The Effects of Presence on Small Group Collaboration and Interaction in a Collaborative Virtual Environment

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ABSTRACT

With the fast development of computer networks and computer graphics technology, collaborative virtual environments are becoming a feasible way to address computer-supported activities, and open the way to new forms of Computer Supported Collaborative Work (CSCW). To be successful, however, such systems must provide the participants with a realistic experience. This paper describes an experimental design created to examine the effects of presence (the feeling of being in a virtual environment) and co-presence (the feeling that other people in the environment are real) on collaboration and interaction between members of a 3-person group.

1 INTRODUCTION

The ability to communicate and collaborate to exchange information and ideas has always been a vital component of human development. Virtual Environments (VEs), which can be shared by a number of participants in remote geographical locations, provide new possibilities for this interaction.

This paper presents an experimental design aimed at investigating collaboration and interaction between members of a small group in a Collaborative Virtual Environment. As behaviour in the real world differs from that in virtual environments [1, 2], it seems likely that a different style of collaboration will predominate in a high-presence world compared to that in a low-presence world. It is important to note that the emphasis in this experiment is on type of collaboration, and not degree of collaboration. In addition, while task performance measures will be taken, they are incidental to the main focus of the experiment.

The specific aims of the experiment are:

- To test how presence is increased in a collaborative virtual environment.
- To identify the effects of presence on collaborating problem solving.

Section 2 of this paper covers some background on collaborative virtual environments, and on presence in virtual environments. Section 3 describes the virtual environments used for on this research project. Section 4 gives details of the subjects participating in the experiment, while section 5 describes the experimental method. Section 6 explains the process by which data will be gathered and analysed; Section 7 describes the equipment to be used.

2 BACKGROUND

2.1 COLLABORATIVE VIRTUAL ENVIRONMENTS

A Virtual Environment is a computer-based virtual reality system in which the user can interact with objects within the virtual world. Collaborative Virtual Environments support collaboration and communication between geographically separated users.

One such system is DIVE[3, 4, 5], a CVE developed at the Swedish Institute of Computer Science (SICS). DIVE (Distributed Interactive Virtual Environment) is an experimental platform for the development of applications based on shared 3D virtual environments. Users navigate in 3D space and see, meet and collaborate with other users and applications in the environment.

2.2 PRESENCE

Slater *et al* [6] define presence as "a state of consciousness, the (psychological) sense of being in the virtual environment". Slater et al [7, 8] classifies presence into *personal* presence and *shared* presence (or co-presence). Heeter [9] defines a third type of presence, namely *Environmental Presence*. Personal presence is concerned with the subjective feeling of being within a given environment. The user should not perceive the existence of any technology between them and the environment, leading to a sense of "places visited, rather than images seen" [6]. Shared presence has two aspects: that of feeling that the others in the VE actually exist, and that of feeling part of a group and process [10]. Social behaviour within the VE should correspond with that in the real world [6].

Various factors influence the perception of presence. They can be broken down into 4 broad categories, described in [11]:

- *Control factors*, such as degree and mode of control.
- *Sensory factors*, such as environmental richness and degree of movement perception.
- *Distraction factors*, such as isolation and interface awareness.
- *Realism factors*, such as scene realism and consistency of the VE with the real world.

3 VIRTUAL ENVIRONMENT DESIGN

3.1 VIRTUAL WORLDS

Two virtual environments will be created in order to measure the effects of presence on collaboration: one high presence world, and one low presence. The differences in presence will be achieved by controlling some of the factors which affect presence.

In the high presence world, which will attempt to model the real world, all participants will have a first-person, 3-dimensional perspective. Participants in the low presence world will have a third person, top-down perspective. However, the "visibility", distance-wise, will be approximately the same in both worlds.

In the high presence world, participants will be able to communicate with one another using real-time audio. In the low presence world, however, communication will only be possible through the use of text boxes.

For both worlds, participants need to be within a certain distance of the object they wish to manipulate. In the high presence world this distance will be smaller, requiring that the avatar be standing "next to" the object before the participant can manipulate it. This distance will be increased in the low presence world, allowing participants to manipulate or grab objects that are some distance away from them. The high-presence world will also have more objects with which the participants can interact - for example, doors will be able to open and close (they will start off closed, to bring this capability to participants' attention). In the low-presence world, all objects which do not need to be moved to complete the task will be fixed.

"Unintentional" interactions such as walking through walls and objects, and grasping and moving objects such as walls or floors, will be disabled in the high-presence world. In the low presence world participants will be able to move through objects. The ability to move walls, etc, will be disabled in both worlds simply due to the inconvenience of resetting the layout, and the real-world intrusion this action would involve. In order to strengthen the visual influence on presence, the high presence world will have textures mapped onto surfaces. This will allow more realistic rendering of objects such as walls and tables. In the low presence world, however, objects will be displayed as simple shaded polygons.

The general layout of both worlds will resemble that of an open plan office. This layout was chosen because it lends itself to a maze-like construction while remaining a familiar concept. It can also be sufficiently generalised to avoid the possibility of a level of environmental interaction above or below that of the expected level. In order to preserve the validity of the experimental results, both worlds will have the same layout. To test both the structure and interactive capabilities of the world, regular walk-throughs will be made during construction. In addition, once the worlds have been completed, a computer-literate outsider (who is unused to virtual environments) will be asked to walk through the world, possibly performing some parts of the experimental task, in order to provide an objective evaluation of the usability of the worlds.

3.2 AVATARS

All participants in a given world will have the same style avatar. Each group member will have a different colour avatar, to enable members to be distinguished. The name of the avatar (and thus of the participant) will be indicated only by the avatar's colour. The

colour of the avatar will have no other significance.

The participants in the high-presence world will be embodied using a humanoid avatar ("Walkman") which has the ability to "walk" (i.e. perform natural-looking movements of the legs and arms) when it moves around the environment. On the other hand, in the low-presence world the participants will use a simple block-like avatar shaped as a 'T' (Blockie) (See figure 1).

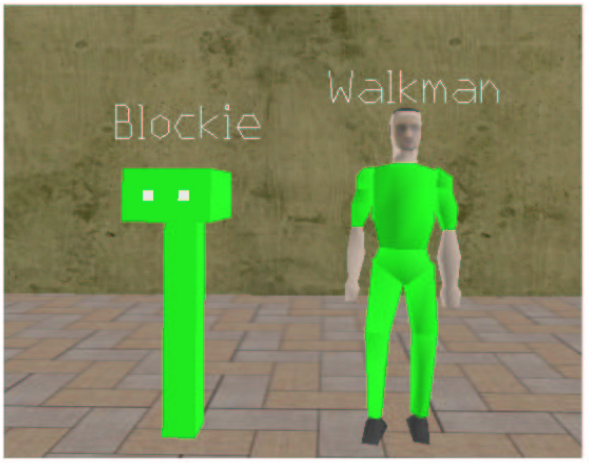

Figure 1: Screenshots of the 2 different avatars to be used in the experiment. The avatar on the left ("Blockie") will be used for the low-presence world; that on the right ("Walkman") for the high-presence world.

4 SUBJECTS

We will be using a sample of 24 subjects, who will be paid volunteers. The sample will be divided into groups of 3, giving 8 groups in total. Groups will randomly be assigned to worlds, four groups to each. However, participants will not be told which world they have been assigned to - in fact, they would probably not be aware that theirs is not the only world implemented. Participants will all be of the same gender, and approximately the same age. It will be arranged that within each group, participants will not know each other in real life (or at least will not be more than casual acquaintances). In addition, participants will be fluent in English, as the task will be language-based.

For ethical reasons [12], participants will be told that their speech (or typed communcation, in the low-presence world) will be told that their speech will be recorded. While this may cause slight inhibition, the effect should be small and is unfortunately unavoidable.

5 METHOD

Participants will only be allowed to communicate with each other through the virtual environment, and will not be able to see or hear other group members. This will be accomplished by putting up partitions between workstations, and, in the high-presence world, possibly using earphones for audio communication (thereby blocking out extraneous external sounds, including other participants' speech).

For each group, members will have the environment, controls and task explained to them individually. Thereafter, there will a short practice session, where the group members will meet in the virtual world. An avatar controlled by one of the experimenters will greet them in the virtual environment (in the high-presence world, this will be done verbally, so as to draw their attention to the fact that normal speech is possible and to make it seem natural). At the end of the practice session, the experimenter's avatar will lead them to a room where they will begin the task (the experimenter's avatar will leave the room at this point).

Each group member will have an experimenter assigned to them, who will be on hand should severe interface difficulties occur. However, the experimenter will remain unobtrusive, and will not volunteer any help or information. An exception to this is in the low-presence world, where in order to increase distraction the experimenter will occasionally interrupt the participant to ask if everything is alright. The number and timing of these interruptions will be more or less constant across participants.

5.1 TASK

The task is a language-based task designed to encourage discussion and collaboration. More specifically, the task must encourage intellectual collaboration rather than physical collaboration, while still providing enough opportunities for participants to interact with the world (in order for the difference in presence to play a large enough role). While there will be a time limit involved, this will not be revealed to the participants. This time limit will be decided on after completion of the worlds.

The task to be performed by the participants is as follows. Certain rooms in the world will have a word printed on the door (for the 3-D perspective) and on the floor (for the top-down perspective). Each word will have a letter missing, replaced with a '-' (for example, "h-t"). The missing letters will be scattered around the world, preferably (if space permits) not in rooms associated with words. These missing letters

must be brought into the correct room and dropped there. They may be removed if it is decided that the letter was placed in the wrong room. To complicate the task and encourage collaboration, one letter may be used in two or more different words - however, if it is used in the wrong word, the puzzle will not be able to be completed. For example, consider the two words "h-t" and "c-t", with scattered letters 'i' and 'a'. If the 'a' is used to form "hat", which seems correct, only the 'i' is available for the second word, forming "cit" which is clearly incorrect.

The number of words to be completed, as well as the time limit of the task, will be decided on after completion of the two worlds. Test walkthroughs will be done to determine a feasible number of words to be completed.

6 DATA AND ANALYSIS

6.1 GATHERING OF DATA

6.1.1 PRESENCE

To measure the degree of presence and co-presence felt by each participant in the study, they will be asked to fill in a questionnaire after exiting from the VE. The presence part of this questionnaire will be based on that developed by Bob Witmer and Michael Singer [11]. As no established questionnaire to measure co-presence was found in the literature, questions created by the authors will be added to the questionnaire in order to have some measure of the degree of co-presence felt by participants. In addition, the questionnaire will include items from the Immersive Tendencies Questionnaire (ITQ) also developed by Witmer and Singer [11]. These questionnaires make use of a 7-point Likhert type scale to measure respondents' answers.

6.1.2 COLLABORATION

All lingual communication between group members during the task will be logged. Text or typed communication will be sequentially written to a log file, while verbal communication will be recorded by means of tape recorders. This will be accomplished by having an experimenter control an invisible avatar (similar to that used by Steed *et al* [13]) which will remain close enough to participants' avatars to be able to "hear" their speech. The tape-recorder will be situated at the experimenter's workstation, and will record all speech heard by the avatar. The identity of the person speaking or typing does not need to be recorded. Recording speech will introduce another factor limiting the amount of time allocated for the task, as changing the tape in the middle of a session would cause an unacceptable level of distraction, thereby decreasing presence.

6.1.3 TASK PERFORMANCE

As a measure of task performance, the system will record, for each group, the number of words correctly completed at the end of the task. (Once again, this is incidental to the main purpose of the experiment, and is mostly to see whether further research into the assumption "greater presence implies greater task performance" is necessary.)

6.2 ANALYSIS OF RESULTS

6.2.1 PRESENCE

Copies of the PQ and ITQ, as well as scoring instructions, have been requested from the authors [11]. The results obtained from the questionnaires will thus be analysed according to the authors' instructions.

6.2.2 COLLABORATION

All dialogue between group members will be categorised according to the schedule proposed by Bales [14]. Briefly, there are four main categories (each of which can be broken down into three subcategories, not described here):

- *Category A*: positive socio-emotional content; group solidarity; satisfaction; general agreement
- *Category B*: attempted answers; giving suggestions, opinions, or orientation
- *Category C*: asking for suggestions, opinions, or orientation
- *Category D*: negative socio-emotional content; disagreement, tension or antagonism

Once classification has been completed, the mean number of statements within each category and subcategory will be calculated for each world. A chi-square test will be performed, with the level of presence as the second factor. This will determine whether differences in dialogue across the two worlds are significant or not.

6.2.3 TASK PERFORMANCE

The number of words correctly completed will be averaged for each world, and a t-test will be performed to determine whether the difference is significant.

7 EQUIPMENT

The participants will be using SGI workstations with 21 or 17 inch screens. The movement through the virtual environment will be accomplished using the keyboard or the mouse. Objects in the virtual environment will be selected and moved using the mouse.

The following workstations will be used for the experiment:

- An SGI O_2 with an R10000 processor, 128 Mbytes of RAM, and a 21 inch screen.
- An SGI O_2 with an R10000 processor, 256 Mbytes of RAM, and a 17 inch screen.
- An SGI O_2 with an R10000 processor, 64 Mbytes of RAM, and a 17 inch screen.

The experimenter taking part in the initial introductory portion of the experiment will be using a SGI Onyx with four R4400 processors, 128 Mbytes of RAM, and a 21 inch screen.

In addition, participants who have been assigned to the high-presence world will use earphones for audio communication, as well as to block out extraneous real-world sounds. Three tape-recorders, along with enough audio cassettes to record all speech, will also be needed. Twelve 90-minute tapes should be sufficient.

8 CONCLUSION

In the case of the presence portion of the questionnaire, we hope to show that there was a difference between the mean degree of presence felt by participants experiencing the high-presence world to that felt by participants of the low-presence world.

In the case of the ITQ portion of the questionnaire, we hope to show that there was no mean difference in the immersive tendencies of participants of each world, i.e. that this factor was effectively randomised out and did not play a significant role in the difference in degree of presence measured for each world.

For the analysis of the collaborative dialogue, we hope to show that more of one of the categories of statements occurs in one of the worlds than the other; i.e., that a difference in presence leads to a difference in collaborative communication between participants.

In the case of task performance, it is generally assumed that higher presence will lead to greater task performance. However, we suspect that the factors inherent in the increasing of presence might lead to lesser task performance - for example, localised sound increases presence, but may reduce productivity. We hope to show that either no difference in task performance exists between the two worlds, or that the lower-presence world actually increases task performance. While this would not be a definitive result, given the limitations of the experiment, it may point out that further research into this topic is necessary.

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