

# HOW REAL IS THE SENSE OF PRESENCE IN A VIRTUAL ENVIRONMENT? : Applying Protocol Analysis for Data Collection

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**Abstract.** This study attempts to investigate the sense of presence in a fully immersive virtual environment. The methodology applied in this study used protocol analysis for data collection. A preliminary experiment was conducted to explore noticeable phenomena to develop a hypothesis for the final experiments. Four different virtual reality models, representing four different kinds of virtual space, were navigated in C6 (CAVE facilities) by two human subjects. Results of the research in this direction have provided valuable understanding regarding the sense of presence in the virtual environment.

## 1. Introduction

Presence, the concept of a sense of “being there”, is becoming an important idea in a growing number of products and has evoked interdisciplinary research interests. Generating a sense of presence is often a main goal for training simulators, video games, home theatres, IMAX films, and especially for virtual reality (VR) systems. Virtual reality has been around for years. As time passes and technology matures, one sees many applications of technology entering modern life. The current major applications for virtual reality include architecture, visualization, entertainment, manufacturing, education, training, and medicine etc.<sup>1</sup> All these applications attempt to generate a high degree of presence, because the experience of presence makes the products or simulations appear more natural, immediate, direct, and real as well as more effective and enjoyable (Slater and Usoh, 1994; Lombard & Ditton, 1997; Nunez and Blake, 2001).

On the other hand, thanks to the development of VR technology, new possibilities to experience presence in virtual space have been explored by various studies. Virtual environments (VEs) which can generate a high degree of presence are thought to be more effective, enjoyable, and well received and will contribute towards better

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1. (see <http://vresources.jump-gate.com/home.htm>)

task performance on the systems (Slater, 1994; Nunez and Blake, 2001). Thus, more and more researchers from different fields have investigated maximizing the sense of presence in VEs. As a result, many diverse approaches to this research concerned various kinds of visual displays, human interaction technologies, and psychological factors that may determine the sense of presence (Davies, 2003; Heeter, 2003; Hogue et al., 2003; Slater, 1994, 1999; Witmer and Singer, 1998).

In terms of technical aspects, compared to the common head-mounted display (HMD), the spatial immersive display (SID) (or Immersive Projection Technology, IPT) provides a higher immersive experience in a room-sized display (Stanney and Zyda, 2002; Stanney, 2003). Among these SIDs (or IPTs), the fully enclosed (six-side) environment definitely generates the greatest sense of presence, as users perceive themselves to be totally within the environment (Chan et al., 1999; Thalmann and Thalmann, 1994). Beyond this obvious feeling while being in a full-scale immersive VE, there should be more specific factors of a VE and subtler mechanisms underlying the cognitive systems that may provide a better sense of presence. Given this premise, this project attempts to discover the factors that determine the degree of presence within VE and how these factors respond to the human cognitive mechanisms relating to the sense of presence.

## 2. Virtual Presence in Immersive VE

The concept of presence is broad and research concerning this topic is interdisciplinary. Similar to discussions of cyberspace driven from the invention of the Internet, the concept of presence involves many fields, technology to psychology.

Due to the multi-dimensionality of presence, this study would first like to clarify the definition and dimension of presence.

### 2.1. THE DEFINITION OF PRESENCE

According to the International Sociality for Presence Research (ISPR), which developed a comprehensive explication of the concept of presence, the definition of presence is: “a psychological state or subjective perception in which even though part or all an individual’s current experience is generated by and/or filtered through human-made technology, part or all of the individual’s perception fails to accurately acknowledge the role of the technology in the experience” (see <http://lombardresearch.temple.edu/ispr/>).

From this definition, presence is a psychological state, generated by human-made technology, and is a perceptual illusion that an individual believes to be non-mediated. Thus, investigating the concept of presence needs three major parts: the mediated technology, the content, and the response of the participant. The purposes of this study are to explore what reaction participant would generate (response) when navigating different kinds of virtual space (content) in an immersive VE (media).

## 2.2. TYPES OF PRESENCE

IJsselsteijn and Riva (2003) presented three types of presence, driven from two broad categories conceptualized by Lombard and Ditton (1997). They are physical presence, social presence, and co-presence. Physical presence refers to the sense of being physically located in mediated space, while social presence refers to the feeling of being together, of social interaction with a virtual or remotely located communication partner. The intersection of these two categories is identified as co-presence as a sense of being together in a shared space, combining the characteristics of both physical and social presence.

Obviously, current research into presence has gone beyond an endeavour for realism or fidelity in terms of physical presence only. As media become more interactive and immersive, the approach of social presence or co-presence will become relatively dominant. However, the concept of presence still remains indefinite. How physical presence works in our perception and cognition needs more thorough explicitness. The impact physical presence generated by different types of media is also investigable. Thus, this study focuses on physical presence, trying to explore its properties in an immersive VE.

## 2.3. MEASUREMENT OF PRESENCE

The research on presence is still controversial, and has yet to overcome major challenges, such as how to measure presence. Insko (2003) makes a review of three kinds of methods to measure presence: subjective, behavioural, and physiological measures. Subjective measures rely on participant's self-reported sense of presence. The most common method is the post-immersion questionnaire. The behavioural method measures participant's responses to objects or events in the VE, while the physiological method attempts to measure presence by gauging changes in heart rate, skin temperature, and breathing rate, etc. trying to avoid the subjective bias.

Clearly, using as many methods as possible to measure presence is the best solution. However, it is somewhat difficult to put into practice. In our study, we applied a psychological method used to investigate the human cognitive process; which we hope could evoke some inspirations regarding future methodology

## 3. Methodological Steps

In order to investigate virtual presence in immersive VE, a preliminary experiment in C6 as the case study was conducted to explore the concept of virtual presence. The C6 is a 10x10x10 feet room in which computer-generated images are projected on all four walls, the ceiling, and the floor to deliver an enclosed, interactive, and fully immersive experience (<http://www.vrac.iastate.edu/>). Through this pre-

experiment, there were some interesting and remarkable phenomena found, which became the hypothesis of the formal experiment.

### 3.1. PRELIMINARY EXPERIMENT

A volunteer recruited from architecture department was asked to navigate four different types of architectural space. These spaces are VR models of a Firecave, the Adaptable Workplace Laboratory (AWL) installed in the 7th floor at the National Headquarters Building of the General Services Administration in Washington DC, Notre Dame de Paris, and the building of the College of Design (COD) in Iowa State University.

These four models respectively represented different kinds of virtual space:

- **Firecave** is a fictional space with sound effects, simulating a grotto with flames and bubbling lava (Figure1).
- **AWL Office in Washington DC** is a typical office space with cubicle partitions. Numerous office features, such as computers, desks, chairs, and conference rooms are simulated within it (Figure2).
- **Notre Dame de Paris** is the original design of the famous Gothic cathedral, which stands for the historical architecture and religious space (Figure 3).
- **College of Design**, originally created for a first-person shooting game, is a simple model with fundamental spatial elements of the building (Figure 4).



*Figure 1.* Firecave.



*Figure 2.* AWL Office.



*Figure 3.* Notre Dame de Paris.



*Figure 4.* College of Design.

The subject, a senior female architecture student, was asked to navigate through these virtual models in C6, equipped with shutter glasses and the controller pack.

Inasmuch as the measurement of presence still remains controversial and does not reach a convincing and reliable resolution, we attempted to apply the “think-aloud” method, which derives from psychological procedures developed by Ericsson & Simon (1980). Through the verbal data gained from the subject’s self-report while navigating, we may gather more comprehensive information that reveals the thinking process and perception of the space more thoroughly.

### *3.1.1. Methodological modification*

During the experimental procedure, some important issues relating to methodological problems emerged. The most intriguing issue was that it is difficult to interpret what you are thinking and how you really feel. The possible reasons for this phenomenon may be :

1. Subject’s personality: the subject may not be talkative or expressive.
2. Controlling problems: being novel, it takes some times fore the subject to get used to the control of the equipment.
3. Navigating skill: like playing video games, the navigating skill is important for getting good performance, especially when the task relates to navigating in a space.
4. Cognitive burden: There are many activities progressing simultaneously. This may cause burdens on cognitive process and result in difficulties explaining the thought process.

Due to these phenomena, we made some modifications for the formal experiment, such as a selection process for subjects, warm-up for navigating, and data replenishment afterward. These will be described in the following session.

### *3.1.2. Hypothesis*

Eliminating extrinsic influences of navigating skill, technological control problem, and fluency of model representation, and focusing on how the sense of presence was generated in each model, we can establish the following hypothesis by above given phenomena; that is, that there exist different modes of sensing presence in immersive VE, which are related to an individual’s experiences and intrinsic differences.

## 3.2. FORMAL EXPERIMENT

For verifying the hypothesis, a formal experiment was conducted by recruiting two more architecture students, one freshman, another senior. The subjects were inclined to be talkative and were willing to engage in immersive VE. Both subjects navigated the same four models in the sequences of COD, AWL Office, Notre Dame Cathedral,

and Firecave; the models were ordered from the simplest representations to the most complex and from the most familiar to the most alien from subjects' knowledge and experience.

### 3.2.1. Procedure

The experimental procedures of formal experiments were modified after the preliminary study was completed. In the new sequences, each subject should have a warm up navigation of a wire frame model to facilitate controlling and to avoid fumbling in the C6 environment.

Two subjects were asked to think aloud while navigating, and answer the following questions after finishing the experiment:

1. What's the first feature that catches your attention in each model?
2. What feature do you think is the most dominant in each model?
3. What's the most impressive and distinguishing thing in each model?
4. In each model, do you feel it is real? Any difference between than?
5. Do you feel that you are inside of the building or space when you are navigating each model? Are these feelings all the same or different?
6. Does it happen in your navigating that you are totally immersive into the virtual space and forget where you are (forget the physical world)?

Combining the protocol data gained from thinking aloud and the answers to the afterward questions, abundant information was collected to explicate the concept of presence.

## 4. Results and Discussions

Based on the protocol data provided by two subjects, the cognition of perception and its resulting senses obtained during navigating in each virtual model revealed some interesting and noticeable results.

### 4.1. DOMINANT FEATURES

First of all, each model presents different types of special features that distinct and become the dominant feature that catch subjects' attention.

For the College of Design building, the most impressive feature to subjects was the surreal pink colour representing the French window and atrium ceiling of the building, because it stands out above other gray representations and turns into a focus. For the AWL Office in Washington DC, the cubicle space drew subjects' attention at the first sight of the model, attracting them to explore what may be inside the space. As soon as they approached, the vividly realistic objects evoked further impressions that both subjects even reached out and tried to grab the items.

For the Notre Dame cathedral, the choral background sound appearing gradually before the virtual model arising brought subjects great immersion into the majestic towering space. The feel-like infinite space compelled subjects to sense the presence of being inside and both of them would like to fly within the model to get closer to the structures, the pillars, and the ceiling. For the last model, Firecave is the only dynamic space where not only all the realistic simulations but also some interactive features exist. These interactive features make the cave space more than just an object or a single space to look at, as there are more things to do in this space.

#### 4.2. SENSE OF PRESENCE

Many researchers investigate the concept of presence from different points of view, and present some determinations of presence. As a result of experiments conducted in this project, it was found that the sense of presence in an immersive VE has different modes, determined by the representation of the virtual space, knowledge and experience of the space, and personal characteristics.

For COD, although it was a simple model consisting of only the necessary basic features, both subjects still can feel the sense of presence, because they are familiar with this building. Once they recognized that the model was of the College of Design, they started to search for specific features meaningful to them, and to map these features onto their memories and experiences in the real world. Through this cognitive process, a sense of presence was generated and enhanced; even a flat gray panel with no textures seemed real to the subjects, because they knew what the object was in the physical building (Figure 5). Thus, the more familiar the subject is with the building, the greater the sense of presence. A good example of this is that the senior student could even point out where her workspace and drawing table should be in the empty room that referred to the room of her design studio.

For the AWL Office in Washington DC, it is a small rectangular space with cubicle partitions in both sides, and represents a typically common office space. Neither subject has been to the office, but they learned this space from the layout,



Figure 5. Skylights in COD.



Figure 6. Conference room in AWL model.



Figure 7. The huge proportion of the space.



Figure 8. Reaction in Firecave model.

the facilities, and the furniture. Through the fine rendering details, subjects sense this space simply via perception, with no need for further transferring or any mapping. The generation of the sense of presence was direct and intuitive in this case (Figure 6).

For Notre Dame, the scale of the space represented in this virtual model is huge and towering. Accompanied with the background music, subjects were immediately engaged in the ambient surroundings. Looking up at the soaring space by wearing the shuttle glasses, the seam in the C6 suddenly disappeared, and the space seemed to open up to infinity. The sense of the depth and scale in this model was so

TABLE 1. Items of contents, sensory stimuli, and cognitive mechanisms applied in each model.

Models	Content of model	Sensory/Stimuli	Cognitive Process	Individual Differences	
				S2	S1
COD	a. Specific fundamental features/forms b. surreal colour	Visual (simple)	Searching & Mapping	Very familiar	Kinda familiar
AWL office	a. fine details b. good texture c. lighting effects d. intimate cubical spaces	Visual (realistic)	Perceiving Searching	Similar experience	Similar experience
Notre Dame	a. architectural structure patterns b. towering space c. good texture d. music	Visual (realistic) Audio (music)	Perceiving Recognizing Searching	Never been there	Never been there
Firecave	a. different features with some story embedded b. dynamic space c. sound effects d. good texture e. interaction	Visual (realistic) Audio (sound effect) Motion	Perceiving Imaging	Video game experience	No experience

convincing that both subjects tried hovering to experience the feeling that they could not have in the real world (Figure 7).

For Firecave, movement and motion effects dominate the sense of presence in this virtual space. Subjects' reactions to those interactive features, such as evading, bracing, ducking, etc., were objective evidence of being fully immersive to the virtual space (Figure 8).

#### 4.3. SUMMARY TABLE

Table 1 is a summary that itemizes the special contents included in each model, the possible cognitive activities occurred in all experimental sessions, the sensory stimuli involved, and individual differences discovered in the protocol data. In this table, data items show that the more activities involved, the more sense of presence occurs, because protocol data had proved that both subjects did suffer minor motion sickness in both of the Firecave and the Notre Dame models, but not in the College of Design (COD) and AWL models.

### 5. Conclusion and Future Study

This on-going study provides some understandings of the sense of presence in virtual space. As Table 1 indicated, the more sensory input provided, the more involvement exists. Therefore, the factors of sensory stimuli (visual, audio, and haptic) and the cognitive mechanisms utilized in the process (perception, feature mapping for recognition, searching for orientation, attention paid to focus points, and the problem solving exercise for navigation) are all attributed to the generation of the feeling of "being there". It is likely that the more factors encountered and the more cognition occurring in the experience, the stronger the sense of presence. Of course, more subjects and more experimental evidence would be able to better show a correlation; this will be a goal for future study. Furthermore, studies should also be done to explore the details of cognitive mechanisms involved in the subject's mind.

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