Chapter 10 Reflections on Experimental Results

> "The [interactive systems designer] creates not just a set of scenes but a world of narrative possibilities."
>
> Murray, (1997).

Chapter 10: Reflections on Experimental Results

This chapter reviews and compares the results from the experiments with key-issues from the review of collaborative activities, key-problem predictions for CVE usability as derived from the HTA of collaboration, and key-issues about CVE usability as identified through the COVEN usability studies.

10.1 Introduction

This chapter concludes the analysis of the experimental work presented in this thesis by comparing the results from the experiments with the key-issues from the review of collaborative activities as they were described in Chapter 3. Furthermore, it discusses the match between the CVE usability properties identified through the HTA of collaboration (as described in Chapter 7), with the results from the experiments, and with the results from the COVEN usability findings. Next, it identifies and discusses four main CVE usability design recommendations, derived from the analyses of all research findings presented in this thesis. Finally, it presents all CVE usability design guidelines as created by the author during the COVEN project, amended with the results from the research presented in this thesis.

The next section (10.2) describes the experimental results as compared to the collaboration theories, the usability properties derived from the HTA of collaboration, and the COVEN usability findings. The four main CVE usability design recommendations are outlined and discussed in section 10.3. Section 10.4 presents CVE usability design guidelines. Finally, section 10.5 presents conclusions about CVE usability and CVE design.

10.2 Discussion of Experimental Results

In order to analyse the experimental results more closely in the light of the other explorations of CVE collaboration that were made, a comparison is made between the experimental findings and the other information on collaboration in CVEs that has been described in this thesis. First the data are compared to the collaboration theories (section 10.2.1), next they are compared to the predictions of usability problems derived from the HTA of collaboration (section 10.2.2), and finally the data are analysed against the key-findings of the COVEN Project (section 10.2.3).

10.2.1 Social Collaborative Activities

In order to discuss the collaboration theories (as summarised in table 3.1), the author has made an analysis of the responses to the longitudinal COVEN network trials questionnaire and the interviews with CVE users (see appendix D). There is an obvious match between the elements of social conduct during collaborative activities and the experimental data (see table 10.1). The table shows the social behaviours in the left hand column, and the predicted collaboration categories, by top-category in the following columns. When a top-category can be said to be part of a social behaviour they are marked with an 'X'.

Social Behaviour	Communicate	External	Gesture	Manipulate	Navigate	Position	Scan	Verify
Verbal Communication	X							
Phatic Communication	X							
Spatial Regulation					X	X		
Proxemic Shifts		X			X	X		

Co-Verbal Behaviour			X					
Turn-Signal	X		X	X				X
Peripheral Awareness		X					X	
Trust Building					X	X		X
Reciprocity	X			X	X	X	X	
Indexicality	X		X					

Table 10.1: Social behavioural repertoire mapped onto collaboration categories.

As evoked in chapter five the social behaviours which CVE users will be trying to employ and express to collaborate are intentional. In this exploratory research these social behaviours have not been ‘measured’ directly (see table 10.1). However, the expected social behaviours can be compared to the observed CVE user behaviours, and illustrated with information gathered from longitudinal user attitude elicitation and interviews. During the COVEN project network trials longitudinal questionnaires and interviews with CVE users were employed, which addressed collaboration issues (see Appendix D for the respective questions). The answers have been analysed specifically to give an insight in how the relatively abstract notions of collaboration as they were implemented in the COVEN CVE, were experienced by the users while attempting to collaborate. Their personal observations illustrate in telling detail what impact of the design had on the perceived usability of the CVE for collaboration. Out of consideration for the anonymity of the respondents to the research presented in this chapter. Appendix D contains only the questions used for the longitudinal questionnaires. The full replies to the questionnaires and interviews are available from the author on request. The analyses of the user’s opinions are presented below (section 10.2.1.1 to 10.2.1.10). To preserve anonymity, each quote is referenced by a code for each participant. Quotes from the questionnaire replies are coded as follows:

Rx, where x is a number, Ix the respective institutions (where x is a character), and the date at which it was received. For the interview responses: ID xxx, where x is a number. Ellipsis and those parts of quotes that had to be amended to preserve their meaning out of the context of the complete questionnaire replies, are surrounded by square brackets.

10.2.1.1 Verbal communication

Roughly 50% of the collaboration process seems to consist of verbal utterances and given this high percentage, it would be important to support this type of act as effectively as possible. Due to network congestion audio transmissions can break up, which means that it can become more difficult to be understood, more difficult to understand other speakers, and more difficult to follow the flow of the discourse between participants.

> *R 3, I C, Sep 17 11:49:59 1998*: "*[C]hoppy audio reduced confidence in communication"*

The flow of the discourse gets interrupted more often with requests for repetitions of inaudible communications, which exacerbates the problems in establishing a common frame of reference.

> *ID 106: "[Two] people talking at the same time is impossible to understand. We could do with a co-sign, of who's going to talk next or something. It becomes a vicious circle. Both talk at the same time, and we all say what? At the same time, than we all answer, at the same time, and we all have to go What? Again.."*

The common language during the CVE interactions was English, but some of the participants in the experiments were not native English speakers. This is another potentially complicating factor for the success of CVE collaborations with an international user population, especially when the audio reception is not good.

ID 114b: "The bloke had an accent, so I was not sure whether he understood me at all."

ID 113: "[X] was a bit out of it, audio was bad, I was never sure whether she had heard us. This also due to her language, she seemed non-English, because she had a bit of an accent - just audible."

ID 120: "It was strange – it shows how you can judge people based on their voice alone. I found it easier to communicate with Blue, just because he was English."

Participants can be made to feel rather uncomfortable not knowing whether they are being ignored, or not heard.

R 4, I B, Sep 17 12:20:11 1998: "[My a]udio channel was breaking down in the first part of the trial, and it was completely cut off in the second part. I could see the waves but I could not hear anything. I tried to communicate through text channel but no one replied. I had impression that I was left out completely. Not a nice feeling at all."

R 4, I B, Sep 17 12:20:11 1998: "When [my] audio channel broke up and no one was paying attention to the text windows in which I was typing the questions I felt very bad. [...] I gave up participating [...]."

ID 105: "Communication was really bad, and this wasn't just the audio. In the end we just all went off and tried to solve the [task] on our own."

Another factor that seems to influence verbal communications in CVEs is the fact that CVE participants have to talk fairly loudly and clearly in the microphone in order to be understood in the CVE. This may be very different from their normal speaking manners and might be uncomfortable under some circumstances, for some users.

R 1, I A, Sep 17 11:28:06 1998: "Some people were very easy to hear, others almost silent the whole time. This could be due to hardware problems (I think <X>'s mic was shagged) or just quiet mic manner (<X2> said she was talking but there was not much sign of this in the VE - don't think the mic levels were high enough??)"

Additionally, CVE participants may be sharing their real environment with others who may not be engaged in the same CVE. This can contribute to them feeling shy and keeping quiet more than they might do if they had been alone in their office.

R4, IB, Mar 19 17:51:19 1997: "[M]y computer i.e. desk is in the lab with ~20 other people around and sometimes I find myself either consciously or unconsciously 'restricting' not to speak too loud. Sometimes the consequence is

> *that I do not speak at all for longer periods of time. I believe that presence of other people (I am more aware of them as [this CVE] is not an immersive system) distract me to get immersed to the greater extent, what usually and easily happens with me when I am using some immersive system.”*

10.2.1.2 Phatic communication

There are numerous examples on the video recordings of the experiments, where CVE participants have difficulties initiating an interaction. The display of distant gestures (step two in the opening sequence, see section 3.2.6), is limited to verbal indicators in CVEs and participants can indeed be observed calling, or being called by, another participant from a distance in order to attempt contact. These attempts do not always succeed, and it is difficult for the participants to know whether to attribute this failure to failure of the audio connections at either end, the din of communication inside the CVE, or a deliberate attempt on the part of the other participant to ignore the request.

> *R 6, I B, Jul 7 18:14:49 1999: “At points other users avatars failed to move and they did not respond when hailed even though they were close by. I took this trance-like state to indicate that the real world was demanding some of the player's attention!”*

It may be that CVE users need more time at the beginning of an interaction to find their bearings with the CVE controls, within the CVE and with the other participants, than in a real life situation.

> *R 4, I B, Mar 19 17:51:19 1997: “[I]n the first phase I spend more time trying to adjust my movements and see the way everything 'breathes'.”*

R 4, I B, Jul 29 16:26:51 1998: "While I am navigating I can not hear quite well (I guess it has to do with the order the information are processed) so if I want to listen people and hear what they are saying I have to be stationary. I guess it happened to everyone so if someone is moving I am guessing they can not hear me quite well."

Cordiality (step 3), can only be expressed verbally, due to the absence of most non-verbal expressions. Verbally expressed cordiality can easily get lost in the communications inside a CVE due to language and cultural differences between participants, and due to bad functioning of the audio channel. This means that cordiality in CVEs is very difficult to express, and as it is an essential part of phatic communication this could contribute to interaction problems.

ID 108: "Facial expressions were really lacking. I'd have preferred to have smile. It was the one mostly lacking. Also wave would have been really useful to break the ice in the beginning. It's like meeting someone for the first time, just like RL. You need non-verbal feedback to acknowledge that you've been heard / seen."

ID 124: "I didn't like the blank faces. Depending on the situation I would think a happy face or a face that looks like questioning would be very useful. Especially if you could swap between the two."

Cordiality needs support by non-verbal means, such as endowing the virtual embodiment with expressions appropriate to this phase of the interaction. The virtual embodiments were generally seen as too limited.

> *ID 101: "[My] feeling about the embodiments was that they were too plastic, emotionless and with crap hairstyles. Communication was verbal, the bodies tended to just serve as a reference point for location and orientation."*

> *ID 102: "What really lacked where expressions – the [virtual embodiments] could be any shape! I would like to see expressions because I want to know what they are thinking. The kind of expressions we would need depend on the task. I didn't think much of the [virtual embodiments], they were mostly obstructing the view."*

> *ID 117: "Not being able to shake hands made me feel more detached. Shaking hands might make you feel more there."*

CVE participants try and approach other participants in order to initiate an interaction (step four). However, this effort is not always successful in that other participants may not be aware of this approach due to their small field of view of each part of the CVE at the time, and they move on before the next step of the opening phase (step five: greeting that participant) can be initiated. Additionally, participants may find it more complicated to draw another participants' attention due to lack of support for their normal interaction strategies.

> *ID 106: "I did feel rather shy and self-conscious. What was lacking was the facial expressions, the eye-contact."*

> *R 4, I B, Mar 19 17:51:19 1997: "I find myself analysing what I have done/said/the way I moved, more that I do in real world. Sometimes, especially when I speak I find it strange, like it is not me who is talking (I like when I can make eye contact so the tone of my voice and its volume can adjust accordingly)."*

Step six and seven, taking up a mutual bodily orientation in appropriate postures, and positional adaptations made during the exchange of phatic communications, are difficult to perform in CVEs.

> *ID 118: "It would have been nice if we could've introduced ourselves by shaking hands, if we could move our heads and arms, it would give more of an idea of what the others are doing."*

> *R 6, I B, Jul 7 18:14:49 1999: "I could move from place to place and look in different directions but it was not always 'easy'. Navigation in [COVEN platform] can be a little counter-intuitive and sometimes I had to [try hard] to position myself where I wanted to be."*

The indication of a desire to start the main business of the interaction (step eight), seems to be a decrease in positional adjustments for the time being, decrease in the exchange of phatic communications, and atypically long silences in the communications altogether. It is not easy for participants to display signals that they are ready to get on with the business at hand.

R 4, I B, Sep 17 12:20:11 1998: "[I felt t]here was also lack of coordination and we would wait endlessly for someone to propose something / start action. If there are few people it would not be a problem that much, i.e. it would not happen to such degree. However, when there is a big crowd, someone has to take a command otherwise it becomes quite irritating and you get bored. At least I did."

10.2.1.3 Spatial regulation

Spatial organisation is regulated through the designation, adoption and perception of micro-territories. In the real world, micro-territories range from a few inches in diameter to a few square yards, and they have a wide range of duration. In the CVE strong notions of micro-territories do not seem to exist, although experts and novices alike can be observed to acknowledge the personal space as expressed by their virtual embodiments. Sometimes, remarks are made when one participant moves through the virtual embodiment of another participant (either by accident of by intent).

ID 101: "It did feel uncomfortable walking directly in front of someone, socially uncomfortable like it's not what you are supposed to do."

ID 118: "[X] was uncomfortably close at some point. Even in a VE you don't want someone breathing down your neck!"

> *ID 111: "I felt I had to go around the [avatars] of the others. You can't walk through the body of real people, and yeah it just makes you feel really funny walking through the [avatars]. You also don't want to walk through the furniture, because you can't in RL, but you'd rather walk through the furniture than through the [avatars] of others."*

Since each cultural tradition has its own micro-territorial sizes and arrangements, it can be assumed that the interpretation of territories is a learned behaviour. This means that it may be possible that CVE users adapt to differences in size and size ratios of their virtual embodiment in the virtual space compared to their real body in the real world. There are some indications that virtual rooms have to be bigger than ones in the real world. It seems that due to the small field of view CVE participants need to be able to back up further than in real life, before they can get a good overview of the room and its participants.

> *ID 114b: "The room was too small. Because the field of view was small you wanted to back up and see everybody, but you couldn't because of the wall. You'd fall out of the room."*

> *ID 122: "The VBs should have been smaller for the room, they were okay otherwise."*

10.2.1.4 Proxemic Shifts

Proxemic shifts, changes in topic of conversation accompanied by changes in interpersonal distance and body orientation, can frequently be observed on the video tapes of the experiments. Participants move closer to each other when they want to talk, and closer still when they want to show each other something, or want to look at a shared object. Novices and experts seem to do this alike, if and when the interaction proximity changes that demand a close-up, either to hear each other in the din of other ongoing conversations between other participants, to have a quiet conversation, or to see something some other participant is showing them or discussing.

> *R 6, I B, Jul 7 18:14:49 1999: "[W]e sometimes wanted to look over each others shoulders, but this required some quite complex manoeuvring."*

One problem of proxemic shifts is that if too many participants are trying to view the same small item, they crowd each others view, and can be observed blocking each others view with their virtual embodiment without being immediately aware of the impact of their change of position on the view of others. This would suggest that they are not aware of the precise dimensions of their size and the effect of this in terms of distance to other participants and on the view frustum of other participants.

10.2.1.5 Co-verbal Behaviour

Commonly used turn-taking signals are not available in CVEs and the way participants react to these limits of the technology are not always positive, either for themselves (i.e. participants are observed showing frustration and upset at not getting the collaboration going), or for others (i.e. participants are observed deciding to ignore others who do not seem to react appropriately).

> *ID 121: "It was impossible to tell when to take speaking turns - you had to be careful not to talk on top of each other in the VE, in RL this is much easier."*

ID 106: "Non-verbal communication was lacking and it made it harder to understand what was wrong and how to fix it – it contributed a lot to the breakdown of communication."

ID 124: "I never knew whether I got a reaction or whether they didn't hear me. I felt isolated because of that. The moment they were not moving and not talking is the moment where I would feel like giving up."

10.2.1.7 Peripheral Awareness

The COVEN platform provided users with an 'out of body camera view' onto the virtual world, thus providing the participants with the maximum, currently popular field of view. Peripheral awareness in CVEs is limited to perception of movement in the field of view and any surround sound cues picked up from the wider surroundings.

R 7, I D, Aug 26 16:25:48 1998: "Its a bit hard to 'sense' where people not in your visual focus actually are (even if they are close and speaking). I felt a need to repeatedly update my knowledge of the non-visible participants by rotating 360 degrees, or moving backwards until more people came in view."

R 5, I D, Jul 29 16:18:54 1998: "As long as you navigated yourself in to the correct position to be able to keep your eye on someone, it was ok. Within the office world it was much harder, as I found myself often walking through the walls and loosing sight of most things."

Peripheral awareness of the real environment, during CVE interaction, is limited to perception of movement in the peripheries of the human visual field of view. Sound from the real environment cannot be perceived easily, as the CVE user is wearing an audio headset to listen to the goings on in the CVE. This means that the active CVE participants are to a large extent cut of from the peripheral perception of their real environment, and they may be unaware of important happenings, although wearing an HMD as part of the interaction devices to interact in the CVE, would cut a user off even more.

Peripheral awareness of the goings on in the CVE whilst being disengaged from the CVE interface components, is reduced. This is largely due to the fact that:

- The view does not automatically follow the locus of attention.
- The navigation device cannot be controlled while the mouse (or other input device) is engaged in another window than the CVE navigation controls are.
- The headset may not be worn while paying attention somewhere else.

Subjects have been observed to uncover one ear from under the headset, and sometimes also covering the microphone, or turning it away from their mouth. When the microphone is not covered or when it picks up loud sounds in one participants real environment, they can be heard by the other participants in the CVE, thus providing them with peripheral cues to the goings on in the first participants real environment. Indeed, subjects have been observed announcing the fact that they could hear that a telephone was ringing in another CVE participants' real office.

> *R 8, I D, Jul 29 16:30:09 1998: "I could hear a phone and somebody that stop acting once. Otherwise, the fact that the interaction line stop being used usually indicated that a person is not active anymore."*

Interruptions in the attention of other CVE participants' attention to the CVE happening, are not easy to perceive, although it seems that users learn to interpret virtual body language, and the display of a temporary absence.

> *R 3, I C, Sep 17 11:49:59 1998: "No, [it] was very difficult [to tell when there were interruptions in the attention of the other user(s) to the CVE]. Lack of movement over a period more than 20 seconds was a giveaway though..."*

> *R 7, I D, Aug 26 16:25:48 1998: "Once [X] lay down horizontally and I figured (correctly) that he signalled to the rest of us that he was doing 'something else'."*

10.2.1.8 Trust Building

New CVE participants bring their understanding and expectations of social norms from real world interaction, to the CVE. Because of the inherent problems and difficulties of the unorthodox CVE interface and technology, participants have to rapidly adapt their expectations to the limitations of the situation. However, it proves difficult, especially for novice participants, to judge which particular aspects of the CVE interactions can or must be attributed to limitations of the technology, and which to a participant and their possible display of a lack of respect for the social norms, and thus their trustworthiness.

ID 118: "We gave up on [X] after I asked him questions and [X] didn't reply. He also gave answers that didn't seem related to what he was being asked, he didn't make sense. So I gave up on him and double checked his [task], because I felt we couldn't trust what he said."

ID 116: "I wasn't sure what to do, Blue explained it and we started. Ignoring Green, Green was distracting from the task!"

Navigating the virtual embodiment, dealing with other features of the direct interface of the CVE to the user (such as menu's, pop-up windows, etc.) can create a cognitive overhead for novice users that disturbs them from attaining an awareness of the goings on in the CVE.

ID 118: "It was hard to pay attention to the VE because the mouse and the controls needed so much attention. It was really awkward, because I had to keep swapping my attention."

10.2.1.9 Reciprocity

The COVEN platform provided users with a pointer inside the CVE; a thin red line connecting the pointing arm with the object being pointed at or being manipulated, however due to the small field of view participants still had problems connecting the manipulator with the manipulated object.

R 9, I C, May 19 15:31:25 1999: "[W]e were all playing with some objects that had been loaded into the world and could see who was lifting/rotating them from the pointer line."

R 8, I D, Jul 6 10:38:19 1998: "[W]hen I was actually watching towards them, I could see their manipulation focus line (i.e. a red line that is drawn between the avatar and the manipulated/interacted object, each time an object is interacted."

R 10, I C, Aug 26 16:16:43 1998:"Since you are allowed to act on an object from far away you can not always see or hear the persons."

R 11, I A, Jun 30 16:12:07 1999: "[T]he red line that appeared when people were using the mouse w[as] not comprehensible to start with."

CVE participants have to explicitly comment on their activities or whereabouts, in order to help other participants in establishing a mutual understanding of the goings on.

ID 114b: "I've done more experiments like this. Not with VR, but solving puzzles with a group, and it would be MUCH MUCH better. We were using video-only and voice-only connections between the group. And we were really quick at figuring out you had to give a running commentary of the things you were doing because the others can't see that. And we solved lots of problems that way. In this experiment it just wasn't happening, and to me it was really obvious it was because we should be doing that."

R 12, I F, Jul 10 12:49:07 1998: "People have to say they do something, in order for you to find out who is doing what."

R 13, I G, Sep 24 09:19:18 1998: "I noticed that people had to explain in more descriptive terms where they were ("I am in front of the [building]", etc.)."

10.2.1.10 Indexicality

Indexicality problems in CVEs are caused by the fact that users cannot see the direction of each others gaze, can possibly not see each other point, and the view onto the virtual environment is entirely subjective so that one user may not be aware that the other user is looking at a different scene than them or from a different angle than they assume.

ID 111: "[I]f you could see what the other one is looking at while you are looking at your own thing, that'd make collaboration much more natural."

R 8, I D, Aug 27 10:43:30 1998: "I sometimes had to turn around to find out who was talking to me. Generally, this was because I was in that person's field of view, but he was not in mine."

If a participant is trying to follow directions to see something that is currently outside their view, the indexical expressions and deictic references have to be sufficiently detailed and slow for the participant to catch up with their view.

R 12, I F, Jul 10 12:49:07 1998: "Due to the "polygon-richness" of the environment, it was hard to manoeuvre easily. Therefore it could take quite some time to spot a certain [object]."

R 13, I G, Sep 24 09:19:18 1998: "[W]hen we were searching for objects, [X] would say "Hey I found one, I am here!", but [...] this did not help at all. What I did then was turn around and hope to see him, or ask where he was."

The WhoDo game, the experimental environment, has a spatial lay-out of many rooms, connected by many similar looking corridors. These enclosures of the walls and the small navigational spaces of the rooms and the doors connecting rooms and corridors, made it especially difficult to find other participant if the delay in following turned out to be greater than the time taken by the moving participant to move behind something.

R 6, I B, Jul 7 18:14:49 1999: "If users went off into other parts of the model it was difficult to find them again or join them. This was slightly disconcerting as I could still hear other people talking but I didn't know where they were. I started using the overview feature to peek into all the rooms at once from above."

R 4, I B, Sep 17 12:20:11 1998: "[I]t was like a maze and I could not remember the layout - perhaps few landmarks or better 'flatmarks' added would help in navigation and orientation. For example, if we add few different lamps on the strategic walls + different carpets in different corridors + any small object that *would help with orientation but would not obstruct navigation would be more than welcome."*

10.2.2 HTA Usability Predictions

The predictions about usability principles which need to be supported by the CVE in order to avoid usability problems have been compared to the findings from the experiments. The usability principles are listed with their definition and any usability problems found have been listed below each usability principle respectively. Table 10.2 summarises the results from this comparison.

Navigate: Users need landmarks, and global maps to help them navigate effectively.

Subjects get lost in WhoDo mansion due to the large number of similar walls and corridors.

Find other users: Mechanisms are needed inside the CVE that will allow users to locate each other.

The COVEN platform was improved with a menu-based 'find' function that moved participants automatically to certain locations or other participants.

Find objects: Objects need to be designed in such a way that their function is obvious or self-explanatory.

During the COVEN project WEB pages were used to explain the functionality of objects.

Collaboration: Alignment towards the focal area of activity, such as a document needs to be a smooth operation.

> *CVE participants are observed to struggle finding the objects referred to, identifying the current speaker, and encompassing the goings on in one view.*

Unfocused collaboration: Monitor the activities of others whilst performing other responsibilities needs to be possible.

> *Only audio feedback available for goings on outside field of view.*

Peripheral awareness: Information has to be gleaned from the concurrent activities of others within the same virtual space.

> *Difficult to encompass the actor and the acted upon in one view quickly and smoothly.*

Monitoring ongoing activities: Participants' activities should be made visible through their respective interaction with objects and artefacts.

> *The actor or object is found by following the red line connecting actor and object acted upon. Users seeing a red line will try to find the sources.*

Perceive actions of others and system on objects and artifacts: Smoothly align VB towards the focal area of activity, and observe the actions and results of the other participants.

Typically a problem, causing participants to make many small adjustments of their viewpoint and many scanning actions of the environment.

Implicitly coordinate own actions with other users' and system actions: Perceive the actions of others and the system on objects and artefacts in the CVE.

Typically a problem due to small field of view.

Identify group members: The user should be able to identify which participants in the CVE are members of what group.

The COVEN platform provided the participants with a colored embodiment representing their company, and with their name in text above their heads. It was still difficult to identify current speakers if the collaborators did not know each other well.

Organise shared communication resources: Alter some physical aspect of the workspace in order to make communicative resources available.

It was not always obvious to the actors whether the object acted upon was visible to the other participants involved.

Create shared representations: The creation of shared representations is used to express ideas, add meaning to the accompanying talk and to summarise work.

Subjects in the experiments were observed helping with the interface controls needed for showing each other the game cards.

Work on same object: The system should allow for smooth transition between ownership of the object and user rights.

No controlled experiments were performed.

Individual in group: Group members take advantage of lulls in the group activity for the opportunistic use of time they are together to do something else.

Subjects in the experiments are observed using quiet corners and quiet moments to discuss topics of their own interest.

Seize the moment: Group members seize the moment to do something else when one or more of the others are attending to something else.

The beginning and end of an interaction or collaboration process are not very clearly marked due to absence of direct feedback of the focus of attention of each CVE participant.

Do something else: Most of these activities allow the individual to remain peripherally aware of the group activities and return to focused collaboration should they wish to do so.

Subjects have been observed reading their electronic mail in another window on their desktop whilst waiting for the CVE task to start.

Personal preference: Allow the users to do something else whilst maintaining peripheral awareness of goings on in CVE.

CVE users can perform multiple tasks whilst maintaining a audio connection to the CVE.

Called away: Leave some information behind for the other users about the estimated duration of absence from the virtual embodiment.

Not implemented in the COVEN platform. Sometimes users announce their situation, but not always.

Catch up: Monitoring the current group activities in order to deduce what has taken place, or by asking another group member.

Subjects in the experiments are observed asking others for information to help them catch up after a temporary absence.

Converse: Maintaining a single conversation involving the whole group, or maintaining more than one conversation involving different subsets of the group.

The larger the group, the more difficult it becomes for individuals to become the centre of attention.

Maintain central conversation: Observe and contribute to the discourse that is taking place within the group.

Due to bad audio connections for some participants perceiving and contributing to the discourse was cumbersome.

Share discourse: Perceive turn taking in the conversation and ones own turn so that one can contribute to the central and subset conversations.

Due to bad audio connections it was difficult for some participants to perceive an opportunity to take a turn and be perceived as doing so.

Perceive discourse: Perceiving verbal information, perceiving non-verbal information, and detecting contextual influences.

Difficult due to bad audio, small field of view, and difficulties in attributing a speakers utterance to the speakers' embodiment.

Perceive verbal information: Receive audio signal.

Audio signal processing chops first part of utterances off.

Perceive non-verbal information: Perceiving virtual body language, and perceiving textual information.

Not a lot of virtual body language available. Text windows may pop up obstructing main CVE window.

Perceive virtual body language: View changes in virtual body of other participants; recognise the signals.

Due to small field of view movements of other participants may be invisible.

Perceive textual information: Receive textual information.

Text windows may pop up obstructing the main CVE window.

Detect contextual influences: Interpreting the reasons for changes in verbal and non-verbal information exchange

Hampered by small field of view.

Contribute to main conversation and subset conversations: Utilising the different communication channels simultaneously.

Subjects in the experiments have been observed using audio and textual communication simultaneously.

Maintain subset conversation: Communicate with other users in the same virtual space, and receive communications from other users in different locations.

Utterances can become inaudible due to din of other conversations going on. Textual communication overcomes this problem.

Look at the same thing at the same time: Enabling the inclusion in the conversation of some aspect of what is being looked at.

Sometimes difficult to assess what is being referred to.

Look at single shared representation: See when and where the other participants are looking.

Not obvious where precisely another participant is looking.

Look at series of shared representations: Become aware of the changes in the shared representations at the same time these changes take place.

Locating the shared representation is sometimes difficult.

Look at several shared representations at the same time: Look from one to the other shared representation.

Participants have no real feedback other than verbal indexical expressions to become aware of where the focus of attention of the others is aimed.

Look from one to another: Find and select the objects between which one wants to share ones view.

Locating the view to find an object may make it difficult to relocate to the previous object.

Work on the same thing: Rules, rights and permissions to change shared object should be transferred smoothly.

Not explicitly assessed during the COVEN project.

Work at the same time: Whose changes will be shown.

Not explicitly assessed during the COVEN project.

Work in turns: Object hand-over needs to be smooth and effective.

Not explicitly assessed during the COVEN project.

Collaborative act	Usability problems observed due to absence of property
Navigate	Yes
Find other users	Yes
Find objects	Yes
Collaboration	Yes
Unfocused collaboration	Yes
Peripheral awareness	Yes
Monitoring ongoing activities	Improved but still clumsy.
Perceive actions of others and system on objects and artefacts	Yes
Implicitly coordinate own actions with other users' and system actions	Yes
Identify group members	Yes
Organise shared communication resources	Yes
Create shared representations	Yes
Work on same object	NA
Individual in group	No
Seize the moment	Yes
Do something else	No
Personal preference	No
Called away	Yes
Catch up	Yes
Converse	Yes
Maintain central conversation	Yes
Share discourse	Yes
Perceive discourse	Yes
Perceive verbal information	Yes
Perceive non-verbal information	Yes
Perceive virtual body language	Yes
Perceive textual information	Yes
Detect contextual influences	Yes
Contribute to main conversation and subset conversations	No
Maintain subset conversation	Yes
Look at the same thing at the same time	Yes
Look at single shared representation	Yes
Look at series of shared representations	Yes
Look at several shared representations at the same time	Yes
Look from one to another	Yes
Work on the same thing	NA
Work at the same time	NA

Work in turns	NA

Table 10.2: Summary of usability problems found through the HTA predictions.

By looking at the HTA for peripheral awareness in its simplest form (see figure 10.1), it can be illustrated that the process of achieving and maintaining a view of the goings in the CVE is essential. Peripheral awareness clearly depends on being able to perceive who does what to whom, where, and what effect(s) does this have on what, where.

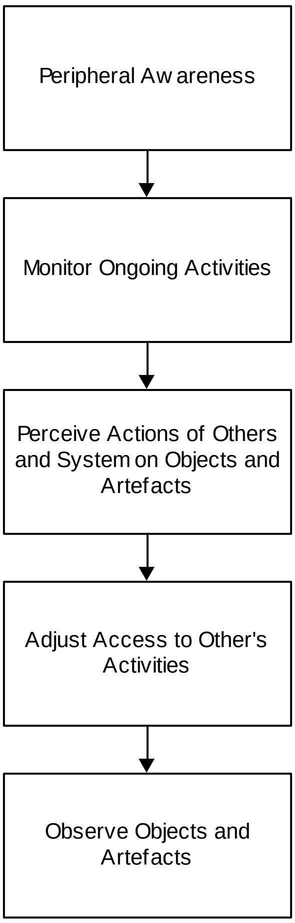

Figure 10.1: Simplified HTA of Peripheral Awareness.

The problem with peripheral awareness in CVEs seems to stem from the small field of view offered of the CVE to the user on a typical desktop.

> *ID 106: "Spatial awareness was really hampered. You had to go all the way back to see what the others were looking at – if you don't see them in your field of view you have absolutely no idea what they are doing or where they are, and neither have they about you!"*

This problem can be overcome by:

- Increasing the field of view, by means of peripheral lenses (Fraser, 1999); perspective walls (Clarkson, 1991), providing three screens (Zhang et al., 1999), or making the walls 'stretchable' (see section 10.x).
- Building bigger CVE spaces. There are some indications from the research findings that the relative size of objects, and their size in proportion to each other may have different affordances in CVEs than their real world counterparts would suggest.
- Exploiting all other means with which CVE users could gain extra means of feedback about who does what to whom, where, with what effect. This feedback would have to be derived from selected additional information about acts that are taking place, such as visual signals, auditory signals, textual signals, and additional visual displays such as bird's eye view, dynamic maps, etc. (c.f. Sandor, Bogdan, Bowers, 1997).
- Discarding desktop CVE technology as not suitable for the support of peripheral awareness sufficient for serious collaboration.

By looking at the HTA for focused collaboration in its simplest form (see figure 10.2), it can be illustrated that the process of achieving and maintaining a sense of the goings in the group is essential. Focused collaboration depends on knowing who is part of the activity and allowing each group member to contribute to the activity as necessary.

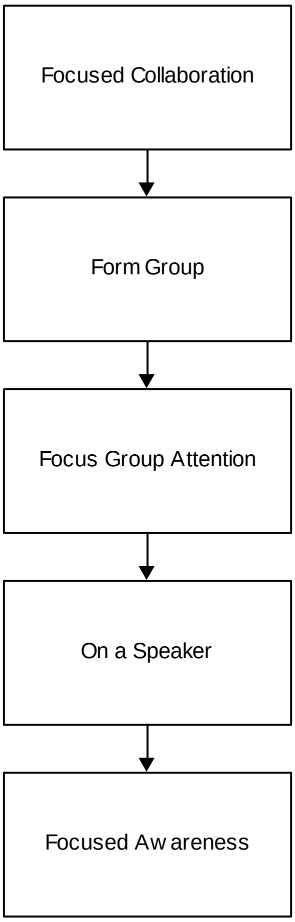

Figure 10.2: Simplified HTA of Focused Collaboration.

The problem with focused collaboration in CVEs is that it is not easy to determine and interpret from the presence of the virtual body what the actual degree and direction of the user's attention is.

R 4, I B, Sep 17 12:20:11 1998: "I guess it was lack of collaboration that I experienced. I had an impression that we were group of individuals who just happen to be there together rather than a group of people who were supposed to share some information."

This problem can be overcome by:

- Displaying video data of the user's face on the face of the virtual embodiment. Showing increasing degrees of detail as the users approach each other (Reynard, 1998).
- Displaying a computational representation of the user's real movements and activities on the virtual embodiment by tracking some of the user's body and facial movements (Kalra and Magnenat-Thalmann, 1994).
- Endowing the virtual embodiments with automated, exaggerated stereo-typical movements and expressions, appropriate to display their intentions. These actions are initiated by the users, but they do not have to be executed by the users in each act, rather the computer does this for them (see section 10.x).
- Discarding CVE technology as unsuitable in supporting the interactive effectiveness necessary for collaboration.

10.2.3 COVEN Research Findings

The inspections performed during the COVEN project raise a number of related usability issues:

- The perception of the correct action.

- The performance of the correct action.
- The performance of action sequences to perform a task.
- The perception of the next task to perform.
- The perception of feedback.

These usability issues are related in that they concern the design of the interactions. They all have in common that they cause a lack in guidance and feedback for the user in terms of what task should be performed and how, what actions are available when. Numerous remarks made by the inspectors illustrate the need for more structure in the design of the interactions. Below a few examples are given:

> *"The overall design of the rooms is not consistent in terms of realism and details. The 'semi-real' metaphor is not fully consistent: there is a real world feeling but still some objects are floating in the air. This can sometimes be confusing. Also, some task-unrelated objects are represented (typically, radiators) - why these, why not others (lamp, plants, etc.)?"*

Another example is the CD player, which was implemented to provide a metaphor for the presentation of a slide-show, accompanied by a voice-over with tourist information, inside the CVE. These are some of the comments on the design:

> *"CD player is not obviously visible unless you are close to it"*

> *"I find it very hard to read the CDs. I hardly can speak of a 'selection process'; as user I just try."*

“Not clear what the choices are unless you get right in front + look down (too difficult to navigate such a move), only then can one read names of the CD’s”, “It is not obvious to me that playing a CD would involve a slides show. When I activate a CD, I am expecting sound, not images. This is because the CD player looks like the audio CD player I have at home, not like a multimedia CD-ROM appliance.”

“The option for playing a CD-ROM is not obvious. You come upon it when playing with the mouse. It actually comes as a surprise that a simple CD selection activates the player (not consistent with the usual behaviour of selections within the application). Risk for errors.”

“Anyway, the show is fine. But once started, how do I stop this lady telling me about Rhodos? I cannot find a stop button."

An example of the need for guidance for the sequence of tasks is the lay-out of the main tourist information office room and the task-related or functional objects in it. The user first has to go through the door.

“Opening the door of the Meeting Room wasn’t as easy as I thought. The door was slammed in my face for three times. And what a sound was accompanying it: for a moment I thought I was in Michael Jackson’s thriller! I think a user prefers that the doors opens after touched the handle and will place him in the middle of the next room.”

Next, the user is expected to find the CD slideshow, but the table with the CDs and CD-player is not placed in a very prominent position. After having negotiated the CD slideshow the user is expected to take a virtual flight over the holiday destination by means of entering a teleporter, which is located in a corner of the room. However, again the object is not placed in a prominent position, and there is not a lot to guide the user's interest towards this other main functional object in the room.

> *"It is not clear what the function of the teleporter is, unless you know what it is. The outside does not suggest anything about its' functionality" and "Maybe a textual tag would help, e.g. 'to virtual Rhodes'. Or is it part of the fun to entertain mystery? Teleporter needs a label."*

During this part of the task problems on the level of lack of structure in the object interaction occur again.

> *"The controls for the teleporter are not obvious since they are unlabelled. Indeed one has to open the teleporter first before these controls become apparent."*

Expressing these types of usability problems in terms of their most general shortcoming leads to the definition of three CVE usability guidelines that will support the design of user guidance and feedback:

- Perceptual affordances of interactive objects have to be designed carefully.

- Sequential affordances for each action and sub-action in a task have to be designed carefully.
- Narrative affordances of objects and spaces in the CVE have to be designed carefully.

Perceptual affordances for CVEs are visible controls suggesting functionality. Sequential affordances for CVEs refer to the notion that acting on one perceptual affordance, leads to the perception of new affordances. Narrative affordances, a term coined by the author, refer to the notions that users need guidance and feedback throughout their interactions. Narrative affordances are essential to the design of usability for 3D objects and spaces such as common to CVEs. Narrative affordances are further discussed in section 10.3.1.

Perceptual affordances and sequential affordances are popular 2D usability principles, however the design of narrative affordances, or lack thereof appears to be a typical problem for 3D interaction in 3D spaces.

Other problems exist, which also seem to be caused by the lack of design guidelines due to paradigm shift from 2D to 3D interaction. Pressing areas for further research and development identified in the final COVEN inspection report are (Del.3.6):

- 2D Disturbing 3D: 2D menus pop up over the CVE window, thus disrupting interaction in the 3D interface.
- Unsupported 3D actions: many actions that could be performed directly inside the 3D space are relegated to 2D menus.

- Lack of 3D feedback: actions performed on 2D menus that affect 3D objects in the CVE often do not give recognisable feedback in the 3D environment.
- Two object tasks: the 2.5D ‘drag and drop’ mechanism is not supported in CVEs, making selection and manipulation an arduous task.
- 3D interface: realistic portrayals of real-world representations and manipulation methods to the virtual world does not employ the added value of CVEs and makes recognition and update-rate less effective.

These issues are all concerned with the tension between two interaction paradigms, 2D and 3D; the immediate interface between the user and the CVE application consisting of menu’s and icons for the control of certain actions in the CVE, and the interface as it is presented to the user inside the CVE, to the objects and actions available. What needs to be addressed is the link between the two interfaces, what overlap in functionality would be useful, which actions are best represented where, and who should receive feedback of which actions from which user.

Finally, the 3D interaction paradigm needs to be extended with knowledge from other fields such as exhibition design and industrial design of objects. There is an obvious lack of understanding on how to design 3D objects in CVEs for usability. Generally, the actions and objects are designed relying on vague principles of iconisation; simplification of the object representation, using a real-world metaphor to suggest functionality, and not in terms of the actual task and task sequence of its real world counterpart. Object interactions and human interactions in CVEs seem to become more complicated due to this iconisation principle. In order to come to usability principles for CVEs it will be necessary to develop a systematic approach to creating a consistent representation of all affordances in the CVE and all human conduct with the CVE interfaces, sufficient for a CVE participant to be able to observe and understand what is going on as they would in the real world.

10.3 CVE Usability Design Recommendations

A number of key CVE usability principles and guidelines can be derived from the work presented in this thesis. These issues can be divided into five groups:

- Narrative affordances (10.3.1).
- Collaboration (10.3.2).
- Automation (10.3.3).
- Education (10.3.4).
- Layered design (10.3.5).

The next section (10.3.1) discusses how the careful design of narrative affordances for the interactions with and inside the CVE can support CVE usability. Section 10.3.2 discusses how more attention to the designation of CVE actions to the CVE can improve the usability of CVE interaction. Section 10.3.3 discusses how users and designers will adapt to the new 3D interaction paradigm. And section 10.3.4 discusses how to design for CVE usability by presenting a systematic method to focus on the different layers of CVE functionality.

10.3.1 Narrative Affordances

Designing the affordances of objects in the VE is a trade-off between realism and simplification - between user needs and utilised computing resources. A balance needs to be found between the essential and non-essential elements of the object, so that the user can still perceive the correct actions and functions, while the machine load is kept to the minimum. Often this simplification results in a more or less cartoon-like representation of the CVE and the objects; the iconisation principle evoked above. If objects, spaces and interactions are subjected to iconsation, the objects should be represented as caricatures of their real world counterparts. Caricatures act as a form of amplification through simplification (McCloud, 1993). The iconisation design process should be guided by a systematic decision making to reduce the representation of the object to its most salient features and functions, in such a manner that the design will guide the user through the task.

In addition to exploring the caricatures of representations, an exploration of caricatures of situations, such employed in the creation of live action films, could be fruitful. Live-action films are stripped-down versions of reality, to increase the intensity of the story, thereby guiding the viewers in their anticipation of the next action (Straczynski, 1996). Similarly, each CVE user could be said to create their own story-line in a CVE - of all possible actions, the user will have to select one, which could lead to the next, etc. The designer will have to help the user identify the actions and objects necessary to perform their tasks, especially the order in which they are to be used. Some chunks of information have to be interpolated by the user; some have to be attached to the objects, before the user can make sense of the environment. The sequence of appearance of the available actions would thus seem to be important. The items of information function as elements of a story, and while the arrangement may be flexible and open, the elements have to be assembled in a particular order to make sense of the story. The order will have to be designed to guide the users through their tasks, in a similar as exhibitions are designed. . Exhibitions are ideally regarded as a form of sculpture: "They are three-dimensional compositions which recognise the importance of solids and voids and strive for satisfactory spatial relationships." (Lawson, 1981). Guidance for sequential affordances in CVEs can be provided by structuring the lay-out of the rooms and position of the objects more deliberately Instead of arbitrarily positioning objects and rooms, they can be grouped and ordered into meaningful parts which intentionally draw the user from action to action. Deliberately and purposefully simplifying the situation in which the users find themselves at a particular moment in the VE interactions, allows for a better prediction of which action the user is most likely to perform next. More accurate predictions of CVE user actions will help when designing for usability. It is expected to have at least two main advantages:

- Clearing the path of the user ‘story’ in the direction the user is intended to go.
- Reducing the likelihood of introducing usability problems due to lack of affordances.

Standard HCI alerting techniques for guiding user attention to the next action, such as the use of colour highlighting, flashing, wire frame, and reverse video are not very elegant solutions for a CVE, especially because of multi-user aspects. However, the use of spatial cues (increasing the perceptual affordances) and temporal cues (increasing the sequential affordances) may be more effective. Additionally, the use of audio, and text, and map type feedback could be explored.

The design of narrative affordances follows the interaction cycle structure:

- Make it obvious or recognisable what to do.
- Make it obvious where to find it.
- Make it obvious or recognisable what to do next.
- Make it obvious how to do it.
- Make the feedback obvious.
- Make it obvious what do to next.

The order in which things appear to the CVE user determine to a large extent what the user will do next. Designing the narrative affordances carefully using the list will contribute to an easy flow of interaction.

10.3.2 Collaboration

The main questions that CVE users are trying to answer are who does what to whom, when, so that the user can understand why and adjust their involvement accordingly. CVEs need to be carefully designed so that the relevant actions of users are visible to all concerned, and so that the relevant feedback about the results of executed actions is available to all concerned. This involved a very detailed design of user activities, user embodiments, CVE objects and spaces. Such a detailed design can only be generated through very thorough application of design knowledge and teamwork.

10.3.3 Automation

A number of design recommendations can be made for future CVE usability designs, which concern the automation of certain parts of tasks. These recommendations have not been empirically tested. However, there are indications from empirical research performed by others that similar design recommendations are effective for CVE interface design. Most notably, navigation problems are eased by creating autopropelling properties around objects (Xiao and Hubbold, 1998; Hix, et al., 1999). Social distancing is facilitated by creating automatic group-member positioning mechanisms (Rocco, 1998). And general aids in recognition of functionality can be provided by highlighting and changing emphasis of the representations of functional elements in the CVE space (Kaur, 1998).

Function: Automatic Overview Generator

Interaction Cycle: Normal task action Cycle 2D

Scenario: Field of view is subjectively enlarged by stretching the outside edge of the workspace in the outward direction only. By making the walls impenetrable but at the same time flexible to pressures in an outward direction, the participant can increase their field of view until they can encompass the number of other participants and relevant shared objects in one view.

Task Analysis: The user elects to see the room from the perspective where she can see:

- The largest number of other participants & objects
- The largest number of members from her own group

The user can start the automatic movement by:

- selecting the activity from a menu using a key-board shortcut command
- The user can stop the automatic movement by

- clicking on a stop-button
- using a key-board shortcut command
- moving their Avatar in another direction.

Function: Autopropelling

Interaction Cycle: Normal task action Cycle 2D

Scenario: Navigation and fine-tuned positioning works by ‘trenches’ that automatically bring a participant to the optimal path or viewing distance. All objects have and optimal viewing distance associated with them, which increases with the number of participants trying to access the same area. Participants have an optimal collaboration distance associated to their embodiments. The autopropelling and autotracking properties of the furrow or trenches and personal space distancers propel the participants to their goal automatically. Participants can interrupt this automatic movement by a proportionally greater co-movement from their input device. With long intensity user-control participants are simply gravitating inside the gravity wells of the surrounding others and objects; like a slow-motion pinball in a pinball-machine.

Task Analysis: The user is automatically transported along the most obvious path, when a junction is reached the Avatar prompts the user for a choice. Alternatively the user can opt to always automatically

- -Take the left or right turn
- -Go straight forwards
- Take the turn to where the nearest large assembly of other active users is
- Take the turn which leads to the nearest group-member

- The user sets the autopropelling option in motion by starting movement along an obvious path, such as walls, doors, other objects, and other users.

Function: Autopositioning

Interaction Cycle: Normal task action Cycle 2D, System Initiative Cycle

Scenario: Participants intending to collaborate can make their avatars automatically assume positions oriented at an angle of about ninety degrees, where they may turn their heads to interact in face-to-face relation. When other avatars get close to the group all avatars automatically move into a bigger ‘circle’ e.g. from small triangles, squares, to circles, depending on the number of participants in the group. When an Avatar comes close to interactive objects or other users the Avatar automatically assumes a precise position from which the user can view most of the object(s) and/or other user(s) in one view.

Task Analysis:

- - Objects: When coming close to an interactive object the Avatar is automatically positioned within the optimal manipulation distance.
- - Other Users: When coming close to one or more other users the Avatar automatically positions itself so that as many as possible Avatars can be seen from the front.

Function: Proxemic Positioning

Interaction Cycle: System Initiative Cycle

Scenario: Automatic behaviours to initiate phatic communication and signal turn taking are a sequence of automatic actions which start the moment a participant enters the VE. The avatar automatically searches for the optimal place in the VE space where the participant will have the best view of the other participants. If this automatic sequence is uninterrupted by the participant the avatar will start waving automatically, go up to the nearest other active avatar and smile, when still uninterrupted it could go to the next nearest other avatar, etc. Once a participant is a member of a group this automatic behaviour will be restricted to group members only. When an Avatar enters into a group-position it starts to assume proxemic behaviours indicating informal group-membership.

Task Analysis:

- Other Users: The view of the Avatars automatically pans from one avatar group-member to the next. The Avatar smiles at each group member in turn. When uninterrupted by the owner the Avatar assumes a ‘waiting’ posture.
- Shared Objects: A user can select an object within the vicinity and elect it as a shared object. The user’s view is then distributed between the other users and the shared object. The user can choose how often the shared object is viewed (e.g. once after viewing all group-member, once after viewing each group member, etc.).

Function: Initiate Conversation Tool

Interaction Cycle: System Initiative Cycle

Scenario: To initiate a conversation with another participant or group of participants the addressee will be warned by a text-message and an accompanying sound which includes information on who is initiating contact. The user can signify that they wish to initiate a conversation using a number of simultaneous automatic behaviours. The user starts this behaviour by clicking a button and selecting an addressee. The automatic behaviour sequence can be edited by the user, but generally consists of a cough and a raised hand.

Task Analysis:

- Single Addressee: When selecting a single addressee the user should be able to select this addressee quickly as the opportunity for interaction may be endangered if the selection process is too time-consuming.
- Multiple Addressees: When selecting a group of addressees the user should not be restricted in their choice to just the nearby other users.

Function: Turn taking

Interaction Cycle: System Initiative Cycle

Scenario: Turn taking is automated in several ways. A listener wishing to take a speaking turn has a button to press which causes an automatic sequence of simultaneous actions e.g. the Avatar coughs, and sticks up its arm. An utterance from a current speaker is automatically accompanied by slow nodding of the head, smiling, slowly turning the head from one side of the view to the other, etc. Listeners' views are automatically tracking the current speaker.

Task Analysis: In order to facilitate the turn taking a speaker will make automatic speaker gestures, a listener will make automatic listener gestures and a potential next-speaker will give automatic turn-taking signals. Users can create their own sets of behaviours for these automatic sequences of gestures.

- Speaker: A speaker will automatically raise and lower her arms and smile while speaking.

- Listener: A listener will automatically nod in the direction of the speaker while listening.
- Next-Speaker: A would-be next-speaker will cough and raise a hand. The user can press a button to initiate this behaviour.

Function: Absence

Interaction Cycle: System Initiative Cycle

Scenario: To signify a temporary disengagement of the attention from the VE, users can make their heads slump. Avatars will automatically slump their heads and snore (only heard when close up) when the owner has not given any input to the VE for an x amount of time.

Task Analysis: When a user has to switch attention away from the VE they can make the head of their Avatar slump. After x amount of idle time the Avatar will make very soft snoring noises.

Function: Privatised Group Audio

Interaction Cycle: System Initiative Cycle

Scenario: A group facility, privatised-group audio is available, similar in approach to that offered by the text chat facility, but based on audio. Users are able to select to use group audio, and proceed to discuss privately with other members of the group.

Task Analysis: Users are able to select to use group audio, and proceed to discuss privately with other members of the group. The actual arrangement of the groups, and as a result the audio, might be done in a couple of ways:

- The members of the group be the members of the team, and the audio range would be amongst them, irrespective of their location i.e. members in a different room would still hear their team members. A walkie-talkie effect.
- The group could be based on a spatial location, so that for example it is room based, and only the users in the room could hear, irrespective of which team they are on.

Function: Group Navigation

Interaction Cycle: System Initiative Cycle

Scenario: Teams automatically navigate the general CVE space as a group, and only have individual navigation facilities when within a room. The largest density of users within a group determines the speed and direction of the group. If a leader has been chosen the group is 'pulled' along by the leader. If a user actively moves away from the group or lags behind she will be asked whether she wants to be automatically disengaged from the group. To signify the location of largest density of the group a 'mascot' travels in the centre of the group.

Task Analysis: This navigation could be in a sense competitive, i.e., the result of the average position of each member of the group, or it could be user led, whereby the perceived leader of the group is in sole charge of navigation. It could also be use in conjunction with the autopropelling functionality.

Function: Generic Automatic Behaviours

Interaction Cycle: Normal task action Cycle 3D, System Initiative Cycle

Scenario: All automatic behaviours are user-interruptible and can be found on the menu's as a toggle-switch.

Task Analysis: At all times should a user be enabled to edit, switch on and off, and interrupt all or certain parts of the automatic behaviours. It should be made clear to the user when an automatic behaviour starts and ends. It should be made clear to other users that the Avatar is operating in auto-mode.

10.3.4 Education

There is a whole generation of game players who are users or potential users of CVE technology. This generation and the ones to follow are more prepared in their expectations of CVE technology as a medium for collaboration, than previous generations. It is to be expected that regular CVE users will develop great skill in turning the technology to work for them, and they will the ultimate judges of the usability of CVE design choices.

ID 112: "It was similar to a phone conversation. The interface was too awkward to control. It felt generally unreal, there was no agility to the VBs. I'm used to Quake, and I get quite immersed in it. This VE was too clumsy to use which broke the immersion. I missed being able to side step for instance. And collision detection was really needed."

R 15, I C, Jul 23 10:24:08 1998: "[T]he [CVE] motion interface takes some getting used to, I still keep trying to use Doom keys to move my avatar."

So far, a CVE designer will have to anticipate what a CVE user might want to do and write the software so that the user is enabled to do this. However, it is to be expected that the type of user support and the type of tasks available within the CVE are going to be standardized in the same way that Apple and Microsoft have standardized their interfaces. The interaction paradigm for CVEs is by no means clear yet, and until than CVE designers will have to educate themselves about the design options and methods, and they will need all the design guidance available. In order to support the designers, CVE design guidelines have to be made easy to use, easy to share, and easy to implement.

CVE usability engineers need to systematically pool their results, and test existing evaluation methods on CVEs. The debate as to what usability for CVEs entails will be slow and laborious, since the subject covers a wide area and involves experts from many different fields. For this reason it seems especially important to try and coordinate research in a fruitful fashion, so that new development efforts are properly informed by previous developments.

10.4 CVE Design Guidelines

It is not possible to derive complete guidelines for CVE usability design from the research presented in this thesis, however it is possible to provide some design guidance. The guidelines below (see table 10.3) have been derived from a systematic method with which to create usability specifications for CVEs from design-team discussions (see Appendix F). The design guidelines are divided into five sections, referring to their respective sections in the design method: team-preparations, temporal space, architectural space, semantic space, and social space as evoked in Chapter 2. The design method provides a functional breakdown of the usability requirements for CVEs. It does not list all CVE usability requirements that are known to date, nor is it an exhaustive list of heuristics to keep in mind when building CVEs. Rather, it is the description of techniques with which a design team can decide what the essential human needs are and how to support them, and where to negotiate the necessary simplifications of representations and interaction. For reasons of brevity only the guidelines derived from the method whilst building the COVEN platform and writing this thesis have been presented here, the actual method is presented in the appendix and complements the COVEN Inspection method (Appendix G).

Design Activity	**Guideline**
Team Building	Build a team comprised of members sufficient to defend all design angles; minimum configuration of design team is a designer, programmer, usability expert and a user.
	Work as a multi-disciplinary developers-team; none of the trade-off design choices are made by one expert only.
	Include meetings with representative end-users and external experts.
	Develop and maintain a shared vision of future product by holding frequent team meetings.
	Divide roles for each part of the design process amongst the team members.
	Create work-plan for team-members working in sub-groups where necessary.
	Perform a requirements analysis at the start of the design process, involving the whole design team to make sure that user and system requirements are properly understood by everyone involved in the design.
	Explicitly formulate areas where trade-off decision making has impact on usability and run-time performance throughout the design process.
	Create a user interface design specification for each interaction layer of the CVE, each task, and each task object.
Temporal Space	Create a scenario description of typical user activity in the future application to develop a sense of the user space.
	Consider typical user activity, high-demand user activity, and low-computer literacy user activity.
	Involve the entire team in the creation of the scenario, this will lead to a shared vision of the future product.
Architectural Space	The layout of the space should guide users from one action to the next.

	Support users in their way finding by providing landmarks.
	Suggest social usage for the space by including typical features and objects.
	Spatial organisation will help users find things and focus on their task.
	Distant ground, middle ground, and foreground, provide levels of task supporting context.
Semantic Space	Amplify functionality by simplifying the representations.
	Find the minimum number of conceptual elements needed to convey the available function of spaces and objects.
	Control the effort invested in each iteration of the design by determining the number of conceptual elements needed balanced against the technical complexity to create it.
	Use contextualisation by providing a visual framework for the data, to make it easier to interpret.
	Use selective emphasis by highlighting the interactive features and suppressing non-interactive features, to reveal patterns of functionality.
	Use transformation by changing the representation in order to make interpretation easier.
	Create objects and spaces, which look and behave like their real world counterparts, whenever possible.
	Employ realism to aid recognition and understanding of the object or space is for.
	Emphasise functionality with a combination of visuals, interactions, and sounds.
	Preserve real world proportions and relationships.
Social Space	Users learn to identify with their virtual body and the virtual space by interacting in the CVE, provided the CVE sends consistent and continues feedback to the user about the results of action performed.
	Create automatic co-verbal behaviours where possible.
	Create support for displaying and perceiving co-verbal behaviours.
	The CVE should allow for switching from unfocussed to focussed collaboration, which depends on the peripheral awareness of one participant of the other participants and their activities.

Table 10.3: CVE Design Guidelines.

10.5 Conclusions

Since the design of social spaces in CVEs is far removed from the need of the users, this is the most immediate area for improvement of CVEs. Basic research in this area is needed to test different ways of representing physical interaction, using different degrees of automated embodiments', performing gestures and expressions essential to the continuation of the collaboration process.