Effects of Depth Cues on Simulator Sickness

Nolwenn Bigoin
VisoR Research Group, VR Lab
Macquarie University, Sydney, Australia
61 2 98509065
Nolwenn.bigoin@etumel.univmed.fr

John Porte & Iwan Kartiko
VisoR Research Group, VR Lab
Macquarie University, Sydney, Australia
61 2 98509065
ikartiko@ics.mq.edu.au

Manolya Kavakli
VisoR Research Group, VR Lab
Macquarie University, Sydney, Australia
61 2 98509572
manolya@ics.mq.edu.au

ABSTRACT
In this paper, we discuss our experimental results on Simulator Sickness (SS). A series of experiments were conducted in our Virtual Reality (VR) Lab. Our aim was to investigate the correlations between the perception of depth and the feeling of discomfort, as well as the role of gameplay regarding the familiarity of the viewer with computer games in the feeling of discomfort. Participants were immersed in two different stereoscopic landscapes projected on a semi-cylindrical screen. The results indicate that participants have felt simulator sickness more intensely in the landscape where they perceived less depth cues. We also observed that participants who often played computer games felt simulator sickness less than others.

Categories and Subject Descriptors
I.3.7 [**Computer Graphics**]: Three-Dimensional Graphics and Realism – V*irtual reality.*

General Terms
Design, Experimentation, Human Factors.

Keywords
Simulator sickness, Depth, Computer Games.

1. INTRODUCTION
In this study, we investigate the perception of depth in an immersive environment, and its association with the feeling of discomfort, known as Simulator Sickness (SS) or Virtual Simulator Sickness (VSS). SS is an acute condition of medical distress that results in skin pallor, weakness, nausea and vomiting. It often starts as stomach discomfort, bodily warmth, headache, dizziness and/or drowsiness, then proceeds to stomach distress, then nausea and vomiting. SS may happen due to differences between perceived motion and actual motion in virtual reality. According to the experts, almost everyone will get motion sickness if the conditions are extreme enough. In rough seas, nearly all the occupants of a life raft will vomit. As reported by Biobands (http://www.biobands.com/motionsickness.htm), a study conducted in India involved 535 subjects. They found the prevalence of motion sickness was about 27%. Among EMT ambulance personnel, 46% report problems with nausea. 7% of seagoing cruise ship passengers report vomiting. 60% of student aircrews get airsickness during training.

Perception and visual cues in virtual reality are important topics to explore, due to its association with real time rendering and computing power. SS was investigated by a number of researchers [1, 4, 5, 6, 7, 8, 9], however, none of these focused on the effects of depth cues in SS. [2] focused on shape perception (different visualization techniques of 3D generated free form surfaces) on participants' perceptual and cognitive processing, while performing CAD tasks in immersive environments. [3] evaluated space perception in immersive virtual environments. However, none of these studies addressed the relationship between visual cues and simulator sickness. In this paper, we focus on the correlations between depth cues and SS, as well as the background of users related to their experience of playing computer games.

2. EXPERIMENTAL PROCEDURE
We have created two different virtual environments to test the impacts of depth cues in SS. One of the virtual environments, Hills, is a landscape of snowy hills (see Figure 1) including much soft and rounded geometry expected to minimize perception of depth and reduce the effectiveness of active stereo. The second environment is Trenches that is intended to present a stronger sense of depth due to sharp edged geometry; this is expected to provide some crisp edges for the viewer's eyes to focus on. To further add to the depth perception, Trenches is viewed from within a spaceship, the interior providing some foreground depth (see Figure 2). Our assumption was that Hills should not induce as much discomfort due to its relatively lower levels of perceivable depth. Users were immersed in those environments, as if they were flying over the landscape guided by a tour guide. The scene navigation was controlled by a data glove, smoothly manipulated.

107 high school students and their teachers participated in this study while they were visiting our VR Lab. All students were in the same age range (15 to 20). Therefore, the age factor is not significant in our study. We had 3 groups of participants:

- 1st group: 19 participants were exposed to only the Hills Scene.
- 2nd group: 58 participants were exposed to only the Trenches scene.
- 3rd group: 31 participants were exposed to both scenes.

Permission to make digital or hard copies of all or part of this work for personal or classroom use is granted without fee provided that copies are not made or distributed for profit or commercial advantage and that copies bear this notice and the full citation on the first page. To copy otherwise, or republish, to post on servers or to redistribute to lists, requires prior specific permission and/or a fee.
Conference'04, Month 1–2, 2004, City, State, Country.
Copyright 2004 ACM 1-58113-000-0/00/0004…$5.00.

Before and after the experiment participants were asked to fill out a questionnaire (see Figure 3). Firstly they were asked to rate their familiarity with computer games and computer graphics on a Likert scale of 7 levels, from unfamiliar to familiar. Then they were exposed to the scene for approximately 15 minutes. Participants who were exposed to both scenes watched the scenes for 30 minutes. Afterwards they were asked to rate the sense of depth and distance they have experienced, on a Likert scale from poor to strong. Similarly, they also had to rate the level of discomfort they have experienced.

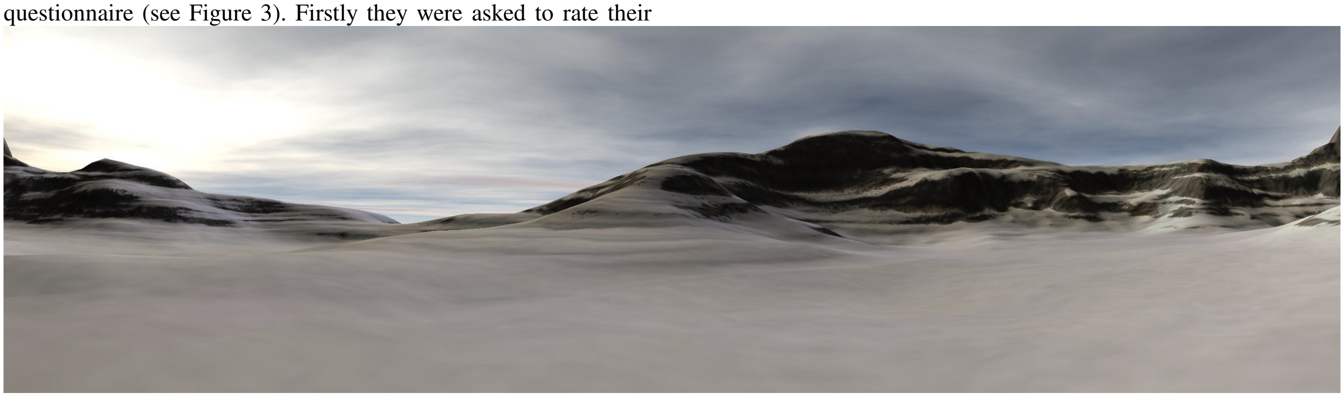


Figure 1. The Hills scene.

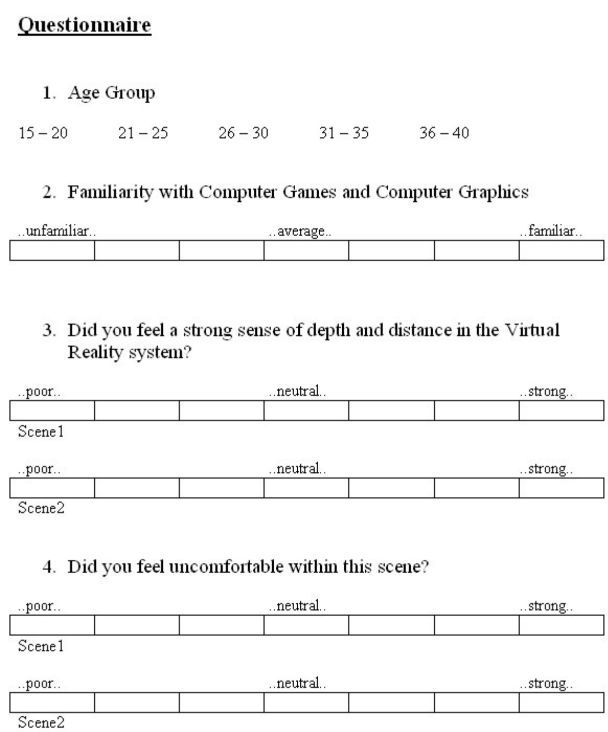
Figure 2. The Trenches scene.

3. HARDWARE

The simulation is run at our VR Lab on an immersive semi-cylindrical projection system. The system consists of three projectors which display the virtual world onto a semi-cylindrical screen canvas. The user is positioned slightly off centre towards the canvas to allow a 160° field of view (FOV). The projection is driven by a synchronized cluster of three PCs on a Gigabit network using specialized graphics cards, Nvidia Quadro FX3000, to achieve active stereo, providing stereoscopic 3D visuals (see Figure 4).

4. RESULTS

A statistical analysis of variance was performed on all the results. One-way ANOVA with an alpha level of 0.05 was used. We analyzed differences between three groups of participants as the ones who saw both scenes and those who saw only one scene. We also analyzed the differences between the two scenes.



Questionnaire

1. Age Group

15 – 20 21 – 25 26 – 30 31 – 35 36 – 40

2. Familiarity with Computer Games and Computer Graphics

..unfamiliar.. ..average.. ..familiar..

3. Did you feel a strong sense of depth and distance in the Virtual Reality system?

..poor.. ..neutral.. ..strong..
Scene1

..poor.. ..neutral.. ..strong..
Scene2

4. Did you feel uncomfortable within this scene?

..poor.. ..neutral.. ..strong..
Scene1

..poor.. ..neutral.. ..strong..
Scene2

Figure 3. Questionnaire about depth and discomfort.

Figure 4. PC cluster with screen canvas in the background.

4.1 Depth Sensation

The first statistically significant result ($F(1,60)=4.21$, $p<0.05$) was the difference between the sense of depth in the two scenes for participants who saw both scenes (see Figure 5).

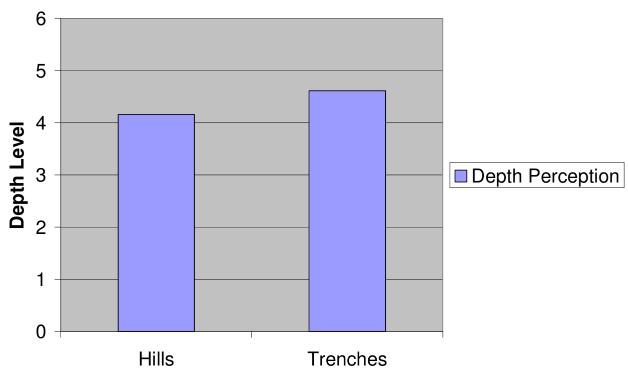


Figure 5. Sense of depth in the two scenes.

They reported an average depth sensation of 4.16 in the Hills Scene against 4.61 in the Trenches scene (where 0 refers to "poor", and 6 to "strong" depth perception). 4 participants out of 31 (12.9%) reported the highest depth score (6) in the Trenches scene, against only 1 (3.2%) in the Hills scene. The lowest depth score reported was 2, by 1 participant out of 31 (3.2%) in the Hills scene, and by no one in the Trenches scene.

The difference of depth sensation between participants who saw only one of the scenes was not statistically significant.

4.2 Feeling of Discomfort

Another significant result ($F(1,75)=5.95$, $p<0.05$) was the difference in the feeling of discomfort between the two scenes for participants who saw only one of the scenes (see Figure 6).

Participants in the Hills scene reported an average discomfort sensation of 2.82, against 1.73 for participants in the Trenches scene. 1 participant out of 19 (5.3%) reported the highest discomfort score (6) in the Hills scene, against 2 out of 58 (3.4%) in the Trenches score. 2 participants out of 19 (10.5%) reported the lowest discomfort score (0) in the Hills scene, against 21 out of 58 (36.2%) in the Trenches scene.

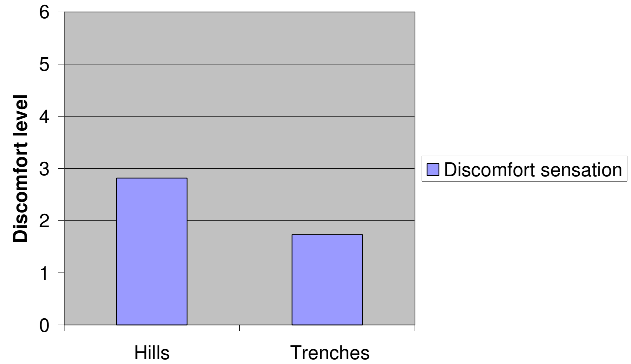


Figure 6. Discomfort in the two scenes.

The feeling of discomfort for participants who saw both scenes was not statistically significant.

4.3 Discomfort and Familiarity with Gameplay

The relationship between the level of discomfort for participants who saw only the Hills scene and their familiarity with computer games was also significant ($F(2,16)=4.11$, $p<0.05$, see Figure 7). We separated the level of familiarity in three categories. Participants with familiarity level between 0 and 2 included were categorized in the group of "poor familiarity" (9 participants). Participants with moderate familiarity between 2 and 4 excluded were categorized in the group of "moderate familiarity" (6 participants). Finally, participants with strong familiarity between 4 and 6 included were categorized in the group of "strong familiarity" (4 participants).

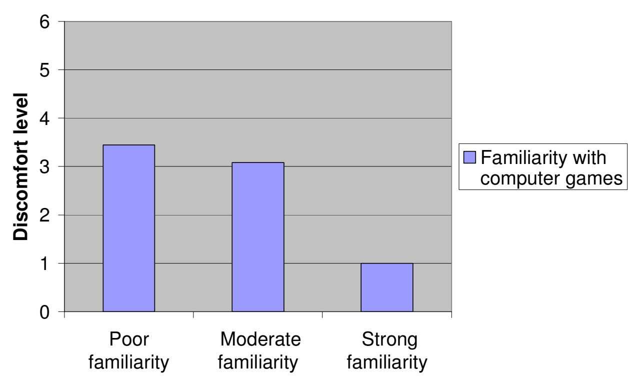


Figure 7. Discomfort related to familiarity.

Participants with poor familiarity with computer games reported an average discomfort sensation of 3.44, against 3.08 for those with moderate familiarity and 1 for those with strong familiarity. 1 participant out of 9 (11.1%) reported the highest discomfort score (6) in the poor familiarity group, against 0 in the moderate or strong familiarity group. 2 participants out of 4 (50%) reported no discomfort at all (0) in the strong familiarity group, against 0 in the moderate and poor familiarity.

Relation between level of discomfort for participants who saw only the Trenches scene and their familiarity with computer games was not statistically significant.

5. CONCLUSION

The results confirm that the Trenches scene contains a higher depth level than the Hills scene (+7.5%). We found that the depth sensation correlates with geometric characteristics of the digital content. The actual dimensions of our digital landscapes are the same. However, sharp edges in the Trenches scene contribute to the depth sensation.

Surprisingly this higher depth sensation does not correlate with a higher level of discomfort. On the contrary, we found that the feeling of discomfort decreases in Trenches 18.2% compared to the Hills scene. Thus, a digital landscape with a strong perception of depth appears to induce less simulator sickness than a landscape with less perception of depth.

Our interpretation is that a strong perception of depth, combined with navigation in the virtual environment, may lead to a greater sense of immersion. Immersion is defined as perceiving oneself to be enveloped by, included in, and interacting with an environment that provides a continuous stream of stimuli and experiences [9]. Immersion is also reported to be an important factor in the presence sense. In virtual environments, presence is described as experiencing the computer-generated environment rather than the actual physical locale [9]. One of the findings of this previous research study is that individuals who report more simulator sickness symptoms in virtual environments report less presence than those who report fewer symptoms. In our case, the feeling of discomfort was higher in the Hills scene, and the depth perception, which is related to presence, was lower in this scene. Our results confirm Witmer and Singer's findings [9], that is if participants do not really feel immersed in the virtual environment, they experience more discomfort.

The results also indicate strong differences in the feeling of discomfort between participants who are not very familiar with computer games, and those who are very familiar. It seems that the more you are familiar with, or the more you are used to computer games, the less you feel sick. This could be similar to the "habituation" phenomenon, which has been described in several studies [1, 4]. Habituation occurs when people are exposed to virtual scenes more than one time, on several days or weeks, and report less simulator sickness along those exposures. To be familiar with computer games, even in non-stereoscopic situations, could produce habituation to computer graphics contents and more or less immersive environments, and thus result in less simulator sickness.

We also noticed that a part of our results were not statistically significant. The design of our questionnaire may be a reason for that. In our upcoming experiments we planned to use another way to quantify simulator sickness, like physiological measure, postural stability [7, 8], well-recognized self-report questionnaire (Simulator Sickness Questionnaire [5] or Revised Simulator Sickness Questionnaire [6], Presence Questionnaire [9]).

6. ACKNOWLEDGEMENTS

This project is sponsored by the Australian Research Council (ARC): ARC Discovery Grant (DP0558852 titled Risk Management Using Agent Based Virtual Environments) and by the Macquarie University New Staff Grant "Gesture Recognition and Motion Capture as a Precursor for Behavioral Biometrics" to Dr Kavakli. Nolwenn Bigoin is sponsored through a French government scholarship for 6 months in Australia during her internship for her degree towards MSc in Computer Engineering.

7. REFERENCES

[1] Cobb, S. V. G., Nichols, S., Ramsey, A., and Wilson, J. R. Virtual reality-induced symptoms and effects (VRISE). *Presence, 8,* 2 (Apr. 1999), 169-186.

[2] Gagglioli, A., and Breining, R. Perception and Cognition in Immersive Virtual Reality, In: Riva, G., Davide, F., *Communications Through Virtual Technology: Identity, Community, and Technology in the Internet Age*, IOS Press, Amsterdam, 2001

[3] Gooch, A.A., and Willemsen, P. "Evaluating Space Perception in NPR Immersive Environments", *Non-Photorealistic Animation and Rendering 2002* (NPAR '02), Annecy, France, June 3-5, 2002.

[4] Hill, K. J., and Howarth, P. A. Habituation to the side effects of immersion in a virtual environment. *Displays, 21,* 1 (Mar. 2000), 25-30.

[5] Kennedy, R. S., Lane, N. E., Berbaum, K. S., and Lilienthal, M. G. Simulator Sickness Questionnaire: an enhanced method for quantifying simulator sickness. *International Journal of Aviation Psychology, 3,* 3 (1993), 203-220.

[6] Kim, D. H., Parker, D. E., and Park, M. Y. *A New Procedure for Measuring Simulator Sickness – the RSSQ.* Technical Report R-2004-52, Human Interface Technology Laboratory, University of Washington, 2004.

[7] Mourant, R. R., and Thattacherry, T. R. Simulator sickness in a virtual environments driving simulator. *Proceedings of the IEA 2000/HFES 2000 Congress,* 1, 534-537.

[8] Murata, A. Effects of duration of immersion in a virtual reality environment on postural stability. *International Journal of Human-Computer Interaction, 17,* 4 (2004), 463-477.

[9] Witmer, B. G., and Singer, M. J. Measuring presence in virtual environments: a presence questionnaire. *Presence, 7,* 3 (Jun. 1998), 225-240.