 to 18 out of 10 possible score in Part II.**

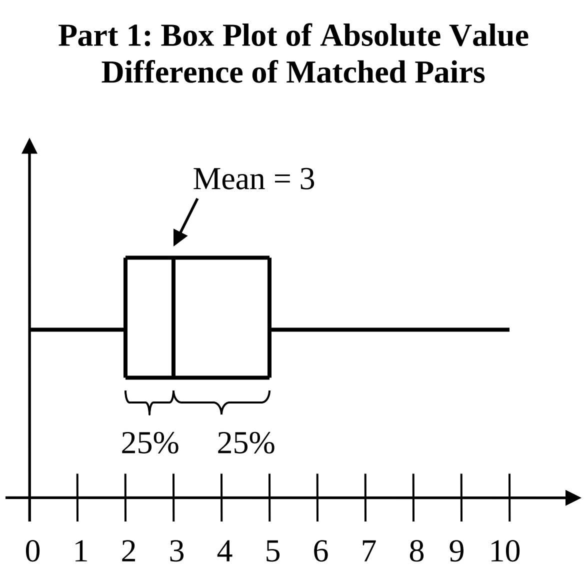

Figure 4. **Analysis of sense of presence differences for Part I.**

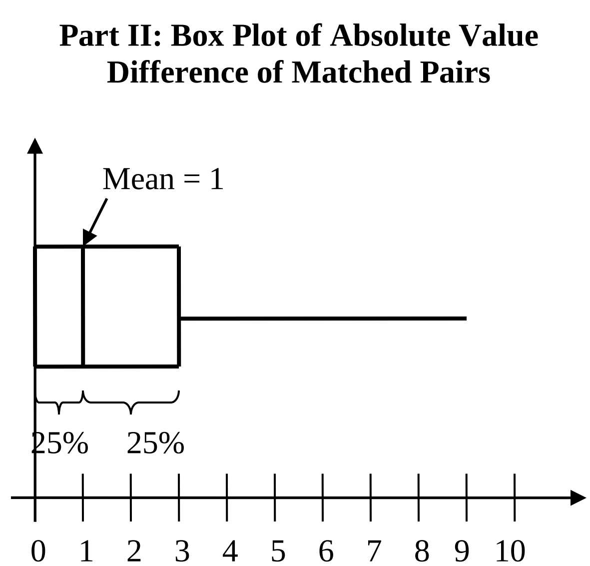

Figure 5. **Analysis of sense of presence differences for Part II.**

In this study, the difference of the matched pairs of data was more important for the results than the averages since it maintained the original pairing of the data sets. Viewing the box plots for the data (Figures 4 and 5), there is a variation in the amount of difference the participants experienced between the two environments in the two parts of the experiment. In Part I, 50% felt between two and five units difference with an average of three units of difference. In Part II, 50% felt between zero and three units different about the two environments with an average of one unit of difference. This difference falls at the edge of the plus/minus two difference expected from this survey. This difference actually indicates a rise in the sense of presence in the real world without a decrease in the sense of presence in the virtual environment for Part II. If there is one factor that could have this effect, it may have been the change in chair. Removing the rotating chair removed an unrealistic aspect of the virtual environment, but it also removed the vibration capabilities of the chair. This could possibly account for a slightly higher sense of presence in real world without lowering the sense of presence in the virtual world. However, if it was more than just an acceptable error, the many factors involved in sense of presence must be acknowledged, making it most likely to have been a combination of multiple factors that caused this slight difference.

Perhaps the most interesting part of this study is found in the total sense of presence scores. While reason would indicate that a subject's total degree of immersion in concurrent environments should be 100% (or ten on the rating scale in this study), from a subjective point of view the total degree of immersion may be considerably higher than 100%. The average total sense of presence felt was greater than 100% in both cases (10.75 in Part I and 12.5 in Part II). In Part I, nine subjects (25.7%) gave total ratings higher than twelve, while in Part II, sixteen participants (45.7%) had totals above twelve. These results could have many implications, all of which would need to be independently studied in the future.

4. FUTURE RESEARCH

These findings raise several possibilities for future research. The next step would be an experiment that used a base study conducted before the participants go through the simulation. It would offer a comparison that may be useful when analyzing the results after the simulation. It was instinctively assumed for both Part I and Part II that before going through the simulation, the total sense of presence was 100% for the real world and 0% for the virtual world. If this were not the case, where does the other percentage go? Perhaps the subjective ratings questionnaire needs a third category, internal environment (thinking about the midterm exam later today, term paper due next week, big date this weekend, etc.). Would inclusion of this internal environment category lead to greater consistency in the total immersion ratings of subjects? If so, what is this total subjective degree of immersion? The results of this study would seem to indicate that it is higher than 100%, but how much higher than 100%, especially if internal environment is included?

Another study would be to determine why subjects' overall ratings of sense of presence varies widely. Does the total subjective degree of immersion correlate with demographic factors and/or psychological characteristics? A more extensive questionnaire may help to determine this. In any case, it is obvious that further investigation into the sense of presence in multiple environments will need to be conducted in order to better understand this phenomenon. Advances into virtual reality research allow the development of technologies that enhance and optimize human abilities and efficiencies; human interaction and learning; and sensory and cognitive capabilities. Research in these areas enhances opportunities for the discovery and generation of new knowledge, which in turn advances the efficiency and effectiveness of man and machine interaction.

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