The Interaction Between Individuals' Immersive Tendencies and the Sensation of Presence in a Virtual Environment

Cathryn Johns, David Nuñez, Marc Daya, Duncan Sellars,
Juan Casanueva, and Edwin Blake

Collaborative Visual Computing Laboratory
Department of Computer Science, University of Cape Town
Private Bag, RONDEBOSCH
7701 South Africa
{cjohns, jcasanue, edwin}@cs.uct.ac.za
http://www.cs.uct.ac.za/Research/CVC

Abstract. Witmer and Singer have developed a questionnaire for presence (PQ) as well as an immersive tendencies questionnaire (ITQ). Their research has shown that ITQ scores are positively correlated with PQ scores. This paper reports on an attempt to replicate these findings in a non-immersive, collaborative setting, by creating one virtual environment designed to engender a high sense of presence in users, and one designed to disrupt and decrease the sense of presence felt by users. The major findings of this attempt were firstly that while there was a difference in the two worlds according to the definition of presence, the PQ did not pick up this difference, and secondly that PQ scores were correlated with ITQ scores only in the so-called "high-presence" environment, implying that Witmer and Singer's results hold only under certain conditions.

1 Introduction

Presence, as a subjective experience, is receiving substantial attention from engineers, computer scientists, and psychologists concerned with virtual environments (VEs)[4]. Presence has been linked to greater knowledge transferability [6] as well as enhancement of learning and performance [8]. Presence is being used as the basis for predicting gains in the effectiveness of learning, comprehension, insight, performance, and transfer of training [5]. More generally, presence is informally used as a measure of how "good" a virtual environment is.

A reliable and valid presence measure is of utmost importance. A predictor for presence, even if it is only a partial predictor, would assist VE designers and researchers in being able to set a given presence level in a VE. Witmer and Singer [8][5] have developed a presence questionnaire, the PQ, as well as a questionnaire designed to measure an individual's immersive tendencies, the ITQ. Furthermore, their research suggests that the ITQ may predict, within a

given VE, the level of presence to be felt by a participant. This paper reports on an attempt to replicate, in a non-immersive, collaborative setting, Witmer and Singer's results with regard to the PQ being a reliable and valid measure of presence, as well as the correlation between ITQ and PQ scores. Versions 3.01 of the ITQ and 3.0 of the PQ were used in this attempted replication. As per Witmer and Singer's instructions, the most recently added questions were not included in the scores as they have not yet been fully investigated and analysed [5].

Section 2 of this paper covers some background to Witmer and Singer's definition of presence, and describes the aims of their PQ and ITQ. Section 3 describes the experiment used to test the PQ/ITQ correlation, as well as describing the VEs, the participant sample, and the equipment used in the experiment. Section 4 describes the results of the experiments, while Section 5 discusses these results and lays out some directions for further research.

2 Background

Witmer and Singer [8] define presence in VEs as referring to experiencing the computer-generated environment rather than the actual physical locale, and distinguish it from the equally subjective sense of immersion. They define immersion as "a psychological state characterised by perceiving oneself to be enveloped by, included in, and interacting with an environment that provides a continuous stream of stimuli and experience", and go on to state that a VE which produces a greater sense of immersion will produce higher levels of presence.

Witmer and Singer grouped the factors thought to underlie presence into four main categories [8]:

Distraction Factors:
- Isolation
- Selective attention
- Interface awareness

Realism Factors:
- Scene realism
- Consistency of VE data with real-world experience
- Meaningfulness of experience

Control Factors:
- Degree of control
- Immediacy of control
- Anticipation of events
- Mode of control
- Physical environment modifiability

Sensory Factors:
- Sensory modality
- Environmental richness
- Multimodal presentation
- Consistency of multimodal data
- Degree of movement perception
- Active search

A Presence Questionnaire (PQ) was developed by Witmer and Singer [8][5] to measure the degree to which individuals experience presence in a VE. As they believe that the strength of the feeling of presence in a VE depends on differences

in the individual participants as well as the characteristics of the VE, an Immersive Tendencies Questionnaire (ITQ) was also developed. The ITQ was designed to measure the capability of individuals to become involved or immersed. Both the PQ and the ITQ rely on self-report information. ITQ scores have been shown by Witmer and Singer [8] to be significantly positively correlated with PQ scores ($r = 0.24$, significant at a 1% level). A recent experiment also found a significant, positive correlation between Witmer and Signer's ITQ and the presence questionnaire developed by Mel Slater [3].

3 Method

The aim of the experiment was to test the PQ/ITQ correlation results reported by Witmer and Singer [8][5] by creating two collaborative desktop virtual environments which engendered differing degrees of presence in participants, and checking that the ITQ and PQ scores of participants were correlated in both VEs.

Two screen-based collaborative virtual environments (CVEs) were thus created, one of which was designed to engender high sensations of presence, while the other was deliberately designed to disrupt and decrease the sense of presence felt by participants. This was accomplished by including more of the factors thought to underlie presence (detailed in Section 2) in the "high-presence" VE than in the "low-presence" VE, and purposefully disrupting these factors in the "low-presence" VE. The DIVE software developed by the Swedish Institute of Computer Science (SICS) [2][1] was used to create the two CVEs.

Participants were divided into six groups of three members. These groups were arbitrarily assigned to either the high- or low-presence environments, and as far as possible the presence factors listed above were kept constant within each group. Group members were represented by avatars of different colours (namely Red, Green, and Blue) in order to distinguish between the participants within the CVE.

The general layout of both VEs resembled that of an open plan office. In order to preserve the comparability of the experimental results, both VEs used the same layout.

In the high-presence VE, participants had a first-person, 3-dimensional perspective. They communicated with other group members using real-time audio, using an unobtrusive microphone placed near the computer. Participants wore headphones in order to clearly hear group members speech, as well as to block out extraneous real-world sounds. In order to interact with objects within the VE, participants had to be standing next to the relevant object. "Unintentional" interactions such as walking though walls and objects, and grasping and moving objects such as walls or floors, was disabled in the high-presence VE. In addition, in order to strengthen the visual influence on presence, the high presence VE had textures mapped onto surfaces. This allowed more realistic rendering of objects.

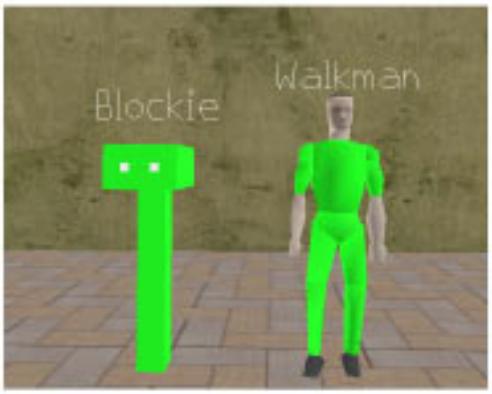

Fig. 1. Screenshot of the 2 different avatars used in the experiment. The avatar on the left ("Blockie") was used in low-presence world; that on the right ("Walkman") in the high-presence world.

The participants in the high-presence VE were embodied using a humanoid avatar which had the ability to "walk" (i.e. perform natural-looking movements of the legs and arms) when it moved around the environment. Participants in the low-presence VE were represented by a simple block-like avatar shaped as a 'T'. These avatars are shown in Figure 1.

Participants in the low presence VE were limited to a third person, top-down perspective. Communication with group members was through the use of text boxes. Participants were allowed to manipulate or grab objects that were some distance away from them, and were able to move through objects. The ability to move walls, etc., were disabled in both VEs simply due to the inconvenience of resetting the layout. In the low presence VE, objects were displayed as simple shaded polygons.

The two VEs can be compared in terms of the factors thought to underlie presence. It can be seen that they differ in the following factors:

- **Mode of Control**: communication in the high-presence VE was more natural than in the low-presence VE (talking vs. typing)
- **Sensory Modality**: the textures in the high-presence VE meant that more visual stimulation was available than in the low-presence VE
- **Environmental Richness**: the high-presence VE conveyed more sensory information to participants than the low-presence environment (speech/sound, textures, etc)
- **Multimodal Presentation**: the high-presence VE stimulated more senses than the low-presence VE
- **Active Search**: in the high-presence VE, the participant's view of the VE changed as the avatar was rotated, while in the low-presence VE the view was independent of the direction in which the avatar was facing

- **Isolation**: the participants in the high-presence VE were more isolated from the physical environment due to the wearing of headphones (extraneous noises were not heard by high-presence participants, but were by the low-presence participants). In addition, the intentional real-world intrusions described later in Section 3.2 contributed to forcing the low-presence participants to remain continually aware of the real world
- **Interface Awareness**: the high-presence interface with regard to communication was less obtrusive than that of the low-presence interface
- **Scene Realism**: the first-person view, addition of textures, and collision detection provided in the high-presence world added to the realism, while the third-person top-down view, flat polygonal shading of objects, and the ability to walk through walls detracted from the realism of the low-presence world
- **Consistency of VE Information with Real-world Experience**: the lack of gravity and the ability to walk through walls in the low-presence VE, as well as the static nature of the avatars, reduced the consistency of the VE information with the experiences learned by participants in the real-world

The two VEs thus differ greatly in the amount of presence which they should engender in participants.

3.1 Sample

Participants were paid volunteers and were mainly drawn from the second year psychology course (a few participants, however, were doing other courses - see Table 1). Psychology students were specifically recruited because the course involves doing assignments on computer, and thus all volunteers would have basic familiarity with a computer and its controls (e.g. using a mouse). However, it was felt that few would have been exposed to 3D first-person gaming environments. This is important, since studies have shown that frequent exposure to 3D first-person gaming environments may affect the level of presence felt by participants in VE's [7].

A sample of 20 participants was used — six groups with three participants per group, and one group with two (the third member of this group suffered equipment failure, and thus did not complete the questionnaires). The first four groups participated in the low-presence environment, while the last three (including the two-person group) participated in the high-presence environment. Participants were not told which environment they have been assigned to, and in fact were probably not aware that theirs was not the only VE implemented.

Table 1. The Composition of Groups with Regard to Gender and Major Subject

	Male:Female	Psychology:Other
Low-Presence VE	5:7	9:3
High-presence VE	4:4	5:3

3.2 Procedure

Participants were only allowed to communicate with each other through the virtual environment, and were not able to see or hear other group members or their view of the VE. This was accomplished by situating participants' computers in different rooms within the same laboratory. In addition, participants in the high-presence environment were using earphones for audio communication, thereby blocking out extraneous external sounds (including other participants' speech).

All participants were given the same information about the experiment. Group members were given an instruction sheet in which they were told that they were to cooperate with the other group members in order to complete a task. The instruction sheet included a detailed description of the task, as well as a brief overview of the basic controls. In addition, the low-presence participants were told that the experimenter who welcomed them (their "helper") would be nearby in case they had trouble with the controls, but would not be able to assist them with the task. High-presence participants were told that their "helper" would be available to help with the controls during the practice session, but that during the task they would be left alone.

After participants had read the instruction sheet, their helper showed them the virtual environment on the screen, and indicated which was their avatar. When all the group members were ready, they were greeted by an avatar controlled by one of the experimenters (in the high-presence environment, this was done verbally in order to draw their attention to the fact that normal speech was possible as well as to make it seem natural). This began the practice portion of the session, where the group members were familiarised with the controls. The practice session involved talking/typing to each other; walking around; and picking up and dropping objects. Once all members were comfortable with the VE, they were told that they could start the task. At this point, the experimenter's avatar left the central area in which the practice portion of the session was held. Once it was out of sight, it was made invisible so that the group could be inconspicuously monitored.

In order to increase distraction and real-world intrusion in the low-presence groups [6], the participants were interrupted nine minutes into the session in order to ask them if they would like a softdrink, and of what flavour. Five minutes later they were interrupted again when the softdrinks arrived. In addition, the drinking of the softdrink served as a continual real-world intrusion.

The task was language-based, and designed to encourage intellectual collaboration while providing enough opportunities for participants to interact with the VE. It involved searching the VE to find blocks on which letters had been placed. These letter-blocks had to be matched up with incomplete words which had also been scattered around the VE. The task itself was irrelevant to the aims of the experiment, as task performance was not analysed at all. A task was only assigned to participants in order to give them some motivation for being in the VE, and to cause them to interact with the VE. However, this was not known to the participants.

3.3 Equipment

As the CVE's were screen-based, no immersive equipment was used. Movement through the virtual environment was accomplished using the cursor keys on the keyboard, and objects in the virtual environment could be picked up and dropped by clicking on them with the left mouse button.

The following workstation configurations were used:

- An SGI Onyx RealityEngine2 with 128 Mbytes of RAM and a 21 inch screen (used for the participant assigned the colour Red)
- An SGI O_2 with an R10000 processor, 256 Mbytes of RAM and a 17 inch screen (used for the participant assigned the colour Green)
- An SGI O_2 with an R10000 processor, 128 Mbytes of RAM and a 21 inch screen (used for the participant assigned the colour Blue)

4 Results

In order to determine whether sampling errors occurred, PQ scores of groups within the same condition (i.e. groups from the same VE) were compared. This was performed using, for each condition, a one-way Analysis of Variance (ANOVA) on group number and PQ score. No significant difference was found in either condition at the 0.05 confidence level (High-presence VE: $F = 0.049$, $p = 0.953$; Low-presence VE: $F = 0.747$, $p = 0.554$), which shows that all the groups within the same VE experienced the same levels of presence.

In addition, it was necessary to determine whether the use of different equipment led to significantly different PQ scores within the same group. A one-way ANOVA on colour and PQ score was performed for each condition, and showed that no significant difference existed at the 0.05 confidence level (High-presence VE: $F = 1.148$, $p = 0.389$; Low-presence VE: $F = 0.376$, $p = 0.696$). This showed that which machine a participant used did not influence their PQ score.

In order to ensure that an inadvertently uneven distribution of participants (with regards to ITQ scores) hadn't occurred, a two-tailed t-test was performed on the mean ITQ scores in each condition. The results of this showed that there was no significant difference at the 0.05 confidence level.

A further test was performed to ensure that the sample used in this experiment was from the same population as that of Witmer and Singer. The mean ITQ score for this experiment was found to be 82.9 with 95% confidence interval of $(74.77, 91.02)$. As Witmer and Singer's mean ITQ score was 76.66 [5], it clearly falls within the confidence interval and thus both samples can be assumed to be drawn from the same population.

In contradiction to Witmer and Singer's results, an initial analysis found the PQ/ITQ correlations to be not significant (at a 0.05 confidence level) for either VE (High-presence VE: $r = 0.54$, with a critical value of r of 0.6215; Low-presence VE: $r = 0.36$, with a critical value of r of 0.4973). [1]

[1] A one-sided test was used as there was a strong theoretical for supposing that any correlations found would be positive (Witmer and Singer [8] have found that higher ITQ scores lead to higher PQ scores)

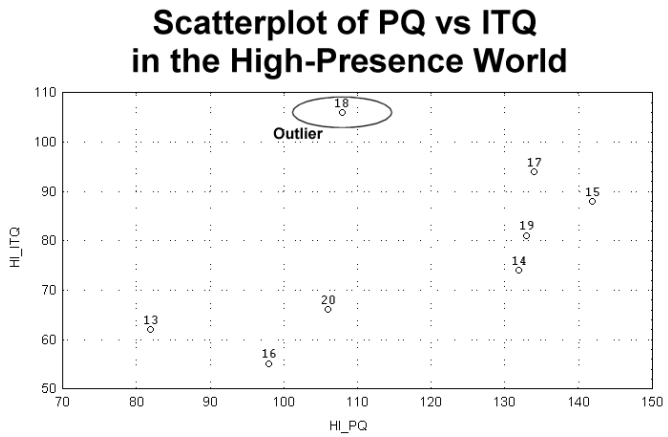

Fig. 2. A scatterplot of PQ scores vs. ITQ scores in the high-presence VE. Data point 18 is clearly an outlier.

However, a scatterplot of the PQ scores vs the ITQ scores in the high-presence VE shows a data point that is clearly an outlier (Figure 2, Point 18), as it lies in a quadrant not occupied by any other points. This participant indicated on the ITQ that he was a frequent game-player, and this may have adversely affected his sense of presence but increased his ITQ score - Steed *et al* [7] have found that frequent game playing decreases susceptibility to presence, while in Witmer and Singer's ITQ frequent game playing increases the ITQ score.

When this outlier was removed from the the high-presence VE data, the PQ/ITQ correlation in the high-presence VE became significant at the 0.01 confidence level with an r of 0.86 (critical value of r = 0.6694). The removal of the outlier did not affect the low-presence VE data, and thus the PQ/ITQ correlation remained not significant in the low-presence VE. However, the removal of the outlier from the high-presence data did result in a difference in PQ/ITQ correlations for the two VEs which is significant at the 0.05 confidence level (p = 0.0158).

The difference in the PQ/ITQ correlations for the two VEs cannot be attributed to a difference in PQ scores between the two worlds, as a one-tailed t-test on the mean PQ scores for each VE was not significant at a 0.05 confidence level (p = 0.0599). [2] This shows that there was no difference in PQ scores between the two environments.

5 Conclusion

Witmer and Singer's findings with regard to the Immersive Tendencies Questionnaire (ITQ) scores being a predictor of Presence Questionnaire (PQ) scores were

[2] As presence would not be expected to be *lower* in the high-presence VE, there is a strong theoretical justification for using a one-tailed test.

not replicated. In the "high-presence" VE, PQ scores were significantly correlated with ITQ scores, but this did not hold in the "low-presence" environment. ITQ scores, as well as PQ scores, were not significantly different across the two VEs, thus removing one possible explanation for the difference in correlations. In addition, the difference between Witmer and Singer's findings and the results of this study cannot be attributed to a systematic subject difference in ITQ scores, as our sample scores were shown to have been drawn from the same population as those of Witmer and Singer.

The PQ/ITQ correlation found by Witmer and Singer thus seems to hold only under certain conditions. However, the measures used in this study (i.e. the ITQ and PQ) showed no difference between the two VEs, and so it seems that there could be some third factor interacting with the PQ and ITQ, related to some unmeasured difference in the two VEs.

The mean PQ scores of the two VEs were not significantly different. According to the factors thought to underlie presence by Witmer and Singer[8], i.e. according to Witmer and Singer's definition of presence, the two VEs created for this experiment should have engendered differing subjective feelings of presence in the participants. However, the PQ showed that participants felt approximately the same level of presence regardless of which VE they were assigned to. This implies that either the factors in which the VEs differed contribute far less to presence than the factors in which they did not differ (suggesting the existence of higher order factors in the PQ), that the PQ is not valid in non-immersive, collaborative VEs, or that the PQ is not suitable for comparing the levels of presence felt by participants across different VEs. This issue of the suitability of the PQ for this kind of analysis may provide another explanation for the difference in ITQ/PQ correlations. While there was no difference in PQ scores, there may have been a difference in presence, and so the difference in the correlations may be attributable to a threshold effect whereby the PQ/ITQ link only holds once a certain level of presence has been achieved.

Interestingly, a recent experiment showed a significant positive correlation between the ITQ and another presence questionnaire developed by Mel Slater [3]. This seems to suggest that to some extent, the ITQ does predict presence and not just PQ scores.

The problems experienced with these questionnaires show that while Witmer and Singer have attempted to show that the PQ and ITQ are reliable and valid, the questionnaires are not yet psychometrically mature. Replications in differing settings will help to refine the scales and allow them to reach maturity.

5.1 Further Research

It may be that the high-presence VE was inadvertently created to be more immersive than the low-presence VE (although currently there is no measure for this), and that the PQ/ITQ correlation only holds when the participants are immersed in the VE. Further studies should be carried out in an attempt to confirm this idea, and a method for determining the immersive quality of a virtual en-

vironment should be developed. This method could be used in conjunction with Witmer and Singer's measure of the immersive tendencies of participants.

A direction for further research which would provide further insight into both the PQ/ITQ correlation issue as well as the issue of a measure for presence would be to investigate ways in which the VE itself could be comprehensively and objectively measured, taking into account all the possible aspects which may affect the way in which users react to the VE. VEs could then be compared to a standard VE, and researchers would be able to definitively tell "how far" their VE is from the standard. This would allow VEs with pre-determined levels of presence and immersion to be created. This VE-based measure should be completely objective, and would eliminate the need for subjective self-report questionnaires. In addition, it would enable all the factors affecting presence to be isolated, identified, studied and measured.

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