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

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Abstract

Presence in Collaborative Virtual Environments (CVEs) can be classified into *personal presence* and *co-presence*. Personal presence is having a feeling of “being there” in the CVE yourself. 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. In this paper we describe an experiment used to investigate the effects that small group collaboration and interaction has on personal presence and specially co-presence in a CVE. We hypothesise that collaboration and interaction enhances co-presence in a CVE. We found that there was a large difference in co-presence between two CVEs which produced different levels of collaboration and interaction. This supports our hypotheses that just having virtual representations of others is not sufficient to create a high sense of co-presence, and that one needs collaboration and interaction in order to enhance co-presence in a CVE. We measured personal presence subjectively, using a questionnaire developed by Slater *et al*. We have developed a co-presence questionnaire which assesses the levels of co-presence subjectively. We have also developed a collaboration questionnaire which measures group collaboration subjectively, as well as the degree of enjoyment and comfort with others in the group.

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 [1, 2], 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. However, 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 [3] 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.

In this paper, we present an experiment which investigates the effects that small group collaboration has on personal presence and specially co-presence in a Collaborative Virtual Environment. A high sense of co-presence in a CVE is crucial to enable a group of people to collaborate and interact effectively. However, it is equally important to investigate if collaboration and interaction between a group of people effect co-presence in a CVE. Our main hypothesis is that collaboration and interaction will enhance the sense of co-presence in a CVE.

In order to address this issue, we have developed two collaborative virtual environments, which we name 'high-collaboration VE' and 'low-collaboration VE'. Both VEs are basically identical and only the task differs. In the high-collaboration VE, participants have to collaborate to solve the given task. In the low-collaboration VE, participants don't need to collaborate to solve the problem.

We measure presence, co-presence, and collaboration subjectively making use of post experiment questionnaires. We use a presence questionnaire developed by Slater *et al* [4, 5] 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 have also developed a collaboration questionnaire which measures group collaboration subjectively, as well as the degree of enjoyment and comfort with others in the group.

In this experiment, we show that interaction and collaboration does enhance the sense of personal presence and co-presence in a CVE. It is also important to see if the sense of personal presence and co-presence are associated. This is a useful issue to investigate, since if personal presence and co-presence are associated this could be because of common factors which influence both, or because they influence one another. We show that contrary to what Tromp *et al* [6] found in one of their experiments, the sense of personal presence and co-presence were not positively correlated in this experiment. Witmer and Singer [7] 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). Since we use a different presence questionnaire, we used Witmer and Singer's ITQ to try and replicate their results. We found that the presence score (as measured by Slater *et al*'s questionnaire) was positively correlated with the immersive tendencies score. However, the co-presence score was not correlated with the immersive tendencies score.

The tasks used in the different VEs are designed so that they make sure that participants need to collaborate and interact to solve the task in the high-collaboration VE, and do not need to collaborate at all to solve the task in the low-collaboration VE. Task performance is not important in this experiment, and the task is only used to make sure that we get different levels of collaboration and interaction in both VEs.

The following section describes presence and immersion in virtual environments. Section 3 provides some information on how to measure the sense of presence in a virtual environment. Section 4 describes the actual experiment we have performed, which tests the hypothesis that collaboration and interaction in a CVE enhances co-presence. Section 5 shows the results obtained, and presents a discussion of those results. Finally Section 6 presents directions for future work and conclusions.

2 Presence and Immersion

Slater *et al* [4, 8] define presence as "a state of consciousness, the (psychological) sense of being in the virtual environment". Slater *et al* [9] classify presence into *personal presence* and *co-presence*. Personal presence relates to the subjective feeling of "being there" yourself, in the virtual environment, leading to a sense of "places visited, rather than images seen" [4, 8]. Co-presence has two aspects: that of feeling that the other participants in the VE actually exist and are really present in the environment, and that of feeling part of a group and process. Slater *el al* [4] also 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.

Immersion is defined by Slater *et al* [8, 10] to mean the extent to which the system delivers a surrounding environment, which blocks out external sensory data, which generates a variety of sensory information, and the extent of the richness of that sensory information. In other words, Slater *et al* define immersion as an objective description of the VE technology.

Witmer and Singer define presence as "the subjective experience of being in one place or environment, even when one is physically situated in another" [7]. When applied to virtual environments, this definition means that presence refers to experiencing the computer-generated environment rather than the actual physical location. Witmer and Singer [7] indicate that presence in a virtual environment depends on one's attention shifting from the real environment to the virtual environment, and that presence depends on both *involvement* and *immersion*. They define involvement as "a psychological state experienced as a consequence of focusing one's energy and attention on a coherent set of stimuli or meaningfully related activities and events" [7], and indicate that as participants become more involved in the VE their sense of presence increases. Immersion is defined as "a psychological state characterized by perceiving oneself to be enveloped by, included in, and interacting with an environment that provides a continuous stream of stimuli and experiences" [7]. They indicate that a VE that produces a greater sense of immersion will produce higher levels of presence.

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 [8], as well as possible enhancement of learning and performance [7]. We postulate that "presence" can therefore be used as a measure of how effective a virtual environment is.

3 Measuring Presence

One of the major issues when dealing with presence in a virtual environment is how to measure it. Held and Durlach [11], and Sheridan [12] note that we don't have a working measure of presence. Suggested approaches include:

1. User reported sense of presence: This involves inquiring 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 behaviour of the participants in the real world, reacting 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* [4, 8, 5, 7].

Slater *et al* [4, 8, 5] 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 measure 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. Slater *et al* [9] indicate that 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" ?

Witmer and Singer [7] have developed a presence questionnaire based on: the factors believed to underlie presence, environmental factors that encourage involvement and enable immersion, and internal tendencies to become involved. These factors are subjectively defined, and the questions in the questionnaire elicit the opinions of the experimental subjects about these matters.

4 Small Group Collaboration Experiment

This experiment is used to investigate collaboration and interaction between a small group of 3 users in a CVE, and the effects that collaboration and interaction has on co-presence in the CVE. The specific aim of this experiment is to test whether co-presence is increased by collaborating and interacting with other participants in the CVE.

4.1 Presence and Collaboration: 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 [13, 14, 9, 15, 6, 16].

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.
- Group collaboration and interaction with other participants in the environment should influence co-presence. It is believed that simply having a visual representation of other users in the environment is not sufficient to create a high sense of co-presence. Having the possibility to collaborate and interact with other participants in the shared environment should very much increase the sense of co-presence.
- Personal presence and co-presence could be positively correlated. Slater *el al* [9] 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 use two collaborative virtual environments (named 'high-collaboration VE' and 'low-collaboration VE'). Both VEs are identical and only the task differs. In the high-collaboration VE, participants can communicate and interact with one another, and have to collaborate to solve the given task. In the low-collaboration VE, participants can communicate with one another but don't need to collaborate to solve the problem.

4.2 Collaborative Virtual Environment Prototype

The CVE is implemented using the DIVE (Distributed Interactive Virtual Environment) system [17]. DIVE is a toolkit for the development of multi-user distributed virtual environment, developed at the Swedish Institute of Computer science (SICS) [18].

The VE consists of a set of rooms which creates a simple maze (see Figure 1). Participants are able to move their avatar around the rooms using the arrow keys, and move their avatar's head using the mouse. They are able to pick up objects in the VE by clicking on them, which attaches the object to their avatar. They are therefore able to move the object by moving themselves, and then release the object by clicking on it again. Participants can communicate with each other using an audio channel.

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

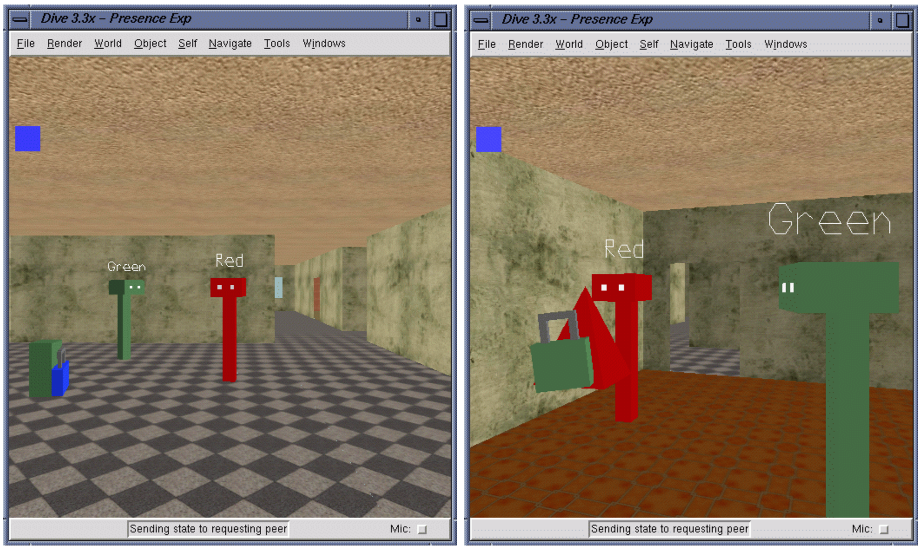

Figure 1: The high-collaboration VE, consisting of a set of rooms forming a maze. In the left picture, the Blue participant is looking at the Red and Green participants. In the right picture, the Red participant has picked up the red pyramid, and can now move around and drop the shape in the appropriate room.

In this experiment, all the participants have an identical avatar, consisting of a 'T' shaped block avatar called 'Blockie' (Blockie is the default avatar used by the DIVE system). The only difference between the participant's avatars is their colour being red, green or blue (see Figure 1). The avatars where labeled Red, Green and Blue, and participants called each other by these names during the experiment.

4.3 Experimental Task

The task consisted of moving different geometrical shapes (pyramids, cubes, rectangles) into specified rooms. There were 3 rooms which had labels to indicate which shapes had to be brought to which room.

In the high-collaboration VE, each participant has an avatar of a given colour (red, green or blue), and the shapes are also red, green or blue in colour. All the shapes are locked by padlocks (refer to Figure 1) and participants cannot pick up locked shapes. The padlocks are also coloured red, green or blue. In addition, only the participant with the same colour as the shape can pick up that shape, and only the participant with the same colour as the padlock can unlock that padlock. Therefore, picking up a red shape locked with a blue padlock involves having the Red and Blue participants within a close range of the shape, and having the Blue participant unlock the blue padlock by clicking on it. Clicking on the padlock causes it to open for 6 seconds, after which it automatically locks itself. During those 6 seconds, the Red participant can pick up the shape by clicking on it. The shape gets attached to the Red avatar, and he/she can move around the virtual environment and drop the shape in the appropriate room. We chose this task because it requires observation and talking, and can only be solved by collaboration since two participants are needed to pick up a shape.

In the low-collaboration VE, the task is basically the same except that there are no padlocks locking the shapes. Therefore, a given shape can be picked up by the user having the same colour as the shape, without needing the help of another participant. This means that participants don't need to collaborate to move the shapes around, and so this task can be completed without any collaboration. The low-collaboration VE was used as the control experiment.

Since the participants cannot see their own avatar, a small square with the same colour as their avatar is displayed on the upper-left corner of the display to indicate which colour is associated with the user, and hence which objects he/she can pick up.

4.4 Experimental Procedure

The experiment involved 30 participants, divided into 10 groups of 3 users each. Participants were recruited from the UCT campus, and where approximately the same age. On completion of the experiment, each participants was payed R20.

The first 4 groups (12 participants) were assigned to the low-collaboration VE, and the next 6 groups (18 participants) to the high collaboration VE. None of the participants knew that there were two different VEs.

Before starting the experiment, each participant was introduced to the system. This involved learning how to move through the environment and how to pick up objects in the virtual environment. Once they where familiar with the interface, each participant read the experiment instructions describing the task. In order to make sure that the task was fully understood, the experimenter explained the task to each participant, answering any questions they had about the task.

Participants in a group did not meet each other in real life. This was accomplished by situating the workstations in different rooms. Participants meet for the first time in the VE, and called each other by their avatar colour. Participants were using earphones for audio communication which blocked out extraneous sounds.

The task was 25 minutes long, but this was not mentioned to the participants as knowledge of time limit might affect task performance. Once the time was up, the participants where instructed to stop. After that, each participant was required to fill in 3 questionnaires: the Immersive Tendencies Questionnaire (ITQ), the presence and co-presence questionnaire (PQ), and the collaboration questionnaire (CQ). These questionnaires are described in more details in Section 4.5.

4.5 Measuring Presence and Group Collaboration

In this experiment, we measure 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* [4, 5]. The questionnaire elaborates on the three attributes proposed by Slater *et al* (described in Section 3) to measure personal presence. To measure co-presence, we have developed a co-presence questionnaire which uses questions similar to the ones proposed by Slater *el al* in [9], which are shown in Section 3. The presence questionnaire has been used and validated by Slater *et al* in many experiments [4, 8, 5]. 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 [7] 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 make sure that there is no difference in immervise tendencies between the participants of the low-collaboration VE and the high-collaboration VE. We also use this questionnaire to try and replicate Witmer and Singer's results with regard to the correlation between the ITQ and presence scores.

We measure subjectively rated collaboration by making use of a post-experiment questionnaire. This collaboration questionnaire (CQ) is used to make sure that the two VEs (i.e., the low-collaboration VE and the high-collaboration VE) produced different levels of collaboration and interaction. The collaboration questionnaire is based on the work done by Tromp el al [6]. It assesses the degree of enjoyment, the desire for the group to form again, the degree of comfort with individual members, and the perceived collaboration of the group and of the other members of the group. Our collaboration questionnaire is validated by the fact that it picked up quite a difference in collaboration between the high-collaboration VE and the low-collaboration VE.

4.6 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.

5 Analysis of Results

In this section, we describe the results obtained in the experiment. 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

Using the questionnaires mentioned in Section 4.5, we measured the following variables:

- **The presence score P**: measures the sense of personal presence.
- **The co-presence score CO-P**: measures the sense of co-presence.
- **The collaboration score COLL**: measures the degree of group collaboration and group accord.
- **The immersive tendencies score IT**: measures the tendencies of individuals to become immersed.

The hypotheses for the above variables are: We expect COLL to be higher in the high-collaboration VE, than in the low-collaboration VE. This will show that there was indeed a difference in collaboration between the two virtual environments. We expect CO-P be to higher in the high-collaboration VE than in the low collaboration VE. This will support our hypotheses that interaction and collaboration enhances co-presence in a CVE. Witmer and singer [7] indicate that the IT score (as measured by their immersive tendencies questionnaire) predict the presence score (as measured by their presence questionnaire). It is important to check if this correlation is replicated is this experiment, which uses a different presence questionnaire. Finally, it is important to check if there is a relationship between P and CO-P scores. Tromp *et al* [6] indicate that they found a positive correlation between the personal presence and co-presence scores in one of their experiments.

5.2 Summary of Results

In order to check if sampling errors occurred during the experiment, we compared the P scores and the CO-P scores within the same conditions (i.e., in the low-collaboration VE and then in the high-collaboration VE). For each VE, a one-way Analysis of Variance (ANOVA) [2] on group number and P score was performed. We found no significant difference in either VE at the 0.05 confidence level ($F(3,8) = 0.256, p > 0.05$ for the low-collaboration VE; $F(5,12) = 1.476, p > 0.05$ for the high-collaboration VE). For each VE, a one-way ANOVA on group number and CO-P score was also performed. Again, we found no significant difference in either VE at the 0.05 confidence level ($F(3,8) = 0.873, p > 0.05$ for the low-collaboration VE; $F(5,12) = 0.984, p > 0.05$ for the high-collaboration VE). This indicates that there were no significant sampling errors with the P and CO-P scores.

In order to check if different equipment played a role in the results, we performed for each VE an ANOVA on colour and P score. We found no significant difference in either VE at the 0.05 confidence level ($F(2,9) = 0.613, p > 0.05$ for the low-collaboration VE; $F(2,15) = 0.108, p > 0.05$ for the high-collaboration VE). Also, we performed an ANOVA on colour and CO-P score for each VE. Again, we found no significant difference in either VE at the 0.05 confidence level, with $F(2,9) = 4.22, p > 0.05$ for the low-collaboration VE and $F(2,15) = 1.067, p > 0.05$ in the high-collaboration VE. This shows that the different equipment did not lead to significant differences in P and CO-P scores.

In order to check that both VEs produced a different level of collaboration, we performed a one-way ANOVA to check the difference in COLL score between the low-collaboration VE and the high-collaboration VE. We found that, as expected, there was a very large difference in COLL score between both VEs, with $F(1,28) = 145.025, p < 0.001$. This shows that participants felt that they collaborated quite a lot in the high-collaboration VE, and not at all in the low-collaboration VE.

We then compared the difference in the P scores between the low and high-collaboration VEs. This was done using a one-way ANOVA, and 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. This was achieved by doing a one-way ANOVA on CO-P scores for both VEs. We found that there was a very 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 VE.

A correlation analysis was performed on the P, CO-P, and IT variables in each VE, to check if there were significant relationships between them. We performed two-sided tests in both the low and high collaboration VE, and we obtained the following results:

Low-collaboration VE:

- **Correlation between P and IT scores**: $r = 0.6537$ and $t = 2.7317$. 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 (rcrit) equal to 0.5759. This indicates that P and IT were significantly correlated.

- **Correlation between CO-P and IT scores**: $r = 0.4706$ and $t = 1.6870$. 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 (rcrit) equal to 0.5759. We can see that the CO-P and IT scores were not significantly correlated.

[2] An introductory book to statistical analysis used was "Statistics" by W. L. Hays [19]

- **Correlation between P and CO-P scores**: $r = 0.4919$ and $t = 1.7865$. 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 (rcrit) equal to 0.5759. Here, the P and CO-P scores were not significantly correlated.

High-collaboration VE:

- **Correlation between P and IT scores**: $r = 0.5764$ and $t = 2.8217$. 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 (rcrit) equal to 0.4682. We can see that the P and IT scores were significantly correlated.

- **Correlation between CO-P and IT scores**: $r = 0.3357$ and $t =$. 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 (rcrit) equal to 0.4682. We can see that the CO-P and IT scores were not significantly correlated.

- **Correlation between P and CO-P scores**: $r = 0.341985$ and $t = 1.45571$. 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 (rcrit) equal to 0.4682. The P and CO-P scores were not significantly correlated.

5.3 Discussion

The results show that there was a very large difference in the collaboration score (COLL) between the low and high-collaboration VEs. This indicates that we succeeded in our goal of creating a large difference in collaboration between the two virtual environments.

In the analysis of the co-presence score, we found that there was a very large difference in co-presence between the two conditions. The co-presence score was much higher in the high-collaboration VE when compared to the low-collaboration VE. This supports our hypotheses that just having virtual representations of others is not sufficient to create a high sense of co-presence, and that one needs collaboration and interaction in order to enhance co-presence in a CVE.

When looking at the presence scores, we found that the presence score (P) was higher in the high-collaboration VE than in the low-collaboration VE. This is an interesting result since it indicates that collaboration and interaction with other participants affects personal presence. This might be explained by the fact that since the high-collaboration task was more challenging, it required the participant to be more involved in the experience and hence enhances the sense of personal presence.

Witmer and Singer [7] indicate that their Immersive Tendencies Questionnaire (ITQ) predicts the level of presence recorded with their presence questionnaire in a VE. Since we have used a different presence questionnaire based on the questionnaire developed by Slater *et al*, it is important to check if we can replicate Witmer and Singer's results. We found that in both the low and high-collaboration VEs, the presence score and the IT score were positively correlated. This supports Witmer and Singer's results indicating that the immersive tendencies scores act as a predictor of the presence score. This is an interesting result since in another experiment we conducted [] we failed to replicate Witmer and Singer's results using their presence questionnaire (PQ) and their ITQ. This might indicate that Witmer and Singer's PQ/ITQ correlation (using their PQ and ITQ) seems to hold only under certain conditions, which are unclear. On the other hand, we found no correlation between the CO-P score and the IT score in any of the two conditions. This indicates that the immersive tendencies do not predict the co-presence felt by participants.

When we compared the presence an co-presence scores, we found that there was no correlation between presence and co-presence in any of the two conditions. We therefore failed to replicate the results found by Tromp *et al* in one of their experiments [6].

6 Conclusion

We found that there was a large difference in the co-presence scores between the low and high collaboration VEs, indicating that participants in the high-collaboration VE had a much larger sense of co-presence than participant in the low-collaboration VE. This supports our hypotheses that just having virtual representations of others is not sufficient to create a high sense of co-presence, and that one needs collaboration and interaction in order to enhance co-presence in a CVE.

Our results suggest that contrary to what Tromp *et al* [6] 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 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 confirm if there is a relationship between the sense of personal presence and co-presence in a CVE. 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* [9] postulate that personal presence is a prerequisite for co-presence.

We have used Witmer and Singer's Immersive Tendencies Questionnaire (ITQ) [7] 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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