Presence as a Means for Understanding User Behaviour in Virtual Environments

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Abstract

Presence has become a key concept in characterizing and evaluating Virtual Environments. Our contribution is to show that current measures of Presence, as a metric of users' experience of Virtual Environments, are highly problematic: results from the literature cannot be repeated and it lacks a theoretical basis. We synthesize results from three experiments we conducted and in conclusion point the way to alternative approaches to the problem of characterizing Collaborative Virtual Environments.

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1 Interactive 3D Systems

Interactive three-dimensional (3D) systems, often referred to as Virtual Environments (VEs), can offer a qualitatively different user experience from other interactive systems. Our challenge is to characterize and measure this qualitative difference. Collaborative Virtual Environments (CVEs), where a computer system mediates the interaction of users with one another and with computational objects add a further dimension to the complexity of the user experience. Such systems form a new paradigm for communication between people and can replace the use of plain old telephones and video-conferencing for this purpose.

Our contribution in this paper is to identify some of the limitations of existing work in characterizing CVEs and to point the way for more useful measures that characterize the systems. Our work extends and criticizes current notions of Presence [14, 19, 12, 8, 10, 16] and Co-Presence[15, 17], defined below.

1.1 User behaviour and Virtual Reality

Virtual Environments (VEs), are specifically designed to create a sense in the user of *existing in* rather than simply *viewing*. A 3D visualization of a complex data set might look somewhat like a mountain, but a VE tour of that same dataset would give the user the impression that they are standing on the mountain. It is this sense of "being" [12], or "immersion" [19, 14] or "presence" [19, 14, 12] which defines VEs.

Users are represented in the environment by avatars, which are representations of the users themselves within the environment: and so the user regards the interface not only as one where they may directly manipulate objects, but where the environment can have effects on them as active participants. For example, users will not move onto areas which do not suggest a floor for them to walk on, and so on.

2 Presence

Presence has a number of aspects. We shall consider *immersion* and *subjective presence*. Subjective presence refers to the personal experience of a user and it is the sense of "being" or existing in the virtual environment. Personal presence is further divided into two aspects: the extent to which a users feels present in an environment is called *personal presence*, and the extent to which users regard virtual collaborators as truly co-existing in the environment is called *co-presence*.

Immersion is a function of the VR system; the level to which the VR system replaces real world information sources with generated virtual information sources. A system which provides visual as well as aural information to the user displays more immersion than one which only provides visual information. While immersion is wholly a product of the system, subjective presence is wholly a product of the subject's psychology.

Personal presence is characterized by the user's sense of being in the space indicated by the VE rather than in the real world. *Co-presence*, which can be thought of as a subcomponent of subjective presence, is the feeling that the other participants in the collaborative virtual environment actually exist and are really present in the environment, and the feeling that one is interacting with real people. In other words, it is having a perception that the persons with whom one is engaged in communication are in the same virtual location and environment when in fact they are in a different real locations.

Slater *et al*. [15] indicate that personal presence and co-presence are orthogonal to each other because, for example, talking on the telephone with someone might give you a sense of co-presence (i.e., "being with them") but will not give you a sense of presence (i.e., "being there").

3 Empirical Work on Presence in Collaborative Virtual Environments (CVEs)

In this section we discuss and synthesize the results of a series of user experiments we have conducted [9, 2] to evaluate the notion of presence and where we also attempted to replicate some published results.

3.1 Personal Presence

Study 1: Investigating the relationship between personality factors and presence

We performed a study into the relationship between subject's immersive tendencies [19], a personality trait which is theorized to predict subject's reactions to virtual environments, and presence scores (which included both immersion and subjective presence factors). Immersive tendencies were measured by means of the Immersive Tendencies Questionnaire (ITQ) [19], and presence by means of the Presence Questionnaire (PQ) [19].

A student sample $(n = 7)$ performed a task in a simple virtual environment for some thirty minutes, and were then tested on the ITQ and the PQ. The Pearson product moment between the two scales showed a remarkably high correlation $(r = 0.86, p < 0.01)$. Almost 74% of the PQ variance of our sample can be explained in term of ITQ scores alone. This implies that personality and psychological factors play a large role in the sensation of presence.

Study 2: Investigating the ability of the PQ to distinguish between environments

To investigate the PQ's capacity to make distinctions of subject's experiences between two types of environments, we conducted an experiment which placed subjects either in a VE which was designed to produce high presence levels ("high-presence world"), or in a VE designed to produce low presence levels ("low-presence world"). The subjects were undergraduate student paid volunteers ($n = 20$, evenly balanced for gender), and were divided randomly into a low-presence group $(n = 12)$, or a high presence group $(n = 8)$. The VR system used was DIVE [6]. The subjects entered the VE in groups of three (all three occupying the same world, be it "high presence" or "low presence"), each seated in front of their own terminal, isolated from the other subjects. Communication was possible, and the subjects were given a collaborative word-completion task as a pretext for immersing. Each group was allowed to remain in the environment for about 30 minutes. After their VR experience, the subjects were asked to complete the PQ.

The key to this study was creating a clear distinction between the "high presence world" and the "low presence world". We followed Witmer & Singer's recommendations as to what should induce a high level of presence [19], and manipulated those aspects.

The results were surprising. Although we devised environments designed to create different levels of presence, a Student's independent samples t-test between the "high presence" group mean and the "low presence" group mean showed no significant difference in presence $(p > 0.06, one - tailed test)$. This could not be attributed to a bias in group members' immersive tendencies. A two-tailed Student's t-test on the means of the ITQ scores of the "high presence" group and the "low presence" group showed no significant difference at the 0.05 level.

3.2 Measuring Co-Presence

Co-presence refers to having a sense that others are present in the virtual environment, being part of a group, and having a feeling that one is collaborating with real people.

The easiest way to measure the sense of co-presence in a collaborative virtual environment is to make use of subjective measures such as a self-report questionnaire. Slater *et al*. [15] use three questions to measure the sense of co-presence experienced by the participants in a small group experiment they performed.

We used the three defining characteristics of co-presence to develop six questions which we used to measure it.

In a collaborative virtual environment, where the shared virtual environment is perceived as a common environment, the participants feel present depending on the same factors that influence presence in a single-user virtual environments. However, because the environment is shared between a number of participants, there are additional factors which influence the sense of personal presence and co-presence [3]. For example, the sense of personal presence and co-presence might be increased by collaborative work between the participants.

We have performed experiments to investigate some of the factors which could affect co-presence in collaborative virtual environments.

Study 3: Investigating the effects of collaboration on presence and co-presence

We performed an experiment to investigate the effects of group collaboration and interaction on personal presence and co-presence in a CVE. The main aim of this experiment is to test whether personal presence and co-presence are increased by collaborating and interacting with other participants in the CVE. We used two collaborative virtual environments which were identical and differed only in the experimental task . The task is used to create two different levels of group collaboration, a high-collaboration task and

a low-collaboration task.

The experiment involved 30 participants, divided into 10 groups of 3 users each. The first 4 groups were assigned to the low-collaboration VE, and the next 6 groups to the high collaboration VE. None of the participants knew that there were two different VEs. The task consisted of moving different geometrical shapes (pyramids, cubes and rectangles) into specified rooms. In the high-collaboration VE, the task could only be solved by collaborating with the other participants in the group. In the low-collaboration VE, the task could be completed without any collaboration.

We measured personal presence (P) using Slater *et al.*'s questionnaire (SUS, mentioned above), co-presence (CO-P) using our own questionnaire, and immersive tendencies of participants (IT) using Witmer and Singer's Immersive Tendencies Questionnaire (ITQ) [19]. We also measured the collaboration experienced by the participants (COLL) using a collaboration questionnaire we developed. We compared the difference in the P scores between the low- and high- collaboration VEs. We found that there was a significant difference at the 0.05 confidence level, with $F(1,28) = 16.366 (p < 0.05)$. This indicates that participants had a higher P score on the high-collaboration VE.

We also compared the CO-P scores between the low and high-collaboration VEs. We found that there was a significant difference, having $F(1,28) = 63.317, (p < 0.001)$.This difference indicates that participants in the high-collaboration VE had a greater sense of co-presence than participants in the low-collaboration. We also found a significant difference $(t = 12.04, p < 0.0001)$ in the levels of collaboration between the high-collaboration and low-collaboration conditions, indicating that our collaboration manipulations were effective.

A correlation matrix was constructed on the P, CO-P, COLL, and IT variables in each VE, to check if there were significant relationships between them. We obtained the following results (results with $p < 0.05$ are marked in bold):

Low collaboration VE:

	P	CO-P	COLL	IT
P	1			
CO-P	0.49	1		
COLL	-0.37	**-0.68**	1	
IT	**0.65**	**0.67**	-0.35	1

High collaboration VE:

	P	CO-P	COLL	IT
P	1			
CO-P	0.34	1		
COLL	0.18	**0.47**	1	
IT	**0.57**	-0.23	0.005	1

We found that immersive tendencies are positively correlated to SUS presence scores, regardless of the collaboration condition. This is the same finding as in study 1. Immersive tendencies were also positively correlated with co-presence, but only in the low-collaboration VE. Further, we found that in the low collaboration condition, collaboration *decreased* the sense of co-presence. This situation is reversed in the high-collaboration environment. We also found that presence and co-presence were not correlated.

4 Discussion

4.1 Immersive tendencies and presence

According to Witmer and Singer [19], the level of presence felt by a user will depend to a degree on the user's personality or learning history. We tested this hypothesis in studies 1 and 3, and found good evidence to this effect, using two different measures of presence (PQ and SUS). The fact that the relationship exists with two different scales of presence suggests that the relationship is not an artifact of a particular scale. This supports the postulated relationship between immersive tendencies and presence.

This relationship between personality factors and presence is, we feel, theoretically important. It strengthens the distinction between immersion, the system component of presence, and immersive tendency, the psychological component of presence. Although there are bound to be third factors involved in this equation, this simple division has important practical implications. Firstly, presence levels cannot be predicted accurately by looking at system components only. Secondly, presence measures must always include some degree of immersive tendencies measurement. Thirdly, it implies that presence could be enhanced by psychological interventions such as preparing subjects for the experience. Lastly, it implies that changes to immersion levels should be associated with a corresponding average change in presence scores, regardless of the user.

4.2 Co-presence

Our studies related to co-presence discovered some interesting relationships. Slater *et al*. [15] predicted that there should be no relationship between co-presence and presence, but previous evidence [17], showed a modest relationship between these variables. However, Study 3 shows no relationship between these, in either VE. This supports the notion of orthogonality between these components, in accordance with theoretical predictions.

The relationship we found between collaboration and co-presence is far more complex. Firstly, in the high-collaboration environment, collaboration and co-presence are positively correlated. This implies that working together with the other subjects in the CVE increases the sense that they are truly in the space with you, which is also in line with common-sense notions of co-presence. However, in the low-collaboration environment, the relationship was reversed — higher collaboration was associated with lower co-presence scores. This is difficult to explain, but it might indicate that in the high collaboration condition, levels of co-presence were enhanced by the fact that users manipulated the same objects in the same space. This increase in co-presence may in turn have lead to more

collaboration, creating a positive feedback loop. In the low-collaboration condition however, users could easily complete the task alone, and thus did not have the chance to experience the increase in co-presence afforded by the increased contact of collaboration. This phenomenon requires more careful study, but we feel that it is safe to conclude that collaboration, under the right circumstances, can lead to an increase in co-presence in CVEs.

5 Conclusion

This paper has looked at presence as a method of conceptualizing the unique interaction between users and VR systems. In particular, we focused on three key components of presence: immersion and subjective presence under the headings of personal presence and co-presence. We have also examined issues around the measurement of presence.

The subject's psychological makeup is, we believe, key to the experience of presence. The difficulties of measuring a psychological and thus largely invisible property has lead to two broad approaches to subjective presence measurement — those which rely on subjects' non-verbal behaviour in response to particular situations put to them in the VE, and those which rely on verbal self-reports by the subjects.

We have in essence identified a number of methodological difficulties of presence research.

5.1 Immersion is Relatively Well Understood

The measurement of immersion is simple, since a detailed description of the VR system provides a good measure of immersion [7]. Of course, immersion measurement is not quite so straightforward; it is still not known which system properties contribute to presence, and which do not affect it [14]. It is known that high presence levels are produced by many variables. We have every reason to believe that it should be possible to create a reliable, objective measure of immersion in the near future. Immersion remains a possible way of objectively approximating levels of presence, although, as shown by Study 2 above, changing system variables does not always guarantee a corresponding change in levels of personal presence.

5.2 Subjective Presence Raises Real Difficulties

Subjective presence, on the other hand, is far more difficult to measure. The reasons for this are many, and include a lack of widespread agreement on the definition of presence (cf. [10], [14] and [13]) and the inherent difficulty in measuring psychological variables [1]. These difficulties have lead to two broad approaches: those which rely on subjects' non-verbal behaviour in response to particular situations put to them in the VE, and those which rely on verbal self-reports by the subjects.

Observing subjects' reactions to particular situations, which is known as behavioural presence, assumes that particular reactions would only occur if the user truly felt herself existing in the same place as the virtual objects. Typical examples of this technique include putting users into a virtual room which has a large, deep hole in the floor. If the user feels present in that VE, they will skirt around the edge of the hole, as they would do if faced with a real hole [18, 4].

If the premisses of behavioural presence are correct, then it presents a useful and unambiguous approach. However, its reliance on illusions being built into environment weakens its utility. Even if a subject experiences a powerful sense of fear of falling into the virtual pit, the question remains whether the subject would have felt that same level of presence in that VE had the pit not existed (which would be the case in most types of VEs). Thus, the use of behavioural presence is limited by the types of environments it can be applied to.

The second approach to measuring subjective presence is by means of subjects' reports of their presence experiences. This is currently the most popular approach to measuring presence, although it is often used in conjunction with measures of immersion or behavioural presence (for examples see Usoh *et al*., [18], Freeman *et al*., [4] and Freeman *et al*., [5]). Its popularity exists in a large part due to the ease with which these measures lend themselves to statistical analysis. For examples of this type of measure, the reader is directed at the scales of Slater, Usoh and Steed [15], and Witmer and Singer [19].

Although these scales are quite popular, little evidence exists to suggest that they truly measure what we currently understand to be presence. Currently, we expect presence to be maximized if the VR system recreates an experience for the user that is as close to the real experience of being in an environment would be. It is on this assumption that Witmer and Singer built their Presence Questionnaire (PQ).

The findings of Study 2 suggest that the PQ is not able to distinguish between the experiences of subjects who were exposed to extremely different forms of VE. This lack of difference in PQ scores might suggest that subjects in both groups truly did feel the same levels of presence. A more parsimonious explanation for the lack of difference in PQ scores would be that the PQ is not sensitive enough to measure the differences which were present in subject's experiences. This is a serious failing for any scale, as it does not allow the comparison of presence scores between subjects exposed to different VEs. Although this study applies only to the Presence Questionnaire, it is a legitimate question to ask of any presence measure, self-report or otherwise: does this measure reflect our concepts of presence?

5.3 The Way Forward

We believe that further work should proceed on two fronts.

Firstly, we need much more experimental data of the type described in this paper. There are not nearly enough

evidence of the replicability of claims made for presence measures. Replicability and convergence of findings from independent sources remains important to establishing the validity of presence measurement methods and instruments.

Secondly, we believe that we can begin to formulate a theoretical underpinning for the notion of presence, and other measures of the the effectiveness of Collaborative Virtual Environments. The development of meaningful measures has to be supported by some theoretical understanding. Currently, presence is understood in terms of its component variables and how these relate to other variables. This is not enough to create a true understanding of user behaviour in CVEs or, more importantly, to form predictions about that behaviour. An understanding of the cognitive processes underpinning the experience of presence would be required for this purpose. We believe that there exists enough research on presence variables and scales to begin this process (for examples, cf [11, 16, 8]).

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