HARDWARE, SOFTWARE AND PEOPLEWARE

UNISA

SAICSIT 2001

Edited by
Karen Renaud
Paula Kotzé
Andries Barnard

HARDWARE, SOFTWARE AND PEOPLEWARE

South African Institute of Computer Scientists and Information Technologists Annual Conference

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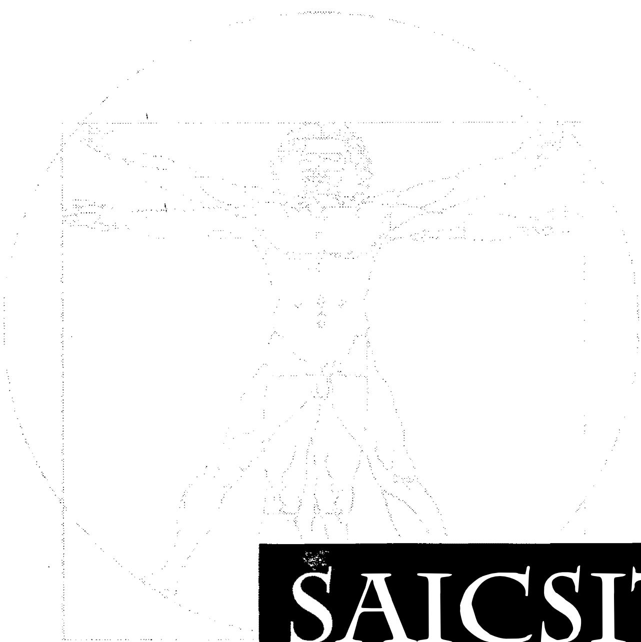

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Edited by Karen Renaud, Paula Kotzé & Andries Barnard
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Message from the SAICSIT President

The South African Institute of Computer Scientists and Information Technologists (SAICSIT) was formed in 1982 and focuses on research and development in all fields of computing and information technology in South Africa. Now in the 20th year of its existence, SAICSIT has come of age, and through its flagship series of annual conferences provides a showcase of not only the best research from the Southern-African region, but also of international research, attracting contributions from far afield. SAICSIT does, however, not exist or operate in isolation.

More than 50 years have passed since the first electronic computer appeared in our society. In the intervening years technological development has been exponential. Over the last 20 years there has been a vast growth and pervasiveness of computing and information technology throughout the world. This has led into the expansion and consolidation of research into a diversity of new technologies and applications in diverse cultural environments. During this period huge strides have also been made in the development of computing devices. The processing speed of computers has increased thousand-fold and memory capacity from megabytes to gigabytes in the last decade alone. The Southern African region did not miss out on these developments.

It is hardly possible for such quantitative expansion not to bring a change in quality. Initially computers had been developed mainly for purposes such as automation for the improvement of processing, labour-reduction in production and automation control of machinery, with artificial intelligence, which made great strides in the 1980s, seen as the ultimate field to which computers could be applied. As we moved into the 1990s it was recognized that such an automation route was not the only direction in the improvement of computers. The expansion of processing power has enabled image data to be incorporated into computer systems, mainly for the purpose of improving human utilisation. For most computer technologies of the 1990s, including the Internet and virtual reality, automation was not the ultimate purpose. Humans were increasingly actively involved in the information-processing loop. This involvement has gradually increased as we move into the 21st century. Development of computer technology based not on automation, but on interaction, is now fully established.

The method of interaction has significantly changed as well. The expansion of computer ability means that the same function can be performed far more cheaply and on smaller computers than ever before. The advent of portable and mobile computers and pervasive computing devices is ample evidence of this. The need for users to be at the same location as a computer in order to reap the benefits of software installed on that computer is becoming an obsolete notion. Time and space are no longer constraints. One of the most discussed impacts of computing and information technology is *communication* and the easy accessibility of information. This changes the emphasis for research and development – issues such as cultural, political, and economic differences must, for example, be accommodated in ways that researchers have not previously considered. Our goal should be to enable users to benefit from technological advances, hence matching the skills, needs, and expectations of users of available technologies to their immense possibilities.

The conference theme for the SAICSIT 2001 Conference – *Hardware, Software and Peopleware: The Reality in the Real Millennium* – aims to reflect technological developments in all aspects related to computerised systems or computing devices, and especially reflect the fact that each influences the others.

Not only has SAICSIT come of age in the 21st century, but so has the research and development community in Southern Africa. The outstanding quality of papers submitted to SAICSIT 2001, of which only a small selection is published in this collection, illustrates both the exciting and developing nature of the field in our region. I hope that you will enjoy SAICSIT 2001 and that it will provide opportunities to cultivate and grow the seeds of discussion on innovative and new developments in computing and information technology.

Paula Kotzé
SAICSIT President

Message from the Chairs

Running this conference has been rewarding, exciting and exhausting. The response to the call for papers we sent out in March was overwhelming. We received 64 paper submissions for our main conference and twelve for the postgraduate symposium. We had a panel of internationally recognized reviewers, both local and international. The response from the reviewers was impressive – accepting a variety of papers and *mostly* returning the reviews long before the due date. We were struck, once again, by the sheer magnanimity of academia – as busy as we all are, we still manage to contribute fully to a conference such as SAICSIT.

After an exhaustive review process, where each paper was reviewed by at least three reviewers, the program committee accepted 26 full research papers and 14 electronic papers. Five papers were referred to the postgraduate symposium, since they represented work in progress – not yet ready for presentation to a full conference but which nevertheless represented sound and relevant research. The papers published in this volume therefore represent research of an internationally high standard and we are proud to publish it. Full electronic papers will be available on the conference web site (http://www.cs.unisa.ac.za/saicsit2001/).

Computer Science and Information Systems academics in South Africa labour under difficult circumstances. *The popularity of IT courses stems from the fact that IT qualifications are in high demand in industry, which leads in turn to a shortage of IT academic staff to teach the courses, even when posts are available. The net result is that fewer people teach more courses to more students. IT departments thus rake in ever-increasing amounts of state subsidy for their universities. These profits, euphemistically labelled "contribution to overhead costs", are deployed in various ways: cross-subsidization of non-profitable departments; maintenance of general facilities; salaries for administrative personnel, etc. Sweeteners of generous physical resources for the IT departments may be provided. We have yet to hear of a University in South Africa where significant concessions have been made in terms of industry-related remuneration. At best, small subventions are provided. As a result, shortages of quality staff remain acute in most IT departments – especially at senior teaching levels. What is even worse is that academics in these departments have to motivate the value of their conference contributions and other IT outputs to selection committees, often dominated by sceptical academic power-brokers from the more traditional departments whose continued survival is underwritten by IT's contribution to overhead costs.*[1]

The papers published in this volume are conclusive evidence of the indefatigability and pertinacity of Computer Science and Information Systems academics and technologists in South Africa. We are proud to be part of such a prestigious and innovative group of people.

In conclusion, we would like to thank the conference chair, Prof Paula Kotzé, for her support. We also specially thank Prof Derrick Kourie for his substantial contribution. Finally, to all of you, contributors, presenters, reviewers and organisers – a big thank you – without you this conference could not be successful.

Enjoy the Conference!
Karen Renaud & Andries Barnard

[1] This taken almost verbatim from Professor Derrick Kourie's SACLA 2001 paper titled: "*The Benefits of Bad Teaching*".

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Keynote Abstracts

The Effects of Avatars on Co-presence in a Collaborative Virtual Environment

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Abstract

Presence in Collaborative Virtual Environments (CVEs) can be divided into personal presence *and* co-presence. *Personal presence is having a feeling of "being there" in the CVE oneself. Co-presence is having a feeling that one is in the same place as the other participants, and that one is collaborating with real people. We investigated the effects that avatar realism and functionality (in terms of simple gestures and facial expressions) have on co-presence in a collaborative virtual environment, by means of two small group behaviour experiments with 18 participants each. We measured co-presence subjectively, using a co-presence questionnaire that we developed. We found that there was a significant difference between the co-presence scores generated by avatars of different degrees of realism in their appearance. More realistic avatars generated higher levels of co-presence. We also found that avatars having gestures and facial expressions produced a significantly higher level of co-presence when compared to static avatars. We were not able to find the correlation between presence and co-presence reported in some studies.*

Keywords: *Presence, Collaborative Virtual Environments, Virtual Reality*
Computing Review Categories: *I.3.7, J.4*

1 Introduction

Collaborative Virtual Environments (CVEs) involve the use of a distributed architecture and advanced interactive user interfaces to create a 'shared' space where multiple users, located in different geographical locations can interact and collaborate. CVEs are seen by many as the future in telecommunications [2, 19], where a multitude of people will be able to meet and interact with each other in the same 3D space as if they were in the same real space, with a full range of sociological interaction provided. In order for CVEs to be usable and successful, they need to provide the participants with a compelling experience and a high sense of *presence*. This will convince the participants that they are present in the virtual environment, and that they are collaborating with real people.

Presence (or personal presence) refers to the psychological sensation of "being there", having a sense of being in the place specified by the virtual environment rather than just seeing images depicting that place. According to Steuer [16] presence means "The feeling of 'being in an environment'."

Co-presence is the feeling that the other participants in the virtual environment actually exist and are really present in the environment, and the feeling that one in interacting with real people.

Presence in CVEs has been linked to knowledge transfer, where skills or knowledge gained in a virtual environment can be successfully transferred to the real world [9], as well as possible enhancement of learning and performance [20]. Slater *el al* [13] mention that while experiencing a high sense of presence, the behaviour of participants in the VE should be consistent with the behaviour that would have occurred in everyday reality under similar conditions. This is an important factor which can be used to measure presence in VEs.

We believe that the way one represents other participants in a collaborative virtual environment is a major issue in enhancing the sense of co-presence. Some participants might find it easy to maintain the sense of co-presence of others with just crude representations of avatars while others might require highly realistic human-like avatars with gestures and facial expressions.

In this paper, we present two experiments which investigate the effects that avatar have on co-presence in a Collaborative Virtual Environment. The first experiment, described in Section 3, investigates the effects of avatar appearance on co-presence. Here we investigate the effects that unrealistic avatars have on co-presence as opposed to human-like avatars. The second experiment, described in Section 4, investigates the effects of avatar functionality on co-presence. By avatar functionality we mean simple gestures (waving, raising arms, joy and sad gestures, hear movements, walking) and facial expressions (sad, happy, neutral, surprised, disgusted and angry).

The two experiments made use of the same collaborative virtual environment. The participants performed the same collaborative task in both experiments where they were asked to rank the characters in a story. Task performance of itself was not relevant to the experimental outcome. The only difference between the two experiments was on the avatars used to represent the participants in the CVE.

We measured personal presence, co-presence, and immersive tendencies subjectively with post experiment questionnaires. We use a Presence Questionnaire (PQ) developed by Slater *et al* [13, 10] to measure the sense of personal presence felt by the participants during the experiment. We have developed a co-presence questionnaire which measures the degree of co-presence felt by the participants during the experiment. We use the Immersive Tendencies Questionnaire (ITQ) developed by Witmer and Singer [20] to asses the levels of immersive tendencies of the participants.

Our main result was that greater realism in avatars generates a greater feeling of co-presence in the participants. In the first experiment a more realistic human form engendered greater realism. In the second experiment we showed that the co-presence generated by avatars having gestures and facial expressions was significantly higher than that generated by static avatars.

Witmer and Singer [20] have developed an Immersive Tendencies Questionnaire (ITQ) designed to measure an individual's immersive tendencies. They have found that the ITQ predicts, within a given VE, the level of presence felt by participants (as measured by their presence questionnaire). We were able to replicate Witmer and Singer's results using a presence score derived from Slater *et al*'s presence questionnaire, that is, in both experiments there was a positive correlation with the immersive tendencies score using a different presence questionnaire from the original study. However, in neither experiment was the co-presence score correlated with the immersive tendencies score.

We showed in these two experiments that, contrary to what Tromp *et al* [18] found in one of their experiments, the sense of personal presence and co-presence were not positively correlated in any of the two experiments. This is in contradiction to well publicised hypotheses and in accordance with a second experiment by Tromp *et al.*

Section 2 provides some information on how to measure the sense of presence in a virtual environment. Section 3 describes the first experiment, which tests the hypothesis that avatar appearance affects co-presence. Section 4 presents the second experiment, used to investigate the effects of avatar gestures and facial expressions on co-presence in the CVE. Section 5 shows the results obtained in the two experiments, and presents a discussion of those results. Finally Section 6 presents directions for future work and conclusions.

2 Measuring Presence

One of the major issues when dealing with presence in a virtual environment is how to measure it. Held and Durlach [5], and Sheridan [8] note that we don't have a working measure of presence. Suggested approaches include:

1. User reported sense of presence: This involves asking the users about their sense of presence. The problem with this approach is that inquiring the state of the user may change that state.

2. Observation of user behaviours: This involves observing the actual behaviour of the participants as they react to different stimuli in the virtual environment.

3. Task performance in the real and virtual environment: This assumes that if a user performs a task in the virtual environment as efficiently and in the same manner as in the real world then they must be present in the VE.

Since presence is a subjective experience, the simplest way to measure it is to make use of questionnaires. In fact the vast majority of presence experiments measure presence using questionnaires and are therefore measuring *subjective presence* [13, 9, 10, 20].

Slater *et al* [13, 9, 10] have developed a questionnaire-based measure of subjective personal presence based on three main attributes:

1. The sense of "being there" in the virtual environment as compared to being in a place in the real world.

2. The extent to which there were times when the virtual environment became the reality. i.e., the extent that the subject forgot that he/she was standing on the lab.

3. The extent to which the participant's memory of the virtual environment is similar to their normal memory of a place.

When it comes to measuring subjective co-presence (i.e., the feeling of presence of others in the VE), one can use a similar set of attributes as for personal presence above. The simplest types of questions that can be used to measure subjective co-presence are of the form:

- To what extent did you have a sense that you were in the same place as [person y] ?

- To what extend did you have a sense that [person y] was in the same place as you during the course of the experiment.

- To what extent did you have a sense of the emergence of a group/community during the course of the experiment ?

- To what extent did you have a sense of being "part of the group" ?

Another way to asses presence in a virtual environment is to measure *behavioural presence.* Behavioural presence cannot be evaluated using simple questionnaires, and requires a more complex method based on observing the behaviour of participants in the real world, reacting to different stimuli in the virtual environment. Held and Durlach [5] suggest a measure of presence based on the ability of the environment to produce a "startle response" to unexpected stimuli. For example, whether users duck, blink or carry out other involuntary movements in response to threatening events. Slater and Usoh [11] measure behavioural presence by observing the reactions of the subjects to danger, such as a virtual cliff, or objects thrown towards the participants head. The problem with behavioural measures is that they may be too complex to clearly identify and measure with clarity. Also, startle-based measurements may only be measuring isolated samples rather than measuring the overall presence created by the environment.

Sheridan [8] and Hendrix and Barfield [6] suggest objective measures of presence based on task performance in the virtual environment. The problem with this method is that task performance may not necessarily correlate positively with presence, and that factors other than presence might influence task performance. One must find a specific task and show that presence correlates significantly and positively with the performance of that task.

3 The Effects of Avatar Appearance on Co-presence

This experiment is used to investigate the effects of avatar appearance on co-presence in a Collaborative Virtual Environment. The specific aim of this experiment is to determine if avatar appearance affects co-presence.

3.1 Hypotheses

The notion of having some sort of virtual representations (or *avatars* [1]) of participants in a collaborative virtual environment is very important to create a sense of presence, especially co-presence [11, 1, 12, 3, 18, 14].

In this experiment, we investigate the following hypotheses:

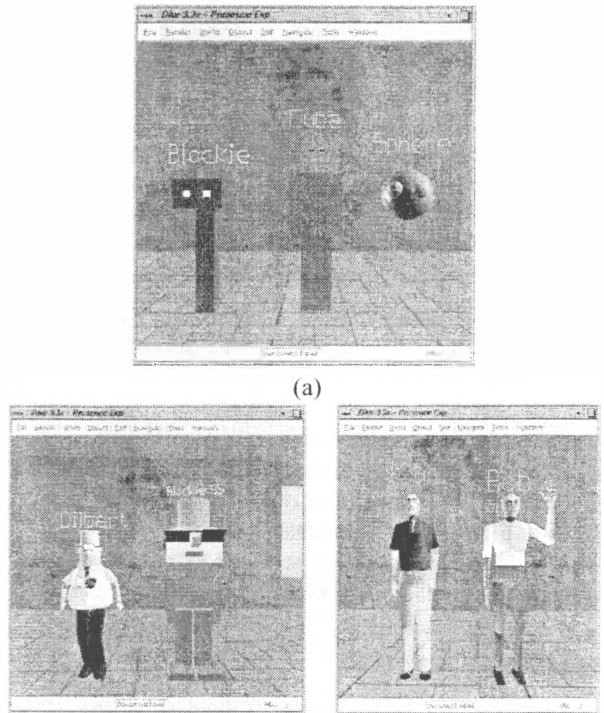
- The notion of a virtual body is crucial to create a sense of co-presence. A participant requires information such as location (position and orientation of others), identity (*who* the avatar represents), availability (conveying some sense of how busy and/or interruptible a participant is), and action (what action is a participant doing) to establish and maintain the presence of other participants in the VE.

- The way one represents other participants in the virtual environment is very important to enhancing the sense of co-presence. The important issue here is to determine how the appearance of the avatar affects co-presence.

[1] The word avatar originates from Hindu mythology and means the incarnation of a spirit in an earthly form

- Personal presence and co-presence could be positively correlated. Slater *el al* [12] postulate that personal presence is a prerequisite for co-presence. It would be useful to know whether these two types of presence are associated.

In order to address these issues, we provide the participants with avatars having different appearances: realistic human-like avatars, cartoon-like avatars, and simple unrealistic avatars (refer to Figure 1 for a screenshot of the avatars).



(a) (b) (c)

Figure 1: **The avatars used in Experiment 1.** The unrealistic avatars are shown in (a). The cartoon-like avatars are shown in (b), and the realistic human-like avatars are shown in (c).

3.2 CVE Prototype and Avatars

The CVE is implemented using the DIVE (Distributed Interactive Virtual Environment) system [4]. DIVE is a toolkit for the development of multi-user distributed virtual environment, developed at the Swedish Institute of Computer science (SICS) [17].

The virtual environment consists of a conference room where multiple users can meet around a table and have a discussion. Each participant has a book on the table which can be used to view a document. There is a white board which is used to help the participants with the experiment task (refer to Section 3.3 for a description of the task). The virtual environment is fully textured to enhance the visual realism (refer to Figure 2 for a screenshot of the virtual environment).

Participants are able to move around the room using the arrow keys. Cooperation is basically supported by directly embodying the users in the virtual environment using different avatars, and providing them with inter-user communication facilities such as an audio channel.

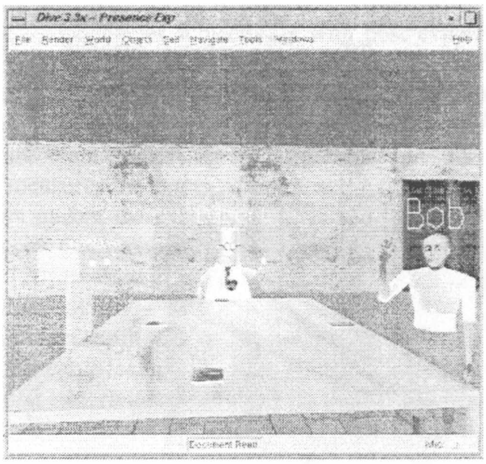


Figure 2: **The virtual environment used in Experiment 1 and Experiment 2.** The world consisted of a conference room where participants could meet around a table and have a discussion.

We provide the participants with a range of avatars of varying appearance. These avatars include unrealistic avatars, cartoon-like avatars, and realistic human-like avatars (Refer to Figure 1 for a screenshot of the avatars). The participants had a 1st person perspective view of the world, and could not see their own avatar.

3.3 Experiment Scenario

The experiment involved 18 participants, divided into 6 groups of 3 users each. The participants were recruited from the second year psychology course. Participants were recruited by means of announcements in lectures, as well as posters placed on the noticeboards in the psychology department.

Four participants were asked to sign up for a given session. Three of these volunteers were chosen to participate in the experiment, while the fourth was chosen as a surplus volunteer in case one of the other participants was unable to arrive to the laboratory.

Participants in a group met for the first time in the virtual environment and could only communicate with one another through the virtual environment. This was accomplished by situating the workstations in different rooms within the same laboratory. Each participant used headphones which blocked out the noises from the real world.

As each participant arrived to the laboratory, they were taken to their respective rooms by the experimenter. Before starting the actual experiment, each participant was introduced to the system. This involved learning how to control the avatars, move through the environment, pick up objects, etc. The participants could not see their own avatar since we used a first person perspective for the avatars. Once every participant was familiar with the interface, they read the experiment instructions stating the task that they will have to perform in the virtual environment. In order to make sure that the participants had understood the task completely, the experimenter explained the task verbally, answering any questions that the participants had about the task.

The task consists of reading a story (4 short paragraphs) by accessing the book on the table in the VE. Once each participant has read the story, they have to agree on a ranking for the five characters in the story. The ranking is as follows: the best character is assigned a "1" and the worst a "5". There was a white-board on the VE which had a simple grid with the names of the five characters of the story. At the bottom of the white board there were five numbers which could be moved around the board, so that the participants could assign the ranking to each character in the story. The participants had to argue with one another and arrive to a group agreement. This task required communication to argue or agree with the other participant's rankings.

The avatars used by the participants were labeled Red, Green or Blue, and participants called each other by these names during the experiment. Since the participants could not see their own avatars, there was a colour strip on the monitor used to indicate the colour associated with the participant.

The task had a time limit of 20 minutes, and after that each participant was required to fill in three questionnaires: Witmer and Singer's Immersive Tendencies Questionnaire (ITQ), Slater's Presence Questionnaire, and our Co-presence Questionnaire. These questionnaires are described in more details in Section 3.4.

3.4 Measuring Presence and Co-Presence

We measured subjective reported levels of personal presence and co-presence using questionnaires. The personal presence questionnaire is based on the questionnaires developed by Slater *et al* [13, 10]. The questionnaire elaborates on the three attributes proposed by Slater *et al* (described in Section 2) to measure personal presence. To measure co-presence, we have developed a co-presence questionnaire which uses questions similar to the ones shown in Section 2. The presence questionnaire has been used and validated by Slater *et al* in many experiments [13, 9, 10]. Our co-presence questionnaire still needs to be validated by performing other experiments. Nevertheless, based on the obtained results, we believe that it produces a valid measure of co-presence in the CVE.

The Immersive Tendencies Questionnaire (ITQ) developed by Witmer and Singer [20] is used to measure differences in the tendencies of individuals to become immersed. The items in this questionnaire mainly measure involvement in common activities. Since increased involvement can result in more immersion, we expect individuals who tend to become more involved will also have greater immersive tendencies. We use this questionnaire to try and replicate Witmer and Singer's results with regard to the correlation between the ITQ and presence scores.

3.5 Equipment

In this experiment, we used 'desktop' virtual environments, meaning that no immersive equipment was used. Movements through the virtual environment was accomplished using the arrow keys. Objects in the virtual environment could be picked up and dropped by clicking on them with the mouse. Participants used headphones and microphones for audio communication.

The red participant used an SGI Onyx RealityEngine2 with four 200-MHZ R4400, 128 Mbytes of RAM, and 21 inch screen. The blue participant, an SGI O2 with a 175-MHZ R10000 processor, 128 Mbytes of RAM, and 21 inch screen. The green participant used an SGI O2 with a 195-MHZ R10000 processor, 256 Mbytes of RAM, and 17 inch screen.

4 The Effects of Avatar Functionality on Co-presence

This experiment is used to investigate the effects of avatar gestures and facial expressions on co-presence in a Collaborative Virtual Environment. The specific aim of this experiment is to determine if avatars with gestures and facial expressions engender a higher sense of co-presence than static avatars. This experiment is very similar to the first experiment described in Section 3. The virtual environment and experiment task is the same, and the only difference is the avatars available to represent the participants.

4.1 Hypotheses

In this experiment, we want to investigate the following hypotheses:

- Simply having static avatars is not sufficient to create a high sense of co-presence in the collaborative virtual environment. We believe that providing simple gestures and facial expressions to the avatars will increase the sense of co-presence in the CVE. Here we will address questions such as: Are fully functional avatars, with gestures and facial expressions necessary or are crude representations of avatars sufficient to maintain the sense of presence of others? We also want to test the hypothesis that having realistic human-like avatars without any body movement could create a worst sense of co-presence than having unrealistic avatars without any body movement. This could be because there is a conflict between the greater visual realism of the human-like avatar and the lack of bodily movement. On the other hand, having an unrealistic avatar could make it easier to understand that it is not functional.
- Personal presence and co-presence could be positively correlated. Slater *el al* [12] postulate that personal presence is a prerequisite for co-presence. It would be useful to know whether these two types of presence are associated.

4.2 CVE Prototype and Avatars

The virtual environment used in this experiment is exactly the same as the one used in the experiment described in Section 3.

In this experiment, in order to investigate the effects of avatar functionality, we provided the set of avatars described in Table 1. These avatars are the same avatars used in Experiment 1 (refer to Figure 1, with the only difference that the "dilbert" avatar has gestures, and the "Bob" avatar has gestures and facial expressions. Each group consisted of 3 participants, using the avatars described in Table 2.

The facial expressions are based on the linear muscle model developed by Parke and Walters [7], and provides six expressions (happiness, surprise, sadness, anger, disgust, and furious. Figure 3 shows some of the facial expressions available to the "Bob" avatar. In order to control the gestures and facial expression, there is a graphical user interface (GUI) which allows the user to select the gesture/expressions (see Figure 4).

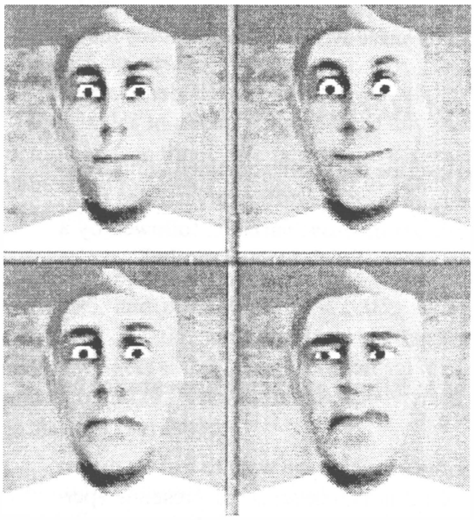


Figure 3: **Facial expressions used in Experiment 2.** Some of the facial expressions available for the realistic human-like avatar. From left to right, top to bottom: neutral, happy, sad, and furious.

Groups 1 to 6 in Table 2 are used to investigate static avatars vs. avatars with gestures and facial expressions. Groups 7 to 10 in Table 2 are used to investigate the claims that having realistic human-like avatars without any body movement could create a worst sense of co-presence than having unrealistic avatars without any body movements.

Avatar name	Avatar description
blockie, cube	Unrealistic with no functionality
dilbertNoGesture	Cartoon with no functionality
dilbert	Cartoon with functionality
bobNoGesture, man	Realistic with no functionality
bob	Realistic with functionality

Table 1: **Avatars available for Experiment 2.** This experiment investigates the effects of avatar functionality on co-presence. By functionality we mean that the avatars have a range of gestures (waving, raising arms, joy and sad gestures, head movements such as yes, no and perhaps, walking) and facial expressions (sad, happy, neutral, surprised, disgusted, angry and furious)

Grp	Participant 1	Participant 2	Participant 3
1	man	bobNoGesture	bob
2	dilbertNoGesture	dilbertNoGesture	dilbert
3	man	bobNoGesture	bob
4	dilbertNoGesture	dilbertNoGesture	dilbert
5	man	bobNoGesture	bob
6	dilbertNoGesture	dilbertNoGesture	dilbert
7	blockie	cube	bobNoGesture
8	blockie	cube	bob
9	blockie	cube	bobNoGesture
10	blockie	cube	bob

Table 2: **Avatars used in each group for Experiment 2.** Groups 1 to 6 are used to investigate static avatars vs. avatars with gestures and facial expressions. Groups 7 to 10 in are used to investigate the claims that having realistic human-like avatars without any body movement could create a worst sense of co-presence than having unrealistic avatars without any body movements.

5 Analysis of Results

In this section, we describe the results obtained in both experiments. We firstly present the different variables measured and the hypotheses on those variable, followed by a summary and a discussion of the obtained results.

5.1 Variables and Hypotheses

5.1.1 Experiment 1: Effects of Avatar Appearance on Co-presence

There are two hypotheses which we wish to test by means of Experiment 1. One is that a sense of presence (personal presence and co-presence) in the CVE is created by embodying the participants in the virtual environment by means of virtual representations. The second hypothesis is that realistic human-like avatars should create a higher sense of co-presence than cartoon-like avatars, which in turn should create a higher sense of co-presence that simple unrealistic avatars.

In order to test the above hypotheses, we measure the following variables:

- *The presence score, P*: This variable is measured by making use of Slater's presence questionnaire. It measures the degree of personal presence experienced by the participant.

Figure 4: **Gestures and facial expressions GUI.** The Graphical User Interface used to control the gestures and facial expressions of some of the avatars used in Experiment 2.

- *The immersive tendencies score, IT*: This variable is measured using Witmer and Singer's immersive tendencies questionnaire. It measures the tendencies of individuals to become involved and immersed in the experience.

- *Co-presence of realistic human-like avatars, CO-P-RHA*: This variable measures the participant's sense of presence of other participants using realistic human-like avatars. This variable is measured using our co-presence questionnaire.

- *Co-presence of cartoon-like avatars, CO-P-CA*: This variable measures the participant's sense of presence of others using cartoon-like avatars.

- *Co-presence of simple unrealistic avatars, CO-P-UA*: This variable measures the participant's sense of presence of other participants using unrealistic avatars.

- *The co-presence score, CO-P*: This variable measures the overall co-presence experienced by the user. This variable is the sum of the individual co-presence variables (CO-P-RHA, CO-P-CA, and CO-P-UA).

The hypotheses for the above variables are: We expect CO-P-RHA to be higher than CO-P-CA, which in turn should be higher than CO-P-UA. Witmer and Singer [20] indicate that the IT score, as measured by their immersive tendencies questionnaire, predicts the presence score, as measured by their presence questionnaire. In this experiment we use a different presence questionnaire (developed by Slater *et al*), so it is important the check if the relationship still holds. It is also important to see if there is a correlation between the P score and the CO-P score. Tromp *et al* [18] indicate that they found a positive correlation between personal presence and co-presence in one of their experiments. This small group experiment is described also in Slater *et al* [15].

5.1.2 Experiment2: Effects of Avatar Functionality on Co-presence

There are two hypotheses which we wish to test by means of the second experiment. The first hypothesis is that avatars with gestures and facial expressions will enhance the sense of co-presence in a CVE. The second hypothesis indicates that having realistic human-like avatars without any body movement could create a worst sense of co-presence than having simple unrealistic avatars without any body movements. This is because there is a conflict between the greater visual realism of the human-like avatar and the lack of body movements. On the other hand, having a simple unrealistic avatar makes it easier to understand that it is not functional.

In order to test the first hypothesis, we measure the following variables:

- *The presence score, P*: This variable measures the degree of personal presence experienced by the participants. It is measured by making use of Slater's presence questionnaire.
- *The immersive tendencies score, IT*: This variable is measured using Witmer and Singer's immersive tendencies questionnaire. It measures the tendencies of individuals to become involved and immersed in the experience.
- *Co-presence of functional avatars, CO-P-F*: This variable measures the participant's sense of co-presence of the other avatars with gestures and facial expressions.
- *Co-presence of static avatars, CO-P-S*: This variable measures the participant's sense of co-presence of the other static avatars (i.e., avatars without gestures and facial expressions).
- *Co-presence score CO-P*: The CO-P variable measures the overall co-presence experienced by the user. This variable is a sum of the individual co-presence variables (CO-P-F and CO-P-S above).

The hypotheses for the above variables are as follows: We expect CO-P-F to be significantly higher than CO-P-S. Also, we might find a correlation between P and CO-P.

In order to test the second hypothesis, which says that having realistic human-like avatars without any body movement could create a worst sense of co-presence than having simple unrealistic avatars without any body movements, we measure the following variables:

- *Co-presence of unrealistic static avatars CO-P-U*: This variable measures the participant's sense of co-presence of the other participants using unrealistic avatars without any gestures or facial expressions.
- *Co-presence of realistic, static human-like avatars CO-P-RS*: This variable measures the participant's sense of co-presence of the other participants using realistic human-like avatars without any gestures or facial expressions.

	Presence (P)	**Co-presence (CO-P)**	**Immersive tend. (IT)**
P	1		
CO-P	0.2075	1	
IT	**0.5032**	-0.257	1

Table 3: **Correlation matrix for Experiment 1.** Results with $p < 0.05$ are marked in bold. We can see that P and IT are significantly correlated.

- *Co-presence of realistic human-like avatars with gestures CO-P-RF*: This variable measures the participant's sense of co-presence of the other participants using realistic human-like avatars with gestures or facial expressions.

5.2 Summary of Results

5.2.1 Experiment 1: Effects of Avatar Appearance on Co-Presence

For each participant, we measured the presence score (P), the immersive tendencies score (IT), the co-presence score of realistic human-like avatars (CO-P-RHA), of cartoon-like avatars (CO-P-CA), of unrealistic avatars (CO-P-UA), and the total co-presence felt by the participants (CO-P).

We compared the co-presence scores generated by the different avatars by performing a one-way ANOVA on the CO-P-RHA, CO-P-CA, and CO-P-UA scores. We found that there was a significant difference, having $F(2,33) = 20.438, p < 0.001$. This difference indicates that the way one represents the avatars affects the feeling of co-presence felt by the participants.

A correlation analysis was performed on the P, CO-P, and IT variables to check if there were any significant relationship between them. We performed two-sided tests and obtained the following results (refer to Table 3 for the correlation matrix):

- *Correlation between P and IT scores*: $r = 0.50325$, $t = 2.3295$, and $p = 0.033255 < 0.05$. At a significance level of 0.05, with $N = 18$ and 16 degrees of freedom we get $t = 2.12$, and a critical value of r (r_{crit}) equal to 0.46829. This indicates that P and IT were significantly correlated.
- *Correlation between CO-P and IT scores*: $r = -0.25707$, $t = -1.0640$, and $p = 0.303101 > 0.05$. At a significance level of 0.05, with $N = 18$ and 16 degrees of freedom we get $t = 2.12$, and a critical value of r (r_{crit}) equal to 0.46829. This indicates that CO-P and IT were not significantly correlated.
- *Correlation between P and CO-P scores*: $r = 0.20746$, $t = 0.8483$, and $p = 0.4087 > 0.05$. At a significance level of 0.05, with $N = 18$ and 16 degrees of freedom we get $t = 2.12$, and a critical value of r (r_{crit}) equal to 0.46829. This indicates that P and CO-P were not significantly correlated.

	Presence (P)	Co-presence (CO-P)	Immersive tend. (IT)
P	1		
CO-P	0.0493	1	
IT	**0.5872**	-0.0387	1

Table 4: **Correlation matrix for Experiment 2.** Results with $p < 0.05$ are marked in bold. We can see that P and IT are significantly correlated.

5.2.2 Experiment 2: Effects of Avatar Functionality on Co-presence

For the first 18 participants (groups 1 to 6), we measured the presence score (P), the immersive tendencies score (IT), the co-presence score of functional avatars (CO-P-F), the co-presence score of static avatars (CO-P-S), and the total co-presence score (CO-P).

We compared the co-presence scores generated by static avatars (CO-P-S) and by avatars with gestures and facial expressions (CO-P-F), by performing a one-way ANOVA on the two variables. We found that there was a significant difference, having $F(1,22) = 6.00678, p < 0.05$. This indicates that the avatars with gestures and facial expressions did create a significantly greater sense of co-presence.

We performed a correlation analysis on the P, IT, and CO-P scores to check if there was any significant relationship between these variables. We performed two-sided tests and obtained the following results (refer to Table 4 for the correlation matrix):

- *Correlation between P and IT scores*: $r = 0.587179$, $t = 2.901595$, and $p = 0.010406 < 0.05$. At a significance level of 0.05, with $N = 18$ and 16 degrees of freedom we get $t = 2.12$, and a critical value of r (r_{crit}) equal to 0.46829. This indicates that P and IT were significantly correlated.

- *Correlation between CO-P and IT scores*: $r = -0.03871$, $t = -0.1225$, and $p = 0.904928 > 0.05$. At a significance level of 0.05, with $N = 12$ and 10 degrees of freedom we get $t = 2.228$, and a critical value of r (r_{crit}) equal to 0.575959. This indicates that CO-P and IT were not significantly correlated.

- *Correlation between P and CO-P scores*: $r = 0.049294$, $t = 0.15607$, and $p = 0.8790 > 0.05$. At a significance level of 0.05, with $N = 12$ and 10 degrees of freedom we get $t = 2.228$, and a critical value of r (r_{crit}) equal to 0.575959. This indicates that P and CO-P were not significantly correlated.

In order to test the hypothesis indicating that having realistic human-like avatars without any body movement could create a worse sense of co-presence than having unrealistic avatars without any body movement, we used groups 7 to 10. We measured the co-presence created by unrealistic avatars (CO-P-U), the co-presence created by realistic human-like avatars without gestures (CO-P-RS), and the co-presence created by realistic human-like avatars with gestures (CO-P-RF). We then performed one-way ANOVAs on CO-P-U and CO-P-RS, and on CO-P-U and CO-P-RF. We found that the realistic human-like avatars (with or without gestures) produce a greater sense of co-presence than the unrealistic avatars. The difference is that the realistic human-like avatars with gestures and facial expressions produce a greater difference in co-presence (having $F(1,6) = 17.14286, p < 0.01$ for CO-P-RF and $F(1,6) = 8.44186, p < 0.05$ for CO-P-RS).

5.3 Discussion

The results of Experiment 1 show that there was a significant difference between the co-presence scores generated by the different types of avatars. The co-presence generated by the realistic human-like avatars was greater than that generated by the cartoon-like avatars, which in turns was greater than the co-presence generated by unrealistic avatars. None of the avatars had any gestures or facial expressions. This indicates that realistic avatars having a human-like form engender a greater sense of co-presence that totally unrealistic simple avatars.

Witmer and Singer [20] show that their Immersive Tendencies Questionnaire (ITQ) predicts the level of presence measured by their presence questionnaire. Since in this experiment we used a different presence questionnaire developed by Slater *et al*, it is important to see if we can replicate Witmer and Singer's results with Slater's questionnaire.

We found in Experiment 1 that the presence score measured by Slater's presence questionnaire and the IT score measured by Witmer and Singer's immersive tendencies questionnaire were correlated. This might indicate that the immersive tendencies score could act as a predictor of the presence score. We also compared the co-presence (CO-P) scores and the immersive tendencies (IT) scores, and we found that there was no correlation between the CO-P scores and the IT scores.

When we compared the personal presence (P) an co-presence (CO-P) scores, we found that there was no correlation between them. We therefore failed to replicate the results found by Tromp *et al* [18]. Tromp *et al* performed two experiments were they investigated, amongst other thing, the relationship between personal presence and co-presence. In the first experiment, they found a positive relationship between personal presence and co-presence. In the second experiment, they did not find a positive correlation between personal presence and co-presence. The first experiment described by Tromp *et al* in [18] is also described in more detail by Slater *et al* in [15].

The results of Experiment 2 show that the co-presence generated by avatars having gestures and facial expressions was significantly higher than that generated by static avatars. This supports our hypothesis that states that providing simple gestures and facial expressions to the avatars will enhance the sense of co-presence in a collaborative virtual environment. It is important to note that the participants which had avatars with gestures and facial expressions had to use the GUI to control their gestures and expressions. This might have disrupted the sense of co-presence felt by those participants and so might have influenced our results.

We also found in Experiment 2 that the presence score (measured by Slater's presence questionnaire) and the IT score (measured by Witmer and Singer's immersive tendencies questionnaire) were correlated. This supports Witmer and Singer's result indicating that the immersive tendencies score act as a predictor of the presence score. When we compared the co-presence (CO-P) scores and the immersive tendencies (IT) scores, we found that there was no correlation between them. When we compared the presence (P) and co-presence (CO-P) scores, we found again that there was no correlation between them. We therefore failed to replicate the results found by Tromp *et al* [18] and Slater *et al* [15] in one of their small group experiments.

We wanted to test the hypothesis that having realistic human-like avatars without any body movement could create a worse sense of co-presence than having unrealistic avatars without any body movement. We found that realistic human-like avatars, with or without gestures and facial expressions, did create a higher sense of co-presence than unrealistic avatars without any body movement.

6 Conclusion

We found that there was a significant difference in the co-presence scores between avatars of different appearance. The realistic human-like avatars produced a greater sense of co-presence that cartoon-like avatars, which in turn produces a greater sense of co-presence than unrealistic avatars. We found that avatars having gestures and facial expressions produced a significantly higher level of co-presence when compared to static avatars. We also found that realistic human-like avatars, with or without gestures and facial expressions, did create a higher sense of co-presence when compared to unrealistic avatars without any body movement.

Our results suggest that, contrary to what Tromp *et al* [18] and Slater *et al* [15] found in one of their experiments, the sense of personal presence and co-presence were not positively correlated in any of the two conditions. This indicates that personal presence and co-presence are orthogonal. This could be explained by the example of talking on a phone with someone, which might give a strong sense of "being with them" but not of being in the same place as them. However this does not indicate that there is no relationship between these two types of presence, but that more research needs to be done in this area in order to find what the relationship between the sense of personal presence and co-presence in a CVE is. The existence of a relationship between personal presence and co-presence is important since it could mean that there are common factors which influences both, or because they influence one another. Slater *et al* [12] postulate that personal presence is a prerequisite for co-presence.

We have used Witmer and Singer's Immersive Tendencies Questionnaire (ITQ) [20] to try and replicate their results indicating that the immersive tendencies score predicts the presence score. We managed to replicate their result using a different presence questionnaire.

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