Strangers and Friends in Caves: An Exploratory Study of Collaboration in Networked IPT Systems for Extended Periods of Time

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Abstract

This study examines pairs of subjects who used networked immersive projection technology systems to collaborate on five tasks over an extended period of time (210+ minutes). The aim was to compare zero history and mutual history partners, to examine how their experience changed over time, and compare their experience of different tasks. Analysis yields a number of interesting findings for these comparisons. Overall, the study shows that users could collaborate effectively over an extended period of time, but that understanding the intentions and activities of the other person remained a hindrance.

CR Categories: I.3.7 [Computer Graphics]: Three-Dimensional Graphics and Realism—Virtual Reality; H.5.2 [Information Interfaces and Presentation]: User Interfaces—Evaluation/Methodology;

Keywords: Immersive projection technology, virtual environments, collaboration, long-term use, task analysis

1 Introduction and Aim

The aim of our study was to examine how two people collaborate for an extended period of time in highly immersive virtual environments (VEs); in this case, networked immersive projection technology systems (IPTs, also known as walk-in virtual reality (VR) systems or CAVE systems [Cruz-Neira et al. 1992]).

There were three facets to the study:

1. To compare how zero history partners (strangers) and mutual history partners who knew each other very well (friends) use networked IPT technology. This aspect of the research arises from a shortcoming that has been identified in studies of Computer-Supported-Cooperative Work (CSCW) and computer-mediated communication (CMC) generally [Scott 1999]; which is that in most experimental studies, subjects don't know each other - whereas in actual CSCW and CMC settings, the collaborating partners will usually know each other.

2. To examine extended usage of networked IPTs. If people use collaborative immersive VEs for an extended period of time, how might their experience change over time? The use of immersive collaborative VEs (CVEs) for extended periods of time has so far not been studied.

3. To compare the subject's experience of different tasks in networked IPTs. Most CVE studies to date have consisted of doing a single task, and we know little about how the experience of collaboration varies between different types of tasks.

The reason for this type of study is that it can be envisioned that in the future shared immersive VE systems will be used on a more regular basis for periods lasting several hours.

2 Previous Studies

Long-term uses of CVEs have only been studied rarely, and studies of networked IPTs are also quite rare. We do not have the space here to review these long-term studies [Nilsson et al. 2002], and other studies relevant to our analysis of CVEs [Churchill et al. 2001; Schroeder 2002], though we note that the combination of long-term use and immersive systems has not to our knowledge been studied in depth.

One limitation in using immersive VE systems for long periods of time has, of course, been the health and safety issues of using systems such as head-mounted displays for long periods of time [Stanney et al. 1998]. Our knowledge about longer-term uses of CVEs comes mainly from desktop VEs that are mainly used for socializing. See Nilsson et al. [2002] for a study of ActiveWorlds and see Tromp et al. [1998] for an analysis of a series of regular meetings in the COVEN project.

We are aware that 210 minutes is an arbitrary length to designate as an 'extended period of time' or as 'long-term use'. Having said this, it is a quite typical period of time if we consider how long people often spend together in a variety of collaborative work and other social situations.

3 Method and Study Design

We used questionnaires with Likert-scales and written answers administered after each task and debriefing interviews at the end of the day. We also made video and audio recordings of the sessions for later analysis. The IPT systems used were a five-sided TAN VR-CUBE at Chalmers University and a four-sided Trimension ReaCTor at University College London. All the worlds were implemented in a customised version of the DIVE system [Steed et al. 2001]. This provides joystick-based locomotion and ray-based selection and manipulation that was the same for all the tasks described below. The DIVE software was also configured to provide an avatar with jointed arm animation, but no facial animation. Both IPT systems tracked the head and one hand. For reasons

*The order of the authors' names is arbitrary; this was a fully collaborative effort.

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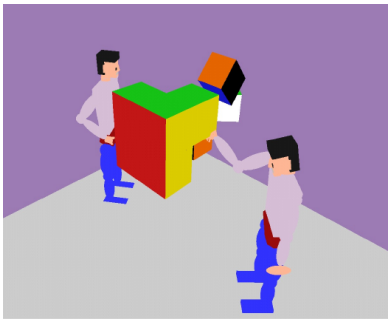

Figure 1: Rubik's Cube Puzzle

Figure 2: Landscape

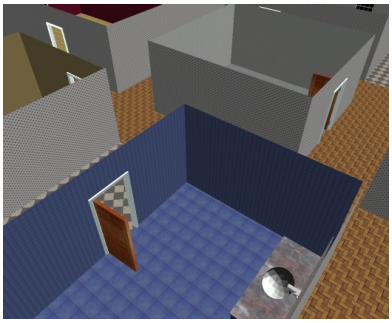

Figure 3: WhoDo Mansion

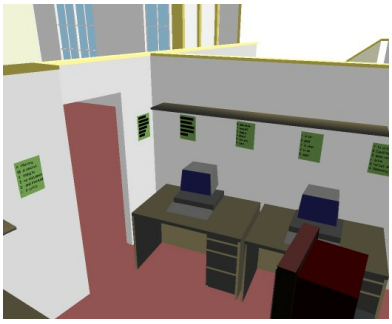

Figure 4: Poster World

of space, we do not include fuller descriptions of hardware, software input/output devices, and network connections here, but see Schroeder et al. [2001].

There were five pairs, two mutual history and three zero history. Each pair spent at least 210 minutes doing the five tasks together. The longest time that one pair spent together was 230 minutes. For a third mutual history pair, the trial was stopped approximately halfway through because both partners experienced severe nausea and anxiety. In this pair one of the subjects may have been experiencing, but not reporting, some symptoms before commencing the trial. The other ten subjects only reported minor discomfort after the individual tasks and after completion of all the tasks, and this is itself an interesting result.

Subjects took a break of between 15 and 20 minutes between each task, and a longer lunch break of between 60 and 90 minutes between the first two and the other three tasks. The times that pairs spent for each task session were between 25 and 70 minutes, with most tasks falling into the middle 40 to 60 minute range. We were not interested in task performance per se, so subjects were encouraged to repeat the tasks if they completed quickly.

All subjects first entered an open environment with portals to the various task environments described below. Before embarking on the task, they were given a chance to familiarize themselves briefly with using the system, and to get acquainted with their partners. All pairs of subjects carried out the tasks in the same order. The order of environments they entered and the tasks they carried out were as follows:

- Rubik's Cube Puzzle. The task was to do a small-scale version of the popular Rubik's cube puzzle. Subjects had to assemble eight blocks with different colours on each side to form a single cube with each side a single colour. See Figure 1.

- Landscape. The environment in this case was a small townscape with surrounding countryside ringed by mountains. Subjects were instructed to familiarize themselves with this landscape and count the number of buildings. They were also told that they would be asked to draw a map of the environment at the end of the task. See Figure 2.

- Whodo. This task was based on the popular 'who-dunnit' board game Cluedo or Clue. The subjects were asked to find five murder weapons and five suspects in a building with nine rooms. They needed to locate the murder victim's body and find and eliminate weapons and suspects. See Figure 3.

- Poster World. This environment consisted of a room with ten posters pasted on the walls. Each poster contained fragments from six different sentences. When all the fragments were collected from the ten posters and put in the right order, they would make a popular saying or phrase. See Figure 4.

- Modelling World. This environment contained 96 shapes in six different colours. The subjects were told to make a building or model of a building to be entered into an architectural competition. See Figure 5.

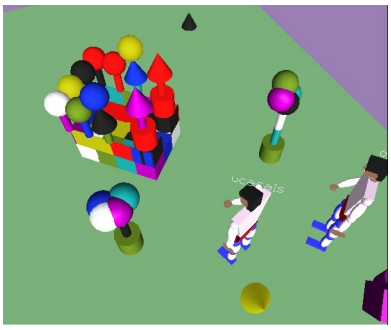

Figure 5: Modelling World

The tasks therefore ranged from an almost entirely verbal task with a fixed goal (Poster World) to an open-ended task which involved lots of locomotion and manipulation of objects (Modelling World). The Rubik's Cube and Modelling World tasks required close collaboration since both required co-ordinated manipulation of objects. The Poster World task required close verbal collaboration because the sentences were usually too complicated to rearrange on one's own. The WhoDo and Landscape tasks did not actually require close collaboration, but never the less subjects did collaborate by, for example, following one another and giving verbal and gestural directions.

4 Results

The results presented here are preliminary and based only on a few of the questionnaire responses, interviews and observations. It is important to point out that the small number of subjects does not allow us to draw quantitative conclusions from this study. However, it hardly needs to be added that even with 12 subjects, this study was highly resource-intensive. However, by combining the subjects' questionnaire responses and interview answers with our observations, we hope to be able to provide a reliable analysis of their experiences.

4.1 Mutual Awareness

If we compare zero history (strangers) with mutual history (friends) pairs, and based on subjects' responses combined with our observations, we can say that the questionnaire responses on the Likert-scale questions were similar for most questions for both types of pairs, apart from one question: For 'How would you rate your awareness of your partner's intentions/wishes in this task?' on a 5 point scale from '5. very high awareness' to '1. very low awareness', strangers reported a somewhat lower awareness than friends (mean for all 5 tasks strangers, 3.37; for friends 4.35).

From written replies to our questionnaire, it is evident that friends commented more extensively on the task and how they coped with doing the task together, whereas strangers commented more extensively on their partners and how they coped with, or found it difficult to cope with, the other person. Typical responses to the question 'what did you enjoy most and least about doing these tasks together?' include, from strangers, 'cool to be able to work together', but also 'the lack of body language makes communication harder'; and for friends, 'performing it [the task] together', and 'good to have her with me'. To the question 'what did you find hardest to do together with the other person', the answers from strangers included 'to make him understand my ideas', and from friends, 'difficult to agree' and 'get him to understand which direction I meant'. Our own observations add another dimension to this point: mutual history pairs engaged in much more small talk that was unrelated to the task.

This finding can also be put the other way around: it might be expected from other studies of CMC and CSCW that zero history and mutual history pairs might be quite different in terms of how much they enjoy the collaboration and feel at ease with one another. It is therefore surprising that in this setting, our finding is that there is little difference between the two types of pairs. With the exception of some key differences in certain aspects (aspects which are obvious, i.e. awareness of each others' intentions and small talk among friends), we found that on the whole, their experiences were rather similar. We would argue that this absence of a major difference is itself a significant finding, with possible implications for the design of VEs and for what kinds of people, strangers or friends, most benefit from using them.

4.2 Collaboration Over an Extended Period of Time

When it comes to how their experience was affected by spending an extended period in this setting, and how their experience changed over time, it was striking that the subjects were not exceptionally tired at the end of the day, and at the same time that they found it difficult to stop themselves from continuing with the tasks. It was easiest to discontinue where the task had an obvious end point (Rubik's Cube) and hardest where it was open-ended (Modelling World).

One pair of strangers deserves to be singled out for a brief description of their relationship over time. This pair started out by reporting in the questionnaire after the first task that their collaboration was poor, and thereafter they continued in this vein throughout the remaining four tasks. The responses, coming from both partners, are full of comments like 'there was no real cooperation', 'I didn't know what he was doing', or I 'can't really relate to him'. These responses are quite unlike the responses from the other four pairs, who if they commented, commented favourably on their collaboration. In such cases of poor interpersonal rapport, we would argue that it is difficult to improve rapport in networked IPTs and create a jointly enjoyable experience even over the course of long working session. The absence of social cues, or in this case of interpersonal ones, seems to be the main cause here. The absence of interpersonal rapport did not, on the other hand, seem to affect their ability to complete or carry out the tasks together. An implication for structuring this type of session is that networked IPTs may lend themselves to effective collaboration, but they may not lend themselves to coping well with interpersonal aspects of collaboration.

4.3 Rating Tasks by Pleasantness and Difficulty

For which task they rated as most pleasant or unpleasant, the responses of strangers and friends did not show any clear differences. Nor is there a pattern over the course of the five tasks which might indicate, for example, increasing fatigue. At the end of the trial, we asked participants to rank the tasks in various ways. When we asked them to 'rank the environments in terms of how enjoyable you think they were', the Whodo was ranked highest by 6 subjects and the Modelling World by 4 subjects. The least enjoyable for 7 subjects was the Landscape.

When we asked subjects at the end of the trial to rate the tasks by difficulty, Whodo was ranked easiest by 5 subjects and Modelling World by 5 subjects. The tasks that were rated most difficult were Rubik's Cube for 6 subjects and Landscape for 4 subjects. Note again that this ranking does not correspond to the order of the tasks during the day. Thus the environments and tasks that were rated easiest (Modelling World, Whodo) were also rated highest in terms of the enjoyment of the environment. Again, there may be design implications: creative, open-ended, sociable and simple tasks may be easier to support in networked IPTs than those tasks which require more analysis and spatial coordination, that are more closed, that are less sociable and harder.

As we have seen, there was no difference between ratings for strangers and friends, or between earlier as opposed to later tasks. There was, however, a difference between the IPT in Gothenburg where tasks were regarded as being more difficult than the London IPT. Here, we suggest that the main factor is likely to be the better display contrast of the London IPT system. Several responses to our questionnaire support this. For example, in response to 'if you could change/improve a feature of the environment, what would it be?', the subjects in the Gothenburg IPT suggested 'picture quality!', 'no 3D feeling, everything was like a film projected onto a screen', 'sharpness' and 'poor contrast'. The London subjects did not comment on the image quality, but rather on specific features of the environment or interaction techniques.

A more general observation that we could make was that doing tasks such moving around and manipulating objects was easy for the subjects, whereas negotiating, keeping track of the other person and coordinating who is doing what was hard. This is a finding that has been obtained for desktop CVEs [Hindmarsh et al. 1998], but we would not necessarily have expected it for IPT systems. Although body gestures are conveyed through tracking we still found that the absence of face-to-face cues and quality of the audio channel hindered flowing conversations. We observed problems with subjects' negotiating agreement about how to go about tasks or deciding whether a suggestion had been agreed upon or not. Physical bodies and environments allow us to keep track of other people's locations easily and accurately, but in shared IPTs the lack of a detailed and rich visual environment, body noises and the like means that it is difficult to monitor one's partner.

5 Conclusions and Future Work

Before we conclude, it is worth re-stating that the aim of the study was not to measure task completion time and subject performance but to allow participants to engage with each other for long periods and to place them in a situation that is closer to the natural setting in which longer-term networked collaboration might take place. Our study demonstrates that novice users can collaborate for extended periods of time within networked IPTs.

In our study we found that subjects collaborated intuitively and the networked environment lent itself particularly well to highly spatial and highly interactive tasks. The subjects generally found it easy to do the spatial parts of the task, being able to use their whole bodies to collaborate and thus avoiding many of the problems that have been identified for collaboration in desktop CVE systems where participants can use their bodies in only limited ways. Nevertheless, several subjects, and especially the zero history pairs, reported that they found negotiating tasks harder because of the absence of facial expressions.

Our main hypothesis in this study, that strangers would collaborate and behave differently from friends in a networked IPT setting, was on the whole not supported. The exception was reported awareness of one's partner's intentions. Apart from this, their reports of enjoyment, and other comments in the questionnaire about their collaboration and partners, did not provide evidence of great differences between the two types of pairs. One implication for future studies is that it would be interesting to see if this result holds up even for cases where partners have photo-realistic images of each other, which might enhance the familiarity between friends but produce no greater estrangement among strangers.

Our second aim, to examine whether the subjects' experience changed over the course of an extended period, also yielded unexpected results. Among the five pairs who completed the tasks, there was no sign of fatigue or of other notable changes in the interaction between partners. Nevertheless, it would be helpful to improve the users' awareness of the length of time they are spending, not only for health and safety reasons [Stanney et al. 1998], but also so that users can pace themselves better and optimise the alternation of collaboration and breaks.

We also found a number of important differences between types of tasks and their experience of collaboration. Some of the differences that we have identified such as whether tasks are more narrow and require more joint coordination as against more sociable and creative tasks could usefully be pursued further in future work.

It might be thought to be obvious that sociable, creative, and open-ended tasks might be preferred to less sociable, more instrumental, and more clearly structured ones. But this should not be taken for granted in longer-term uses of CVEs. In a previous study with a different scenario [Nilsson et al. 2002], we found that more structured tasks were in many respects more enjoyble. Here should bear in mind that short instrumental tasks will have different patterns of collaboration from open-ended longer-term collaboration. We should also bear in mind in future studies that we expected, but did not find, that problems with understanding the other person's intentions would diminish over time.

Finally, perhaps the most important finding for the purposes of directing research in interactive, immersive graphics is that users were able to do the tasks quite easily and did not think the interface itself was a problem. This is a finding in line with similar findings with non-immersive CSCW systems, for example [Hindmarsh et al. 1998]. However, until now most research in immersive systems has focused on single-user interaction without consideration of the role of interaction in communicating to other collaborating users.

References

CHURCHILL, E., SNOWDON, D., AND MUNRO, A., Eds. 2001. *Collaborative Virtual Environments: Digital Places and Spaces for Interaction*. London: Springer.

CRUZ-NEIRA, C., SANDIN, D. J., DEFANTI, T. A., KENYON, R. V., AND HART, J. C. 1992. The CAVE: audio visual experience automatic virtual environment. *Communications of the ACM 35*, 6, 64–72.

HINDMARSH, J., FRASER, M., HEATH, C., BENFORD, S., AND GREENHALGH, C. 1998. Fragmented interaction: Establishing mutual orientation in virtual environments. In *Proceedings of CSCW'98*, New York: ACM, 217–226.

NILSSON, A., HELDEL, I., AXELSSON, A.-S., AND SCHROEDER, R. 2002. The long-term uses of shared virtual environments: An exploratory study. In *The Social Life of Avatars: Presence and Interaction in Shared Virtual Environments*. London: Springer, 112–126.

SCHROEDER, R., STEED, A., AXELSSON, A.-S., HELDAL, I., ABELIN, A., WIDESTROM, J., NILSSON, A., AND SLATER, M. 2001. Collaborating in networked immersive spaces: as good as being there together? *Computers & Graphics 25*, 5, 781–788.

SCHROEDER, R., Ed. 2002. *The Social Life of Avatars: Presence and Interaction in Shared Virtual Environments*. London: Springer.

SCOTT, C. R. 1999. Communication technology and group communication. In *The Handbook of Group Communication Theory and Research*, L. R. Frey, Ed. Thousand Oaks, CA: Sage, 432–472.

STANNEY, K. M., MOURANT, R. R., AND KENNEDY, R. S. 1998. Human factors issues in virtual environments: A review of the literature. *Presence: Teleoperators and Virtual Environments 7*, 4, 327–351.

STEED, A., MORTENSEN, J., AND FRECON, E. 2001. Spelunking: Experiences using the dive system on cave-like platforms. In *Immersive Projection Technologies and Virtual Environments*, Wien: Springer-Verlag, F. B., J. Deisinger, and H. Bullinger, Eds., 153–164.

TROMP, J., STEED, A., FRECON, E., BULLOCK, A., SADAGIC, A., AND SLATER, M. 1998. Small group behaviour in the COVEN project. *IEEE Computer Graphics and Applications 18*, 6, 53–63.