An Experimental Comparison of 3D Virtual Environments and Text Chat as Collaboration Tools

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Abstract: A key prerequisite for effective team collaboration concerns the team members' knowledge about their different backgrounds, skills and experiences. While face-to-face interaction provides multiple opportunities for learning about these vital personal elements informally, a computer-mediated communication setting may make knowledge sharing about team members and their specific backgrounds more difficult. This knowledge sharing, however, may be crucial and should thus be supported also in remote settings. In this paper, we present the design and results of a controlled experiment in which participants needed to share information and make decisions with team members online, in a simulated project kick-off meeting. Five experimental groups collaborated in a three-dimensional Virtual Environment (3D CVE), five control groups in text chat sessions. Opposing these two media, we were able to extrapolate the essential characteristics of 3D CVE. The experiment yields first results proving improved retention when collaborating with avatars in 3D environments and provides insights about the value of this media as a collaboration tool.

Keywords: avatars, virtual environments, experiment, group interaction, decision-making

1. Introduction

A key prerequisite for effective team collaboration concerns the team members' knowledge about their different backgrounds, skills and experiences (i.e., their professional profiles). This situation in which collaborating partners have only partial and biased information has been labeled a *Hidden Profile* situation (Stasser & Titus, 1985). While face-to-face interaction provides multiple opportunities for learning about these vital personal elements informally, a computer-mediated communication (CMC) setting may make knowledge sharing about team members and their specific backgrounds more difficult. This knowledge sharing, however, may be crucial in order to assign roles or tasks according to abilities, to foster mutual understanding, and to ensure team cohesion and trust. Thus, it should be supported also in remote settings and other situations when people choose to work together online, mediated by computers.

In this paper, we present the design and results of a controlled experiment in which participants needed to share information with team members in an online meeting. The experiment simulated the kick-off meeting of a project; participants needed to present themselves and clarify their main goals jointly. They further needed to assign project roles to each member, based on his or her specific experience, skills and education.

The experimental groups collaborated in a three-dimensional Collaborative Virtual Environment (3D CVE), the control groups in a text chat session. With our investigation we attempted to provide evidence for the existence of advantages in using 3D environments for collaboration tasks. In a simplified view, a 3D CVE can be seen as a text chat augmented by (a) the concept of space, (b) the fact of being represented or embodied as a customized avatar in that virtual space, and (c) the feeling of being there together as a team. Thus, by opposing the two media, this experiment was designed to let us examine these latter notions separately, and to extrapolate the supposedly added value, when dealing with real collaboration tasks.

The remainder of this paper starts with describing our research questions and design, then explains the design of the experiment itself, the measurements we took, and its results in detail. After that, we discuss some limitations of the study, and finally present the conclusions we could draw from this investigation.

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2. Research question and design: investigating 3D virtual environments for collaboration tasks

The main research questions of our investigation are "Can 3D Collaborative Virtual Environments bring added value to real collaboration tasks?" and "If so, what exactly is the added value, and how can these virtual environments be designed for collaboration tasks to better benefit from the distinct possibilities these environments offer?"

At a theoretical level, we consider answering these questions as an opening up of novel and innovative ways of working together, harnessing new possibilities recent advancements of communication and technology have brought. Benefits could emerge not only for knowledge management, but also for related fields like collaborative learning and education in general, as well as for entirely different domains like science, healthcare, and games.

At a practical level, we aim to extract important findings on how to design online 3D collaborative virtual environments (also referred to as virtual worlds) and the collaboration settings and tasks for the users, and thus to be able to provide guidelines for practitioners who seek to benefit from virtual collaboration (Kahai et al. 2007). A recent Gartner article points out that businesses focus on technology rather than the users' requirements when trying out virtual worlds, which they believe is one of the main reasons for the failure of 90% of current corporate virtual world projects, as it is anticipated by Gartner (Gartner 2008). Guidelines that we believe will emerge from our research could help in designing memorable virtual experiences that lead to real added value, and thus render the use of virtual worlds and 3D collaborative virtual environments in general more worthwhile for corporate communication, collaborative work, and other business use cases.

To address the aforementioned complex and interdisciplinary research questions, we have chosen to follow a three-step research design:

As a first step, we started to identify existing ways of collaborating in 3D multi-user virtual environments. We looked into the literature, watched relevant news, blogs and online magazines, and observed groups of users in the popular virtual world Second Life (Second Life 2009) with the aim to find out how people interact with each other and work together – which is an important first step in order to identify the users' needs (Tromp et al. 2003). Using a pattern-based approach, we also created novel patterns that harness the possibilities of these environments. We developed a first description logic to formalize collaboration patterns in 3D virtual environments, and classified them according to the design effort they require and to the added value the particular collaboration patterns bring (Schmeil and Eppler 2009). The classification covers both learning patterns and patterns for collaborative work.

With that classification in hand, it was noticeable that the vertical axis unit – the amount of added value the patterns bring – needed to be defined more clearly. We thus developed a framework for collaboration in virtual environments, formalizing the necessary elements, and structuring their interplay (Schmeil and Eppler 2009b). This framework can furthermore be used as a blueprint in order to guide users and virtual environment designers in the creation of new collaboration patterns. Guidelines on how to design usable worlds and virtual objects have long been identified as a major requirement for improving the usability of 3D CVE; however, just little research has been done addressing the issue (Tromp et al. 2003).

The third step of our research concerns the experimental evaluation of 3D CVE and collaboration patterns in these environments. The paper at hand describes the first round of experiments we conducted: a comparison of collaboration using two different media, in order to find evidence that 3D virtual environments bring added value. Future experiments will include evaluating and comparing different collaboration patterns inside CVE.

3. Experimental design

As briefly explained in the previous chapter, the experiment was designed to measure the added value of collaborating in a 3D virtual environment in comparison to collaboration through simple text chat. This systematic media comparison was intended to extrapolate the value of a 3D virtual environment's essential characteristics: the fact of being embodied as customizable avatars in a

configurable three-dimensional space which simulates the real world while having the benefit of not being limited by real physical constraints.

We implemented a 2x3 experimental design, with 3 tasks: (1) information sharing, (2) grounding and team discussion, and (3) decision making and subgroup building, and two conditions: (I) collaboration in a 3D virtual environment, and (II) collaboration in pure text chat. The independent variable was the environment for online collaboration, and the dependent variables were: satisfaction with process and outcome (Briggs 2006), productivity of the collaboration, and retention (memorability).

In this first round of the experiment we had 50 bachelor and master students, who we divided into groups of five students. Five experimental groups used our configured 3D CVE to fulfill collaboration tasks, the other five groups – the control groups – worked on the same collaboration tasks under the control condition, that is, using pure text chat. The 3D CVE groups used OpenSim (an open-source virtual world server and client system that was derived from the released Second Life viewer source code and is now an independent project: http://opensimulator.org), while the text chat groups used Skype (a popular telephony and chat software, http://www.skype.com, used without its audio and video conferencing functionalities).

In order to ensure the simulation of a remote situation while still having a controlled experiment, we conducted it – in five sessions – in one of our university's computer labs, and paid heed to keep the participants from talking to each other. Only text chatting in the respective medium was permitted. Also, we understood it as crucial for the experiment results to not be influenced by any personal relations between the students, and thus placed the participants in a way that did not allow them to see the screens of other participants' in their groups. This way, their hidden profiles could only be shared communicating online, and could not be associated with a classmate's real identity, which could have significantly biased the retention results. The groups were randomly assigned by the experimenter as suitable in most experiment settings (Friedman and Sunder 1994). Prior to these five sessions of which we analyzed the results, we conducted a pre-test with two groups of five students collaborating in our 3D CVE, and two smaller groups in text chat.

After the collaboration task, we measured the participants' subjective assessments through a post-task survey and their objective achievements (the recall of their team members' profiles and the recall of decisions made during the collaboration meeting) through a follow-up test and result evaluation. The following subsections present our hypotheses including their development, then describe the collaboration tasks and the test environment in detail, and explain which measurements we took and how we analyzed the results.

3.1 Hypotheses

Numerous studies have shown evidence that pictures yield better results than simple text in terms of recalled items and comprehension (Nelson et al. 1976, for a review see Snodgrass and Vanderwart 1980), this however is contingent on certain conditions that depend on the application context of images (Stenberg et al. 1995). Collaboration and team knowledge sharing are one such context in which the picture superiority effect has not been analyzed extensively through experiments (for an exception see Stewart and Stewart 2001). Our study thus aims at examining the added value of using visual cues for collaboration based on the premise that the picture superiority effect is also relevant for collaborative settings.

The empirically validated pictorial superiority effect states that the use of images in cognitive tasks leads to systematically higher recall (and recognition) than the mere use of words (because of the additional encoding enabled by pictures and their distinctiveness; see Snodgrass and Vanderwart, 1980, 177; compare also Dual Coding Theory, Paivio 1986). Based on these existing findings, we extend the picture superiority effect to the realm of team communication and hypothesize that 3D collaborative virtual environments – which are based on advanced computer graphics and extensively supported by visual cues (Kahai et al. 2007; Schmeil and Eppler 2009b) – lead to superior results than text-only based ones. These superior effects are not only limited to recall, but also regard team productivity and group work quality.

We thus hypothesize that the fact of being embodied as avatars in an immersive 3D virtual environment will lead to more effective and sustainable knowledge sharing and to a higher satisfaction, motivation and recall of other team members' backgrounds – compared to pure text chat.

3.2 Task and test environment

The simulated project-kick-off meeting consisted of three tasks. First, participants should introduce their personas to their team members, second, the team should discuss the project and agree on main project goals, and third, the team should assign its members to project roles. These tasks were given to all groups. While the control groups could only communicate using pure text chat (in Skype), the experimental groups using 3D CVE (an OpenSim environment) could use all the functionality our virtual environment offered, including the inherent text chat functionality (no voice communication was used). Our OpenSim environment was structured and supported the tasks as described in the following:

Upon login, all participants landed at the location for the first task (shown in Figure 1), facing a signboard on which the main instructions for the first task were given, namely to introduce and present oneself to the other team mates. Each avatar's appearance corresponded to the profile information given to each participant (in terms of age, profession or hobby).

For the *first task* of introducing all the team members to each other, the participants were provided with one table each, on top of which informative objects had been put that helped each subject present its persona to the others (see Figure 2). These objects included a computer with a web portal loaded on the screen for the person with a web publishing hobby, books and chalk for the team member who had a teaching and writing background, or two editions of economic newspapers for the person having worked in Journalism. For the person having worked on housing mortgages a thesis document and a number of houses had been placed on a table. Each participant introduced him- or herself through the text chat function, and by activating customized gestures (mostly used for hobbies; e.g. a tennis serve, dancing, and kick boxing moves).

Figure 1: Entry point and location for the first task in the OpenSim environment

Figure 2: One of the team members presenting himself to the others, with help of personal objects

As each participant began to type and to reveal information about his or her persona, the curtain around his or her own table began to fade automatically (the other curtains closed), thus revealing to the others the objects that illustrated the participants' background. The presentation task lasted for approximately 10 minutes and allowed the team members to learn about each participant's background (important information for the final task: assigning people to project roles). In the far corner of this first meeting location, the participants could see a signpost board pointing to a path that lead to the next task location (seen in Figure 1). Thus, from this first location, the participants then moved on to the second meeting place in order to discuss the project's main goals. All five team members thus walked along the path, leaving the tables and their objects behind, and re-gathering in front of a large target or bull's eye sign, a moment later.

Having arrived at the location for the *second task*, the participants could see another signboard indicating that they needed to discuss the project's goals. The brief instructions also indicated how to capture the main goals on the target board (see Figure 3). Again, there was a signpost and a pathway in the background that indicated where the participants needed to walk once they had completed the project scope discussion and documented it on the large bull's eye canvas. The time given for this task was also approximately 10 minutes.

After their second walk on a pathway, the participants reached the final meeting destination for the *third task*. This meeting spot contained four artifacts: a set of bricks representing the web development or construction role, a megaphone representing the marketing role, a white canvas representing the content and graphic design role, and a top hat, representing the project leader role. While the first three objects were fixed to the ground and connected with three color-coded lines, the top hat was placed in the middle. The participants were instructed (again with a wooden board at the entrance of the area) to position their avatar near the one or two roles that they agreed made sense for their profile (for a description of this collaboration pattern see 'Spatial Group Configuration' in Schmeil and Eppler 2009b; see also Friedman et al. 2007). The person that was decided to be the project leader needed to take the top hat, wear it, and also position him-/herself close to one or in between two roles (see Figure 4). In this way each participant was able to assume the relevant/matching project role(s). With this positioning, the participants had completed their final task, as well as the overall mission of the team meeting.

Figure 3: Project team discussing the project scope to fulfill the second task (with interface)

Figure 4: Project team during the assignment of roles by positioning their avatars (with interface)

3.3 Measurements

Before beginning the experiment task, the participants were given a first questionnaire gathering some demographic data about them including age, gender, mother tongue, and the subjective amount of prior experience in using text chat, and in using 3D virtual environments. An accompanying sheet gave all the required information about the collaboration tasks, the (fictitious) project context, as well as the detailed description of one of the five profiles that was to impersonate.

The dependent variables were measured with both objective and subjective measures. In detail:

- Satisfaction: with process and with outcome. Subjective measures through a post-task questionnaire, the questions of which were oriented by pre-validated scales (Briggs et al. 2006).
- Productivity: subjective measures and open questions through a post-task questionnaire.
- Retention: quantity of recalled items, of team mates' profiles and of team decisions made in the collaboration meeting.

Directly after completion of the collaboration tasks the participants were asked to log out of the virtual environment, or to close the text chat, respectively. They were handed a second questionnaire for subjective measurements: satisfaction with the collaboration outcome, the process, the media that was used, and the motivation/willingness to use the media for collaboration tasks again. In addition to seven-level Likert scales (Likert 1932) we used open questions to get the participants' subjective assessments and opinions about the relatively new media of 3D CVE and its use.

The retention was measured about 20 minutes after the experiment (after a diversion task), by a questionnaire that had not been announced before. This third questionnaire included two empty tables, merely with headings that structured the recalled items. The participants were asked to fill in all the information about their team mates they could recall into the first table, and make crosses in the second table to represent the assignment of project roles to team mates, as far as they could

remember. For this first experiment in a series of experiments (as described in section 2), we decided to use questionnaires instead of longitudinal behavioral data (Yee and Bailenson 2008); we did not expect data of avatar navigation and view control to be meaningful, given that the experiment was designed without any introduction and training prior to using 3D CVE (for a discussion of these two methods of analysis see Schroeder et al. 2006).

4. Results

A first questionnaire was filled in by the participants for us to get their demographics; our subjects were 50 bachelor, master and PhD students with 11 different mother tongues, and of an average age of 25.0 years. 48 of 50 stated they had had prior experience in team work. We also asked about their prior experience in both the media that were to compare, yielding a significant higher result for pure text chat than for 3D environments – on a scale from -3 (no experience) to 3 (a lot of experience) the average results were 0.8 for text chat and -1.5 for three-dimensional environments or video games. This difference is graphed as the leftmost column pair in Figure 5.

The analysis of the main measurements of the experiment was done in three parts. The first part was the analysis of the second questionnaire – using descriptive statistics methods. Having used the same scale from -3 (totally disagree) to +3 (totally agree) for all items, we switched the polarization of some items for the illustration in figure 5 in a way that for every item the positive value is upwards (the higher, the better).

For the items *Common Understanding* (if and how fast a common understanding was reached), *Personal Conflicts* (if there were any conflicts that distracted from communicating and collaborating), and *Perceived Performance* ("I performed well" and "My team mates performed well") the results were equal for both the experimental groups and the control groups. *Satisfaction* (satisfaction of both process and outcome, which yielded the same results) was rated a notch higher by the text chat groups, whereas for the item *Self-Presentation* (the perceived quality of the possibilities to present oneself to others in the online meeting), the results show a significantly more positive assessment by the 3D CVE groups. The *Role Assignment* item (if and how straightforward project roles could be assigned) showed very positive results for both conditions, with a little advantage on the side of the virtual environment condition. For *Media feel/re-use* (how comfortable participants were in using the media), there is an advantage for the text chat groups, as well as for the item *On Topic* (the perceived probability to stay on topic and not get distracted). The second significant difference that could be measured was for the item *No Communication Difficulties* (determining whether communication was problematic), which yielded a much more positive result for the text chat groups.

For the interpretation of these results, we have to bear in mind the novelty effect of the 3D CVE medium: the *Experience with Media* comparison shows that text chat is much more widespread than virtual environments, and participants' comments also confirmed that the majority feels more comfortable in text chat, while some even stated a feeling of confusion when entering the three-dimensional virtual space. We expected this novelty effect to be visible in the questionnaire results and believe it to bias the results in favor of text chat, and indeed some observed phenomena can be explained with it. So does it seem logical that *Satisfaction* is biased negatively by discomfort and confusedness many participants felt that were using 3D CVE. The subjective conception of the 3D environment (which we called *Media Feel*) and the participants' willingness to deliberately use the media for future collaboration tasks with colleagues or peers (*Media Re-use*) is also likely to be influenced significantly by the novelty effect of the 3D environment. Again here, participants commented their answers by stating that they did not feel at ease or that the medium was unfamiliar, and thus confirmed our interpretation of the novelty effect. The biggest differences in the comparison chart in Figure 5 is the better result in *No Communication Difficulties* and *On-Topic* for the text chat groups – meaning that there were more difficulties for communication in the 3D CVE groups, and that they got distracted more often, causing the effect to talk off-topic. Unfortunately, this question had no free-text comment option in the questionnaire which could have confirmed our interpretation, but the possibility of the novelty effect causing a notable bias also here seems logical. On the other hand, there are two measurements that showed a more positive value for the 3D CVE groups; firstly, the participants confirmed one of our main hypotheses, namely that the media richness and particular characteristics of a 3D multi-user environment improves *Self-Presentation,* and secondly, a higher satisfaction value for *Role Assignment* for the 3D collaboration groups was yielded. How far these measurements are biased by the novelty effect is unclear, and could thus be focus of future experiments.

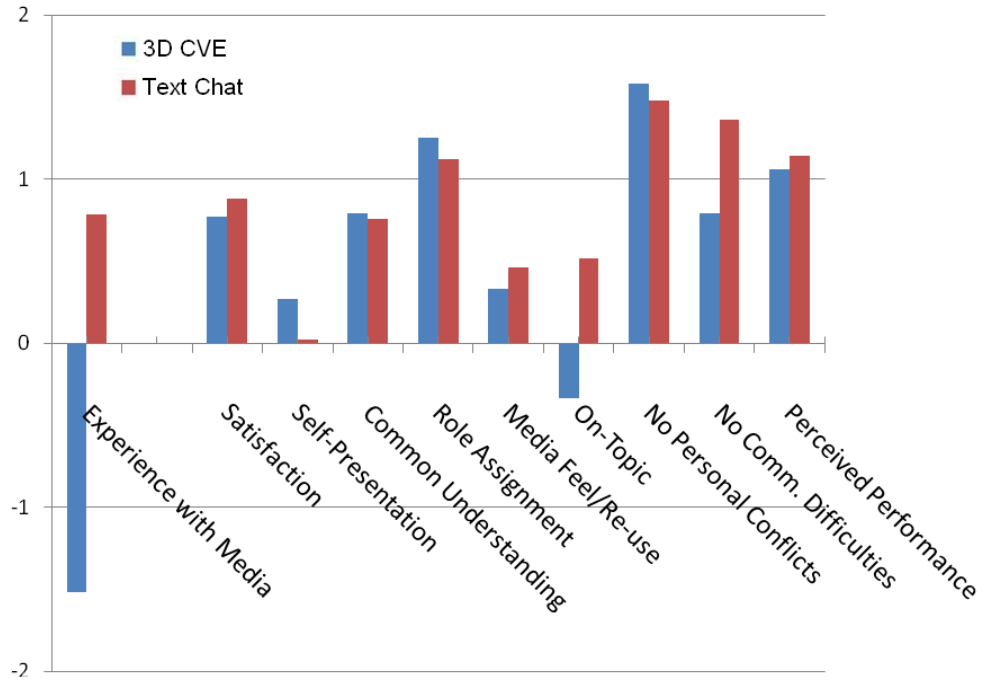

Figure 5: Means comparison of the subjective part of the questionnaire (value range of original vertical axis from -3: very negative through 3: very positive)

The second main part of the analysis was the coding and numeric comparison of the items the participants had recalled from the meeting. In the coded results, each correctly recalled item was marked (for the age value an age interval of 8 years surrounding the actual age of the persona was interpreted as correct answer). These as correct marked items were counted and put into comparison; the results are illustrated in Figure 6. The graph shows a very clear result: the groups using 3D collaborative virtual environments could remember more items about their team mates' profiles, for all the personas, and also about the decisions made in the role assignment task (the unit of the vertical axis denotes the number of items recalled in total). This result proves one of our main hypotheses, namely that 3D multi-user virtual environments improve the recall of information and knowledge shared or created (decided upon) in a meeting in the environment, as opposed to online text chat.

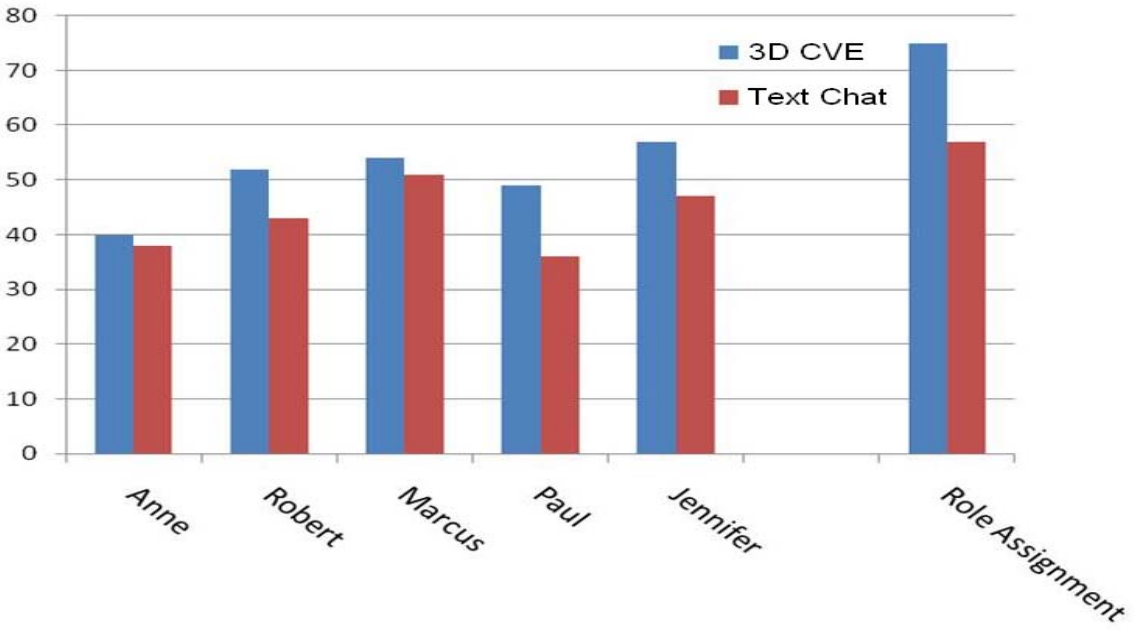

Figure 6: Objective retention measurements: recall of team mates' profiles and final role assignment

The third and last part was a qualitative content analysis of the chat logs of both media environments. Seven of ten teams communicated in English, three in the Italian language. A team meeting had a length of about 40 minutes in average, and consisted of about 1200 chat lines (these values are equal for both media). A first difference in chat usage we could observe was that participants in the 3D virtual environment entered shorter messages, but entered them more frequently than those participants in pure text chat. The use of emoticons was slightly higher in the text chat groups (7.8 emoticons in average per meeting, compared to 6.6 in the 3D CVE). The usage of capitalized text (usually for emphasis of speech, to 'shout') was used 2.2 times in average in the text chat, and only 0.8 times in an average virtual environment meeting. Participants were interrupted by their virtual team mates more often in the simple text chat condition (3.6 times in average, 1.0 times in CVE). We counted 14 deictic references in average in a meeting in the virtual environment (in the text chat groups, there were none – deictic references are not applicable with pure text only).

Participants further stated in the open comment sections in the questionnaires that the pure text chat was often unstructured; 3D CVE users did not comment that once. Thus, it indicates that the concept of space and the environment design we used (above all the spatial separation of tasks with pathways) helped to structure the conversation and the team meeting in general. In debriefing sessions that were held in lectures of the students' master and bachelor programs, several participants confirmed that the several visual cues of different nature that were provided in the 3D collaborative virtual environment helped to memorize both information about the other participants and the decisions that were made during the online team collaboration meeting.

5. Limitations of this study and research outlook

For this first in a series of experiments we had only 50 participants, breaking down to five experimental groups and five control groups. Besides aiming at giving first results about the usefulness of 3D CVE for collaboration tasks we could test our environment and got valuable insights into conducting experiments with this media.

One negative outcome of the conduction of the experiment was that the presence (or rather the absence) of the class's professor was reflected in the results of the satisfaction and the objective retention measurements. Although it occurred for the same amount of groups for the two conditions and thus should not have had too much of an influence on the results, this variable should be kept constant in future experiments. Also, another improvement would be to use pre-validated scales for the questionnaires.

Our current work is preparing to replicate the experiments with more students from classes at other universities (in Switzerland as well as in Denmark), and after that also with managers with professional experience. The analyses of these experiments will include an inferential statistical analysis (factorial analysis / ANOVA). We are also thinking of applying a thorough multi-level analysis; it might be feasible to regard both individual and team levels, once we have a higher number of participants. In another ongoing project, the ShanghAI Lectures (http://shanghailectures.org) we are recording and analyzing longitudinal behavioral data of intercultural student teams collaborating in a 3D CVE; there we are also using another 3D virtual environment platform (Hasler et al. 2009).

For future work, we plan to move the focus of our research towards the design of the virtual environment and the collaboration in it. On that end, we are planning to compare different collaboration patterns in the same 3D collaborative virtual environment. In that new round of experiments we will also try to minimize the novelty effect that we believe was prominent in the presented results by training the participants in the use of 3D CVE before starting the collaboration tasks.

6. Conclusion

The presented work was a first experiment in a series of experiments, aiming to yield first empirical results to the question *if* 3D virtual environments can add real value to online collaboration. In spite of a noticeable novelty effect of the media which we believe has put a negative bias on the results of the 3D CVE groups, our hypothesis that being virtually embodied in a configurable 3D collaborative environment improves retention, was confirmed. Another finding was that the meetings in our virtual environment were found to be more structured. On the other hand, pure text chat was rated more positive in many subjective assessments, including communication difficulties, distraction probability, and also satisfaction with the meeting. For research, these results give motivation and purpose to

investigating collaboration in 3D virtual environments, by showing first experimental evidence that this medium brings real added value. In our belief outcomes other than retention can be evaluated using similar experiment designs. Implications of the study at hand for collaboration practice include the motivation to promote 3D CVE for collaboration tasks, and a verification of the importance of a structured design of collaboration tasks.

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