Presence in Response to Dynamic Visual Realism: A Preliminary Report of an Experiment Study

Pankaj Khanna[†] Insu Yu[†] Jesper Mortensen[†] Mel Slater[†‡]

[†]Department of Computer Science
University College London
London, UK.

[‡]ICREA-Universitat Politècnica de Catalunya
Department de LSI
Barcelona, Spain.

p.khanna | i.yu | j.mortensen | m.slater @cs.ucl.ac.uk

ABSTRACT

This paper describes an experiment that examines the influence of visual realism on reported presence. 33 participants experienced two different renderings of a virtual environment that depicts a pit in the centre of a room, in a head-tracked head-mounted display. The environment was rendered using parallel ray tracing at 15fps, but in one condition ray casting (RC) was used achieving a result equivalent to OpenGL based per-pixel local illumination, and in the second full recursive ray tracing (RT). The participants were randomly allocated to two groups – one that experienced RC first followed by RT, and the second group in the opposite order. Reported presence was obtained by questionnaires following each session. The results indicate that reported presence, in terms of the 'sense of being there' was significantly higher for the RT than for the RC condition.

Categories and Subject Descriptors

I.3.7 [**Three-Dimensional Graphics and Realism**]: ray tracing, virtual reality.

General Terms

Human Factors.

Keywords

Virtual environments, presence

1. INTRODUCTION

This paper is a preliminary report on an experiment that examined the influence of visual realism on reported presence in immersive virtual environments (VE). There have been many definitions of the concept of presence, mostly around the idea of 'being there' within the VE [1-4]. However, we define presence as the extent to which participants in a VE respond to virtual objects and events as if these were real. Response is considered at many levels ranging from low level physiological responses, behavioural responses, emotional and cognitive responses, to a sense of having 'been there' [5]. We refer to the latter as 'reported presence' and emphasise that it is but one particular dimension of the overall phenomenon, and should not be taken as being identical to 'presence' in the wider sense. Factors influencing reported presence have been studied – such as frame rate [6], field of view [7], latency [8], and display realism. Most of the results are clear – for example, higher frame rate, lower latency, wider field of view all positively influence reported presence. The results with respect to visual realism are, surprisingly, not clear – with empirical studies reaching different conclusions about whether higher visual realism induces higher reported presence. Indeed the evidence suggests that the opposite may be the case.

Early papers that addressed this issue [9, 10] compared presence amongst environments with different levels of visual detail and different levels of pictorial realism. Greater reported presence was found for higher visual realism in both senses. Another study compared reported and behavioural presence across rendering styles that either did not support shadows, supported static shadows, or supported dynamically changing shadows. Greater behavioural and reported presence was found for static shadows compared to no shadows, and dynamic shadows compared to no shadows [11]. In a comprehensive study with more than 300 participants that examined the impact of multi-sensory displays on presence, the level of visual detail was the only factor varied that had no influence on reported presence [12]. A similar result was found by [13] – again in a study of a variety of factors including stereoscopy, participant motion, geometry and texture, the visual aspects seemed to have no impact on reported presence. Finally, in an experiment that was set in the 'pit room' environment, similar to the one that we use in this paper, the scene was displayed at various levels of realism (wire frame, without and with textures, and with radiosity) in a between-groups design [14]. In that experiment physiological measures were recorded as well as questionnaire responses. It was found that all subjects exhibited significantly increased heart rate when they encountered the pit in the centre of the room, although there were no significant differences in heart rate or reported presence between the different rendering conditions. Finally in another between groups study that used two levels of radiosity and also flat shading, no difference in reported presence using the SUS questionnaire was found between the three conditions [15].

Results to date therefore show no clear message about the impact of the level of visual realism on reported or behavioural presence. There is evidence to support both conclusions that visual detail or type of rendering may or may not impact presence. Also 'visual realism' includes at least two different aspects – geometric realism in terms of the level of detail at which environments are displayed, and also illumination realism – that is the extent to which the light transport model used (if any) may have an impact on presence.

It may seem surprising that the importance of visual realism (in all senses) is open to doubt based on empirical findings. However, there are good perceptual explanations for this – that the perceptual system uses 'filling in' mechanisms where expectation plays a major role. In other words we see what we expect to see, and only a few minimal cues need to be presented for the brain to fill in missing detail [5, 16].

This paper reports on early results of an experiment that addresses the issue of illumination realism – but this time with dynamic effects rather than only the static aspects of global illumination through radiosity used in [14]. We compare the responses of people to a scene rendered with real-time ray casting (RC) or real-time full recursive ray tracing (RT). Although we recorded physiological measures (electrodermal activity, respiration and ECG), as well as having access to recorded behavioural responses through video, here we focus only on reported presence. The experiment was completed two weeks prior to the writing of this short paper, and physiological recordings are still being processed. However, the advantage of focussing only on questionnaire responses at this stage is that this compares with most of the other studies in the area of visual realism.

2. METHODS

2.1 Virtual Environment

The virtual environment used was a variant of the 'pit room' that has been used in several experiments before [8, 14, 17-19] (Figure 1). This consists of a room that has a precipice in the centre that drops down to about six metres, and below there is some furniture. The room consisted of 1,535 polygons. The VE was displayed in stereo through a Virtual Research V8 head-tracked head-mounted display (HMD), which has 2× 640×480 resolution. The tracking system used for the head and hand-held wand was a Polhemus FASTRACK.

The VE was rendered using a parallel ray-tracing implementation run across a cluster of six dual-processor Xeon 3.2Ghz workstations. Two rendering methods were used both implemented through ray tracing (or ray casting). The first, an illumination model similar to OpenGL per-pixel local illumination without shadow effects (RC), and a recursive ray-tracing method [20] capable of rendering shadows and reflections (RT). Ray-polygon intersections were performed using a 4-ray SIMD intersection method similar to that presented in [21]. Control of the rendering cluster, HMD and the two trackers (head and right hand) were performed by a master workstation that used basic inverse-kinematics to determine avatar pose and issue render tasks. These render tasks were created by a simple tiling of the display surface across the HMD's two screens. Render tasks were requested from the master by client workstations using demand-driven scheduling. The cluster was configured to be able to consistently deliver a stable frame-rate (15fps) that was kept fixed for the two rendering methods. A separate workstation recorded electrodermal activity and ECG physiological data from a TTL ProComp Infiniti[1] encoder during the experiments.

[1] http://www.thoughttechnology.com/proinf.htm

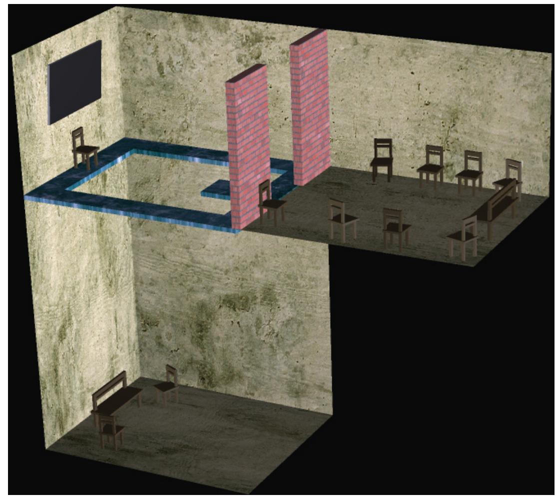


Figure 1. The pit room rendered with the RC method.

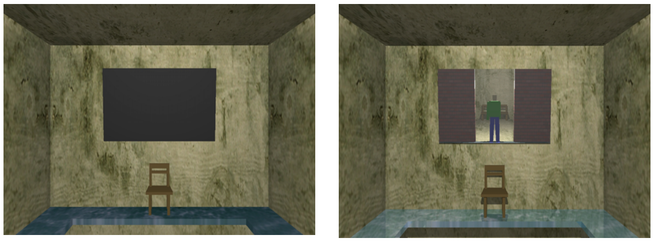
2.2 Experimental Design

33 participants were recruited for the experiment by advertisement around the campus. They were split arbitrarily into two groups of RT-1 (n = 17) and RC-1 (n = 16). Members of RT-1 experienced first of all the pit room rendered using RT and then experienced the environment again but this time rendered with RC. Members of RC-1 experienced first of all the RC rendered pit room and then the RT rendered pit room. The experimental design was, therefore, both between-groups and within-groups. If we consider only the first exposure results then it is between-groups. If we consider both exposures and compare between them it is within groups. We consider it doubtful whether a within-groups design is valid: since the first exposure is bound to have an influence on the results of the second exposure. Nevertheless we recruited large enough sample sizes so that a between-groups interpretation could also be given.

2.3 Procedures

At the start of the experiment participants were given an information sheet that explained the experimental procedures, possible dangers of using virtual reality equipment (e.g., dizziness), and what would be expected of them. If they agreed to continue with the experiment then they were given a disclaimer form to sign. They were invited to complete a questionnaire that gave basic information such as their age, gender, frequency of computer game playing, prior experience with virtual reality, and so on. It was explained to them that they would enter the virtual environment twice, and answer a questionnaire in between each exposure.

Participants then donned the HMD and equipment for physiological recording, and entered the pit room shown in Figure 1, standing in the doorway, but first of all facing away from the room with the pit. They were told that they could look around, and time was given for them to become comfortable with the apparatus. Then they were told to relax for three minutes and physiological baseline recordings were made. They were then invited to turn around and would then be looking directly into the pit room. They were told to look around the room for a period of three minutes. After this they took off the HMD and completed a questionnaire about presence. They then put on the HMD again; the physiological recordings were continued, and once again invited to look into the pit room. The second time, however, they would see the pit room rendered with the other rendering method. After three minutes again they came out of the environment and answered the same questionnaire.



(a) RC rendering (b) RT rendering

Figure 2. In the pit room.

Each participant was represented by a simple avatar that they could see from first person viewpoint if, for example, they looked down. More importantly in the RT condition they would see reflections and shadows of their avatar, and of course these would move dynamically as the person moved. Each participant held a tracked Wand in their hand. As they moved their real arm holding the tracker they would see, in reflections and shadows, their virtual arm move in response. This was the major difference between RC and RT – for example, Figure 2(b) shows a reflection of the avatar in the wall opposite the door to the pit room.

3. RESULTS

3.1 Response Variables

There were two major types of response variable collected, the presence questionnaire and the physiological data. As stated above in this paper we concentrate exclusively on the first.

Here we focus on the results of the so-called SUS questionnaire, as for example, in [22]. This is based on the idea of presence as 'being there', and has 5 questions related to three main issues: the sense of being in the pit room, the extent to which this became the dominant reality, and the extent to which the experience was remembered as somewhere visited rather than just images seen. The normal method for combining the 5 questions into a single score is to take the number of high responses out of the 5 questions. By 'high response' we mean that the score on each 7-point Likert scale question has to be at least 5. Hence the response variable is the number of scores of 5, 6 or 7 out of the 5 questions. We call this 'reported presence' and denote it by 'pres'. We also used another type of questionnaire presence but do not consider this here, since we are primarily concerned with compatability with previous results.

3.2 Independent and Explanatory Variables

The only independent factor (i.e., controlled experimental variable) was the RT or RC conditions.

Data was collected on a number of other variables – gender (15 females out of 33 participants), age (26.6 ± 7.4 SD years), and prior experience with virtual reality, computer games, computer literacy, and English.

3.3 The Between-Groups Results

When we consider the first exposures only for each person there are 17 who experienced RC and 16 who experienced RT. The mean and standard errors of the presence scores are shown in Table 1.

Table 1. Mean and Standard Errors of Presence Scores

Condition	Mean	SE
RC	1.53	0.35
RT	2.31	0.38

Using binomial logistic regression we find that Condition is significant (P = 0.04) for pres. In other words experiencing the RT environment was associated with higher reported presence.
Previous experience with virtual reality is also significant. If we add this variable then the overall fitted model is shown in Table 2.

Table 2. Analysis of Variance Table for Logistic Regression of pres on Condition and VR (Overall deviance = 64.972 on 32 d.f.)

	Estimate	SE	t-value	P-value
Grand mean	-1.6204	0.3910	-4.145	3.4e-05
Condition:RT	0.8121	0.3405	2.385	0.01709
VR	0.3424	0.1266	2.704	0.00685

In Table 2 the estimate for Condition=RT is significantly different from the RC condition (this is subsumed under the grand mean). Also higher pres is positively associated with greater past experience of virtual reality (VR).

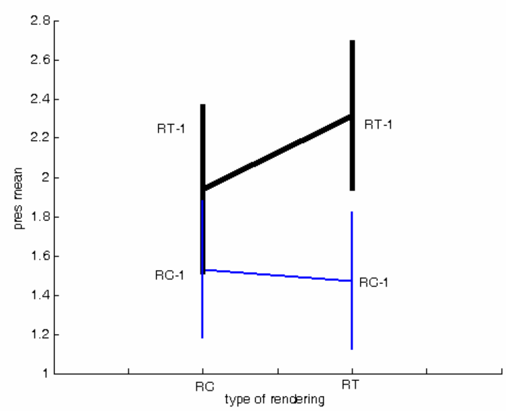


Figure 3. Means and Standard Errors of pres for the RC and RT Conditions by Group

3.4 The Within-Groups Results

In this case there are two groups (RT-1 and RC-1) and two conditions (RT and RC). Figure 3 summarises the situation for pres. The thicker black lines represent the means and standard errors for the RT-1 group, and the thinner blue lines the mean and standard errors for the RC-1 group. For each group we show the change in means between the RC and RT conditions. For the RC-1 group there is no significant difference between RC and RT. For the RT-1 group there is a significant difference (t = 2.345 on 62 d.f.). However, as stated earlier, we do not find a within-groups experiment convincing in this situation, because of the lack of symmetry between experiencing first RT and then RC, compared with RC and then RT. In the first case the participants would likely be affected by the less realistic feedback.

4. CONCLUSIONS

The clearest result is that the reported presence measure in the between-groups experiment is significantly greater for the RT condition than for RC. This situation is the one that is most similar to previous experiments, and for the first time suggests that more realistic illumination that includes dynamic shadows and reflections is associated with higher reported presence.

As has been argued before [23] it is methodologically inappropriate to base conclusions about presence solely on questionnaire results. Therefore we reserve judgement on this issue until we have analysed the results of the physiological recordings. If greater illumination realism results in greater presence then this should be confirmed by signs of greater arousal (which can be measured with electrodermal activity) and greater stress (which can be measured through a combination of heart rate and heart rate variability) under the RT condition than in the RC condition.

5. ACKNOWLEDGMENTS

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