The Visual Cliff Revisited: A Virtual Presence Study on Locomotion

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Contributions:

- A *large scale experiment on presence*
- An understanding on effects of mode of locomotion on presence

Extended Abstract

1. Introduction and Background

This paper presents a study on the influence of locomotion technique on presence in immersive virtual environments (VE). It is a largely extended study to an experiment conducted by Slater (1995) with groups of subjects who explore a virtual environment either by hand navigation or by *walking in place*, i.e. reproducing *naturalistic* movements similar to real walking. Naturalistic is considered here to be actions that maintain the proprioceptive/sensory data loop – the (proprioceptive) movements of the body are congruent with the (sensory) optic flow data as the participant is translated in VE. We replicate this experiment adding an additional group who move through the VE by actually walking. We provide a comparison with the original study as well as an enhanced analysis using new criteria.

In the original study the authors compared the behaviour and subjective presence of an experimental and a control group of subjects in a *visual cliff* scenario. The two groups had virtual body (VB) or avatar representations and differed only in the way they were able to move through the environment. The control group navigated by "button pressing" on a tracked joystick to fly along the ground plane. The experimental group navigated by *virtual walking*. A neural network was used to track their head movements as they walked in place (Slater 1993). When this pattern of motion was detected they were moved forward in the environment along their line of sight.

The scenario was based on Gibson's visual cliff experiment where a glass floor was used to give the illusion of a drop to a lower level (Gibson 1960). It consisted of a virtual corridor with a doorway leading to another room. Through the doorway subjects found themselves standing on a narrow ledge running along the perimeter of the room. On the far side of the ledge was a chair and subjects had the task of taking a box by the doorway and placing it on the chair (Figure 1). A direct path from the doorway to the chair meant walking out over a six metre drop overlooking another room (Figure 2). Subjects therefore had two options in completing the task, i) take a direct path to the chair, or ii) remain on the ledge and go "safely" along the edges of the room. Objectively, a path to the chair over the virtual pit would be associated with a lower sense of presence whereas a path along the ledge would be associated with a higher sense of presence. This was assessed through a questionnaire.

Following logistic regression (Cox 1970) the main conclusion was that for the virtual walkers the higher their association with the virtual body, the greater their presence score. There was no significant relationship for the control group. They note that association with the virtual body is important. It is "…not simply a question of whether a VB is provided by the system and how well it functions, but also the individual's personal evaluation of this VB, the degree of 'match' to their internal world models". They also realised the path to the chair variable to be statistically significant – a direct path to the chair over the drop did correspond with a lower sense of presence.

In this study our main objectives are to:-

- see if the results of Slater (1995) "hold true" given more recent hardware and software technology;
- compare results of walking in place and flying metaphors with the ability of participants to physically walk in the virtual environment;
- assess the differences on presence, if any, between walking in place and real walking.

The focus is on the question, "Does presence increase in the steps from flying to 'walking in place' to really walking?". Also, to what extent can previous results regarding the degree of association with the virtual body be duplicated, and what is the impact of the style of locomotion on ease of navigation.

2. Implementation

The real walking condition was achieved using a custom electro-optic ceiling tracker developed at UNC Chapel Hill (Ward 1992; Welch 1997). The current generation operates over a range of approximately 10 by 4 metres. It uses outward-looking optical sensors mounted on the tracked object to view active infrared LEDs on tiles in the ceiling. The measurements are processed to compute position and orientation records.

The experiments were implemented on a Silicon Graphics Onyx2 with a single graphic pipe and two raster managers. This was a multiple processor system with four 195 MHz R10000 processors and 2Gigs of main memory. The scene was rendered using OpenGL and the system maintained a frame rate of 30Hz stereo. It was viewed with a Virtual Research V8 head mounted display with true VGA resolution of (640x3) x 480 pixels per eye – 921,600 colour elements equivalent to 307,200 triads. This display consists of two 1.3 inch active matrix LCDs with a field-of-view of 60 degrees diagonal at 100% overlap. The input device was a modified joystick with four buttons, two of which were used in the experiment. This as well as the HMD were tracked by the ceiling tracker which returned position and orientation values to 1mm accuracy in the 10 x 4 metre area.

Given the reported importance of association with the virtual body we tried to maintain a detailed and realistic avatar model. This was clothed with training shoes and consisted of over 11,000 polygons. The scene was radiositized with a total of 28,000 polygons nearly half of which were textured. The environment therefore had a total of nearly 40,000 polygons, about 40 times more than in the original study.

Forty five (45) subjects were used in the study. They were divided into two groups - expert and novice. The novice group were naive users who had not experienced virtual reality before or if so, not more than twice briefly. "Expert users" had experienced immersive virtual reality on several occasions (five or more times) and were generally working in the area of computer graphics and virtual reality. The groups were then further divided. The novice users (33) as Vwalkers, Rwalkers, and Pwalkers – each with 6 men and 5 women and the expert users (12) as Vwalkers and Rwalkers.

Vwalkers were able to navigate through the virtual space using the walking in place technique while Rwalkers moved around by real walking and Pwalkers by pressing the thumb button on the joystick. All subjects were able to see their tracked right virtual hand connected with a virtual arm to their virtual body.

3. Analysis

An assessment of presence was made based on presence and simulator sickness questionnaires presented to subjects after the virtual experience (Kennedy 1993). The presence questions were scored on a 1 to 7 scale with the higher score indicating greater presence. They were analysed in terms of the response variables *original presence*, *enhanced presence*, and *behavioural presence*. An assessment was also made on the impact of method of locomotion on ease of navigation.

- Original presence

  This was determined from three presence questions and subjective presence rating as used in the original study.

- Enhanced Presence

  This follows the same idea as the *original presence*, except that the three components are elaborated into seven questions, i.e. the original three plus variations on the same themes.

- Behavioural Presence

  This relates to the extent to which actual behaviours or internal states and perceptions indicated a sense of being in the situation depicted by the VE rather than being in the real world of the laboratory. This was considered in a number of components including the path taken to the chair.

- Locomotion

  This relates to task performance in terms of the ability to move through the environment. Assessment was in three components on the ease and naturalness of moving around.

4. Conclusions

Subjective recording of the sense of "being there" in the experimental scenario was generally reported high across the three groups. A Pwalker commented – "Since I'm afraid of heights I wanted to see what it would feel like to go over the edge, so I just flew out to the other side". They continue later, "Although I was willing to step out over the pit, that took an act of will. I had to remind myself I wouldn't fall, or if I did it wouldn't hurt". Although intellectually subjects are aware that they are immersed in a simulation, the power of the visual system triggers innate responses causing another one to comment, "I was afraid to experience the falling sensation I might have had if I'd walked straight ahead [over the virtual pit]".

Reports on factors that brought subjects out of the experience were consistent. They included the environment and virtual body not behaving correctly, background noise from outside the VE, and interference by the hardware interface. In this respect, by far the greatest comments relate to an awareness of the cables attached to the head mounted display and input device. About 30% of subjects reported this as causing a "break in presence" (Slater 1998). This may be rectified by less intrusive wireless systems. Investigator interference was also reported as causing breaks in presence. About 15% of subjects comment on becoming more immersed in the experience once the investigator had stopped giving instructions. Of these, some were disturbed that the investigator was not visible in the VE – only a "disembodied" voice. For example, "Even when the instructor was speaking I thought he was in the virtual room. I was surprised when he was not there. When I looked for, and didn't see him, it reminded me I was in the laboratory, not the virtual room". This anomaly may be resolved by speaking to subjects through a headphone interface. It is likely that such changes that reduce the interference of the external environment with the VE will lead to greater immersion and reduced breaks in presence.

Statistical analysis of the experiment confirms a previously found result that presence is highly correlated with the degree of association with the virtual body. This seems to hold irrespective of anything else. There is evidence to suggest that presence is higher for the virtual walkers than for the flyers, and higher for the real walkers compared to the virtual walkers. However, this difference diminishes when the oculomotor discomfort measured by the simulator sickness questionnaire is taken into account. In this case the result is that the discomfort reduces presence for the virtual walkers and flyers, but does not do so for the real walkers. This probably has something to do with the match between presence and proprioception. It is likely that since this is maximised for those really walking, it compensates for the negative impact of discomfort. This is in line with our previous hypotheses and results that presence may be increased with a greater match between sensory data and proprioception. Finally, in the assessment of navigation real walkers reported a greater association with overall ease of locomotion. Therefore, if the goal is to have people assess walking as natural, easy, and uncomplicated, then it is better that they really do walk.

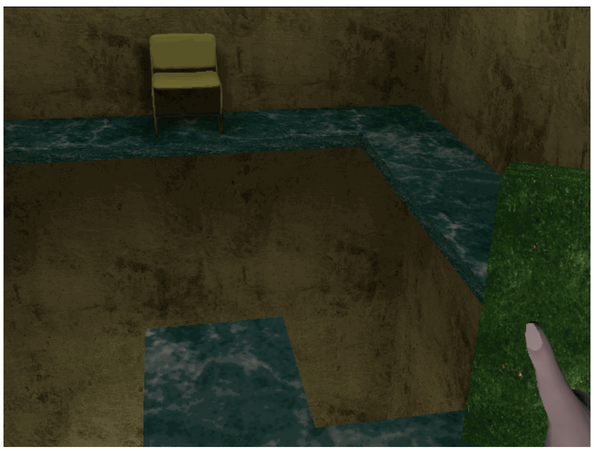

Figure 1: Subject entering the virtual pit room

Figure 2: Subject standing on the ledge

Keywords: Virtual Environments, Presence, Locomotion, Navigation, Virtual Walking, Visual Cliff

5. References

Cox D.R [1970] *Analysis of Binary Data*, London: Menthuen.

Gibson J.J, Walk R.D [1960] *The visual cliff*, Scientific American, 202:64-71.

Kennedy R.S, Lane N.E, Berbaum K.S, Lilienthal M.G (1993) A Simulator Sickness Questionnaire (SSQ): A New Method for Quantifying Simulator Sickness, International Journal of Aviation Psychology, 3(3):203-220.

Slater M, Steed A, Usoh M (1993) The Virtual Treadmill: A Naturalistic Metaphor for Navigation in Immersive Virtual Environments, First Eurographics Workshop on Virtual Reality, ed. M. Goebel, 71-86.

Slater M, Usoh M, Steed A (1995) Taking Steps: The Influence of a Walking Technique on Presence in Virtual Reality, In ACM Transactions on Computer-Human Interface, Special Issue on Virtual Reality Software and Technology, 2(3):201-219, September, 1995.

Slater M, Steed A (1998) A Virtual Presence Counter, submitted.

Ward M, Azuma R, Bennett R, Gottschalk S, Fuchs H (1992) A Demonstrated Optical Tracker with Scalable Work Area for Head-Mounted Display Systems, Proceedings of the 1992 Symposium on Interactive 3D Graphics, Computer Graphics, 25(2): 43-52.

Welch G, Bishop G (1997) SCAAT: Incremental Tracking with Incomplete Information, Proceedings of SIGGRAPH 97, Computer Graphics Proceedings, Annual Conference Series, pp. 333-344.