Chapter 8 Observations: Analysis of Collaboration Data

H2	***General patterns of collaboration can be predicted and observed.*** Observations and analyses.

H4	***New design properties support collaboration.*** Comparison of Observations and Predicted Collaboration Activities.

Chapter 8 Observations: Analysis of Collaboration Data

This chapter contains an analysis of the predicted categories of collaborative behaviour, an analysis of the observed categories of collaborative behaviour, and a comparison between the predicted and observed categories.

8.1 Introduction

This chapter discusses the data analyses that were performed on the observational data, gathered using the observational method described in Chapter 5. It is rather exhaustive in its analysis of all data, and considers in pertinent detail each of the observed behaviours that seem to shape CVE collaboration activities. This approach has been adopted in order to clearly show the depth of the observational method. Furthermore, the analysis allows discussion of any additional usability issues for CVEs derived from the data. The aim of this chapter is to give an overview of the level of usability of CVEs at the time of the experiments, describe the type of collaboration support needed for CVEs, and discuss the open issues regarding the general design for usability of CVE technology.

This chapter test hypotheses 2 and 4, and as such fits into the methodological framework set out in Chapter 5. The hypotheses are explored by using statistical predictions of collaborative behaviours, derived from the observational data, and matching them against the observed behaviours that were collected from the experiments.

The next section (8.2) presents a description of the translations and manipulations of the original data and a comparison of the original categories to the observed categories to analyse the fit. Section 8.3 describes the categorical analyses for the predicted and observed categories.

8.2 Data Collection and Validation Activities

The data that are used for the analysis presented in this chapter have been derived from four different sources. Four experiments have been analysed (see table 8.1). These experiments are introduced in Chapter 5, section 5.4.

Date	Time span of Observation	Platform	Data	Remarks
03.11.97	13:49:29-13:55:25	dVS: Business application.	4 users: Nottingham (UK), London, (UK), Bristol (UK), Den Hague (NL).	1st trial of categories.
12.11.97	15:26:00-15:46:05	dVS: Business application.	3 users: Nottingham (UK), London, (UK), Den Hague (NL).	2nd trial of categories.
30.06.99	15:09:04-15:09:59 15:28:00-15:29:00 15:43:00-15:43:57	DIVE: WhoDo	9 users: Nottingham (UK), London, (UK), Lancaster (UK), SICS (S).	Expert users.
07.07.99	15:37:10-15:38:12 16:01:00-16:01:59 16:18:25-16:19:22	DIVE: WhoDo	4 users: Nottingham (UK), London (UK), Lancaster (UK), SICS (S).	Novice users.

Table 8.1: The four sources of data.

There are four subjects in the 03.11.97 trial, each located in a different geographical location: Nottingham (UK), London, (UK), Bristol (UK), Den Hague (NL). This trial took place in an environment built during the first stage of the COVEN project, referred to as “the Business application”, consisting of a number of rooms built to run on top of the dVS platform. The first room contains a business game, which involves the manipulation of a 3D bar chart representing profit-expenditure. Each participant in the game has a table with their interactive 3D bar chart on it. The second room consists of a conference room, with tables, chairs, and a projection screen. The users can present slides on the projection screen by inserting each successive slide in a device called “the bandy box”. The second trial analysed, 12.11.97, used the same platform and environment, but there were only three subjects in this trial: Nottingham (UK), London, (UK), and Den Hague (NL). The subjects were all closely connected to the development efforts of the COVEN application.

The first WhoDo trial analysed, 30.06.99, had 10 subjects when it started off, but one subject from SICS dropped out, so effectively 9 subjects: four, later three, from SICS (S), four from Nottingham (UK), one from UCL in London (UK), and one from Lancaster (UK). The subjects were all closely connected with the development of the platform, and familiar with the DIVE interface. The second WhoDo trial, 07.07.99, had four subjects: one from SICS (S), one from UCL, London (UK), one from Nottingham (UK), and one from Lancaster (UK). These subjects, although familiar with the concepts of CVE and CVE development, were new to the WhoDo game, not involved in COVEN project, and were not familiar with the DIVE interface.

The analyses of the Business game test 1 covered five minutes and 56 seconds (00:05:56), and the analysis of trial 2 covers 20 minutes and five seconds (00:20:05). Every act visible or audible to the person whose view we are watching has been scored, and the combined data sets from the Business game tests 1 and 2, contains 420 items.

	Beginning	Middle	End	Total
WhoDo trial 1: Experts	63	60	57	180
WhoDo trial 2: Novices	62	59	57	178
Total	125	119	114	385

Table 8.2: Number of seconds analysed during beginning, middle and end of a WhoDo game collaboration.

The observations of the two WhoDo game trials are slightly different from the other data sets, in that they cover three parts of the collaboration process (beginning, middle and end) of a minute each. Thus, in total creating six minutes of observations: three minutes from WhoDo 1, and three minutes from WhoDo 2, see table 8.2. The first minute is taken from the beginning of each game (WhoDo 1: 63 seconds; WhoDo 2: 62 seconds), the second minute from the middle (the 'middle' being determined by calculating the time difference between the beginning and the end of the game) of the game (WhoDo 1: 60 seconds; WhoDo 2: 59 seconds), and the last minute is taken from the end of the game (WhoDo 1: 57 seconds; WhoDo 2: 57 seconds). The two data sets combined consist of 285 items, "beginning" consists of 85 items, "middle" consists of 117 items, and "end" consists of 83 items.

In total there are 705 observations in the database, and generalisations about user behaviour are based on the total data set. Additionally, the data sets for the experts and novices are compared to each other for possible differences in the observed behaviours. Finally, the three time slices of the two WhoDo games are compared for possible differences in type of activities during different times of the collaboration.

8.2.1 The Data Set Related to Original Scoring Categories

In order to check how well the original scoring categories fit the observed categories (as introduced in Chapter 5, section 5.3.2.1), both are compared in table 8.3. The numbers represent how often each category has actually been observed: Thus, for instance a communication act that seemed to be purely intended to communicate something (C-C) has been observed 144 times, while communication acts that seemed to be intended to announce an activity external to the CVE (C-E) has only been observed two times. In this chapter the original categories are referred to as the "predicted categories", however, there is one exception, in section 8.3.4, where statistical predictions are made.

	Comm unicate	Exter nal	Gestu re	Manip ulate	Navig ate	Position	Scan	Verif y	Total
Communicate	144	2	0	0	0	0	0	190	336
External	8	20	0	0	0	0	0	0	28
Gesture	0	0	1	0	0	0	0	0	1
Manipulate	0	0	0	24	0	0	0	0	24
Navigate	0	0	0	0	40	206	0	0	246
Position	0	0	0	0	0	0	0	0	0
Scan	0	0	0	0	0	0	70	0	70
Verify	0	0	0	0	0	0	0	0	0
Total	152	22	1	24	40	206	70	190	705

Table 8.3: The observed items fitted into the original scoring categories.

Furthermore, the data is analysed at two levels:

- By top-category only. Top-categories in left hand column; totals of observed top-level categories in right hand column.
- By subcategory. All cells in table 8.3, representing intentional acts, for instance CC (24), or EC (8).

In table 8.3, it can be seen that by far the most observed top-level act is of type "Communicate" (total 336, right hand column). The second, next most often occurring type of act, is "Navigate" (total 246, right hand column). The third, next most often occurring act is "Scan" (total 70, right hand column). The residue consists of three types of acts, two acts both occurring almost as often as each other: "External" (total 28, right hand column) and "Manipulate" (total 24, right hand column), and finally one instance of act type "Gesture" was observed.

Two original categories were not found at all during the observations. These are "Position" (total 0, right hand column), and "Verify" (total 0, right hand column). In retrospect some reasons may be found for this, which could suggest that the basic acts for collaboration are different from the ones identified originally. Acts of type "Position" have perhaps all ended up in the "intentional acts" category "NP" (table 8.3, cell "navigate - position", 206 items), possibly because the type of positioning acts observed most often involved moving the virtual embodiment into a particular place, so in order to position the VB the user has to navigate. Acts of type "Verify" have perhaps all ended up in "the intentional acts" category "CV" (table 8.3, cell "communicate - verify", 190 items); possibly because the only observed verifications were verbal.

During the scoring process of the data it was also found that the original categories could be broken down into more detailed observations, to increase the richness of the observations. Thus a third level of analysis has been created:

- By subcategory of the original subcategories. For some subcategories additional categories could be defined during the observation, for instance, CC1 and CC2 are particular instances of CC acts.

Table 8.4 lists the original categories; effectively the ‘predicted’ categories, their related ‘observed’ categories and sub level categories; and their respective definitions. Column two of table 8.4 shows all categories used to score the observed behaviours.

Predicted categories	**Observed categories and sub level categories**	**Definition**
CC Communication	CC general	Communicate about the task at hand. General talk.
	CC1 progress	Communicate about the task at hand. Contributing to progress.
	CC2 text	Communicate about the task at hand. Text.
CV Communication to verify something	CV general	Communicate to verify something. General inquiry.
	CV1 self	Communicate to verify present. Introduce one self.
	CV11 noise	Communicate to verify being present. General noises. (Hmm, hmmm.)
	CV2 audible self	Communicate to verify being audible. Having been heard.
	CV21 other	Communicate to verify being audible. Having heard the right person.
	CV3 inaudible other	Communicate to verify having heard correctly. Repeat inaudible audio.
	CV4 acknowledge	Communicate to verify having heard. (Yes!, Uh-huh, Hi there!)
	CV5 happening	Communicate to verify that something is happening. Acknowledgements.
	CV51 scream	Communicate to verify that something is happening. Scream.
	CV6 giggle	Communicate to verify picking up on a joke. Giggle, muffled giggle.
	CV61 laughter	Communicate to verify picking up on a joke. Laughter.
CE Communication to announce going external to the CVE	CE swap to RL	Communication to announce going to pay attention away from CVE.
EC External communication	EC outside talk	External communication. Any verbal communication not aimed at CVE.
EE External activity	EE desktop	Perform action external to main graphical window of CVE.
	EE1 game controls	Perform action external to main graphical window of CVE. Game controls.
GG Gesture	GG general	Performing a virtual body movement that is intended as a gesture.
	GG1 point	Performing a virtual body movement that is

		intended as a gesture. Point.
MM Manipulate	MM manipulate	Manipulate something in the virtual environment.
NN Navigation	NN navigate	Navigate in the virtual environment.
	NN1 forwards	Navigate in the virtual environment. Moving forwards.
	NN2 round	Navigate in the virtual environment. Moving forwards. In circling motion. Around something.
	NN3 up	Navigate in the virtual environment. Moving up.
	NN31 up and down	Navigate in the virtual environment. Moving up and down in one complete motion.
	NN4 down	Navigate in the virtual environment. Moving down.
	NN41 down slope	Navigate in the virtual environment. Moving down, forward slope.
NP Navigation to position the VB	NP general	Navigate into position.
	NP1 closer	Navigate into position. Moving forwards. Closer to object, making circle smaller.
	NP12 through	Navigate into position. Moving forwards, going through wall, object.
	NP2 spot-on	Navigate into position. Moving forwards. Facing object, other user close-up.
	NP21 stop in front	Navigate into position. Moving forwards. Facing object, other user close-up. Stop in front of object.
	NP22 stop behind	Navigate into position. Moving forwards. Facing object, other user close-up. Stop behind object.
	NP3 backwards	Navigate into position. Moving backwards. Increasing field of view.
	NP31 back into	Navigate into position. Moving backwards. Ending up inside other virtual embodiment, or right in front of them blocking them completely.
	NP32 back through	Navigate into position. Moving backwards. Falling through wall.
	NP4 position to left A	Navigate into position. Moving virtual embodiment to left (A).
	NP5 position to right B	Navigate into position. Moving virtual embodiment to right (B).
	NP6 circle to position	Navigate into position. Moving forwards. In circling motion to end up behind something.
SS Scanning the CVE space	SS general	Scan the virtual environment.
	SS1 scan A B A	Scan the virtual environment. Moving view in a continuous fashion from A (left) to B (right) and back to A (left).
	SS2 full circle	Scan the virtual environment. Turning full circle.
	SS3 view left A	Scan the virtual environment. Turning to view more on left (A).
	SS4 view right B	Scan the virtual environment. Turning to view more on right (B).
	SS5 follow object	Scan the virtual environment to follow a moving object.

Table 8.4: The predicted categories and their related observed categories.

During the observations these additional sub level categories seemed to provide important information for the analysis of collaborative behaviours in CVEs and were therefore included into the data collection. These different levels of analysis also allow for better management of the large amount of data, by being able to collapse the data set whenever an overview is needed (i.e. look at top level acts only) and expand when a detailed overview of each type of observed acts is needed, without having to remember more category names.

8.3 Categorical Analyses

The categorical data have been subjected to seven different ways of analysis. First the categories as they were predicted during the development of the observation method are compared to the actual categories as they were found during the observations (section 8.3.1). Next, the observed categories are analysed for frequencies and types of problems (section 8.3.2). Subsequently, patterns in the sequences of observed behaviours are analysed (section 8.3.3), including a statistical prediction of the observed patterns in behaviours (section 8.3.4). Next, a comparison between beginning, middle, and end of CVE collaborations is made (section 8.3.5), and between novices and expert users' observed behaviours (section 8.3.6). Finally, time elapsed between meaningfully connected events is analysed (section 8.3.7).

8.3.1 Predicted Category Analysis

The total data set is first collapsed to show only the top categories (see table 8.5, and figure 8.1). The data are analysed in terms of the number and relative frequency of observed acts for the Business game (two columns: "Test 1 and 2") vs. the WhoDo game (two columns: "Expert and Novice"), and their totals.

Top category	Business Game Test 1 and 2		WhoDo Game Expert and Novice		Total	
	Count	%	Count	%	Count	%
CC Communication	55	13.1	89	31.2	144	20.4
CV Communication to verify something	126	30.0	64	22.5	190	27.0
CE Communication to announce going external to the CVE	0	0	2	.7	2	.3
EC External communication	1	.2	7	2.4	8	1.1
EE External activity	14	3.3	6	2.1	20	2.8
GG Gesture			1	.4	1	.1
MM Manipulate	23	5.5	1	.4	24	3.4
NN Navigation	27	6.4	13	4.6	40	5.7
NP Navigation to position the VB	140	33.3	66	23.2	206	29.2
SS Scanning the CVE space	34	8.1	36	12.6	70	9.9
Total	420	100.0	285	100.0	705	100.0

Table 8.5: Data set distribution.

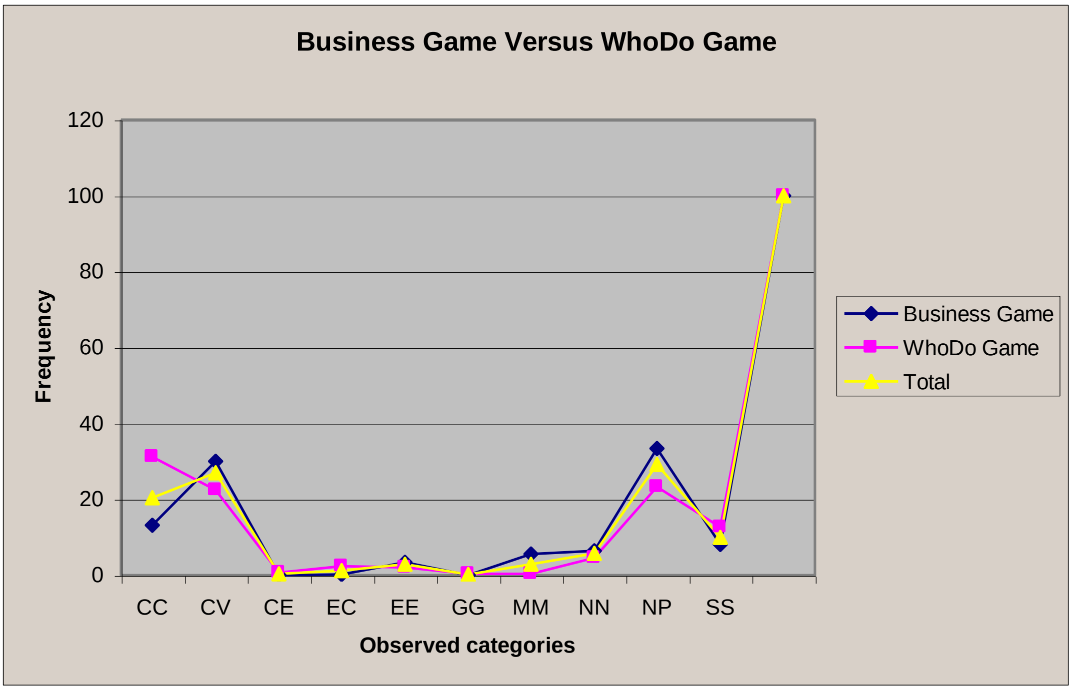

Figure 8.1: Observed activities for two different CVE platforms.

It can be seen that there is a higher percentage of "CC communication" during the WhoDo game than during the Business game (31.2% vs. 13.1%), although there is a lower incidence of "CV communications to verify" (22.5% vs. 30%). This can be attributed to the fact that the Business Game trials were largely dedicated to testing the application for network connectivity and application errors, while the WhoDo games were immediately concerned with collaboration between participants.

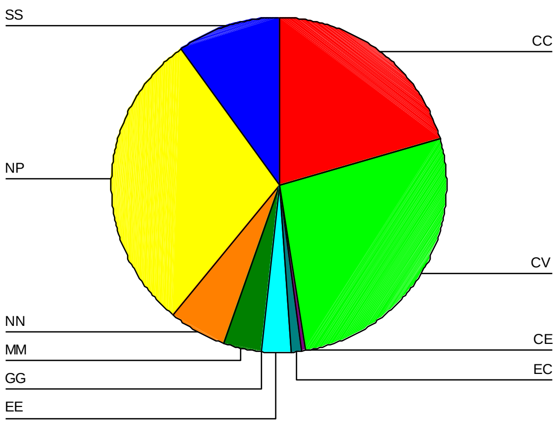

Figure 8.2: Pie chart of observed categories.

Also it can be seen that there is a higher incidence of "NP navigation to position" in the Business game than in the WhoDo game. This difference can be attributed to the fact that the Business game involved standing close to a game table, and regularly having a look at each other's game tables, thus creating many acts of navigating into position. It seems likely that any of the other smaller differences are also due to the fact that the CVE settings were slightly different. Thus the differences between the two data sets seem to be accounted for by the difference in CVE and collaboration task, and as such the two data sets complement each other. The match between the two CVEs, the collaborations and the data sets is considered sufficient for combination into one large data set, in order to make generalisations for CVE collaboration. This data can also be represented as a pie chart, see figure 8.2 (based on the combined percentages in table 8.5):

The high incidence of acts of type “NP navigate into position” (29.2%), points to an important issue. This type of act is concerned with fine-tuned positioning of the VB or the view of the owner of the embodiment in order to act upon an object, perceive acts of others or objects, or to view other participants’ VBs. It is a very good candidate for automation. CVE users should not really have to concern themselves with fine-tuned acts if a simple mouse-click can automatically position them to the desired object or occurrence for direct attention. To gain a deeper understanding of the different types of “NP” acts a more detailed analysis is made in section 8.3.2.2.

The high incidence acts of type “CV communication to verify” (27.0%) points to another important issue. This type of act is concerned with verifying that something has happened. CVE users seem to seek more feedback about the occurrences in the CVE than they are provided with. This type of need is an urgent candidate for better usability design. CVE users should not have to check that what they think has happened, really has happened. To gain a deeper understanding of the different types of “CV” acts a more detailed analysis is made in section 8.3.2.1

The occurrence and frequencies the other acts of types “CC communication” (20.4%), “SS Scan” (9.9%), “NN navigate” (5.7%), “MM manipulate” (3.4%), “EE external” (2.8%), “EC external communication” (0.3%), “CE communicate to go external” (1.1%), and “GG Gesture” (0.1%), are all types of behaviours one would expect to be typical acts, that would occur during a CVE collaboration. The low instance of act of type “GG gesture” can be attributed to the fact that there are very few “gestures” available in the CVEs under analysis. Acts of types “EC external communication”, and “CE communicate to go external”, relate to the user need to interrupt attention and move it away from the CVE to something else. Though it is to be expected that the real environment of each user might create “interference”, it is also obvious that not every act of “EC external communication” is considered worthy of announcing (act type “CE communicate to go external”) as far as the CVE users are concerned, as the incidence of the latter is lower (CE: 2 observations) than the former (EC: 8 observations). To gain a better understanding of the type of support a CVE user could be provided with to deal with switching between the real world and the virtual world, a more detailed analysis of these types of acts is made in section 8.3.2.1.

The major CVE acts of types “CC communication”, “NN navigate”, “SS Scan”, are further analysed in sections 8.3.2.1, 8.3.2.2, and 8.3.2.3 respectively. Acts of type “MM manipulate” have mostly been found in the Business game interactions and involved the manipulation of the game elements, the 3D bars. Although the act of manipulation in a 3D environment, on 3D objects, is difficult and an important subject for further research, the data derived from the experiments is not sufficiently detailed to fruitfully perform any further analysis. Perhaps a healthier picture of collaboration would be one where acts of type “NP” and “CV” no longer occurred, or with a negligible frequency. See figure 8.3 for an illustration of what such a distribution might look like.

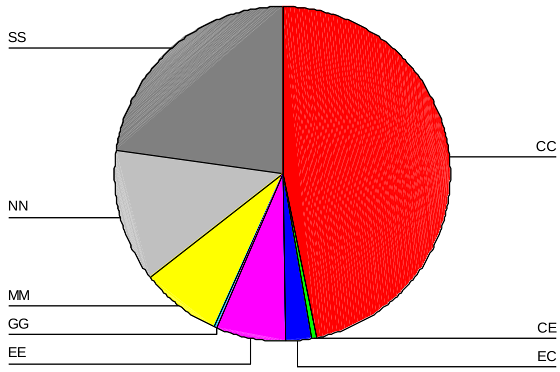

Figure 8.3: More ideal possible distribution of CVE interaction acts.

From the potential distribution displayed in figure 8.3 can be speculated that communication activities are the most frequently occurring acts for a collaboration; which is what one would expect from human-human collaboration, based on the review of collaboration in Chapter 3. It would also be expected that navigation would occur with a relatively high frequency, but certainly not as high as for communication, unless the collaboration involved some kind of relatively silent, object hand-over task. One would also expect the acts of manipulation to be much more frequent, based on an understanding of the significance of sharing objects during collaboration. Similarly, one would expect the act of gesturing, to be much more frequent, based on an understanding of social interaction. It is important to note that these acts are precisely not observed because it is difficult or impossible for CVE users to display them in the CVE. Finally, it may be argued that the act of scanning should occur much less frequently as a user act, because scanning acts are good subjects for automation, similar to fine-tuned navigation acts. Although the issues raised are at best ‘speculations’, they do point to a number of problematic usability issues that could be rectified by:

- Introducing new collaboration functions and features into the system.
- Creating better feedback mechanisms inside the CVE.
- Introducing new collaboration support objects for the users in the CVE.

New collaboration functions and features need to be incorporated into the CVE interface. For instance, fine-tuned navigation, scanning the CVE to locate and follow objects, and gestures have to be made available to the users as options on a menu or automatic actions, i.e. performed by the system. Feedback mechanisms inside the CVE are to do with information about “who does what to whom?”, “what happens to whom?”, “What happened to me?, “did I do that?”, and certainly, “when did it happen?” type of questions. Introducing new collaboration support objects for CVE users, points to a general requirement for more manipulable, interactive objects, that could support the collaboration process by making more use of the pictorial, textual, and perhaps even metaphorical aspects of information presentation. These issues will be further discussed in Chapter 10.

8.3.2 Observed Category Analysis

To be able to analyse the observed acts of CVE users more closely, they were broken down into more detailed categories during observation. The frequency and percentage scores are displayed for each sub category that has been included in the analysis (see table 8.6).

Predicted categories	Observed categories	Count	%
CC Communication	CC general	44	6.2%
	CC1 progress	95	13.5%
	CC2 text	5	.7%
CV Communication to verify something	CV general	56	7.9%
	CV1 self	10	1.4%
	CV11 noise	2	.3%
	CV2 audible self	4	.6%
	CV21 other	1	.1%

	CV3 inaudible other	6	.9%
	CV4 acknowledge	22	3.1%
	CV5 happening	50	7.1%
	CV51 scream	2	.3%
	CV6 giggle	25	3.5%
	CV61 laughter	12	1.7%
CE Communication to announce going external to the CVE	CE swap to RL	2	.3%
EC External communication	EC outside talk	8	1.1%
EE External activity	EE desktop	15	2.1%
	EE1 game controls	5	.7%
GG Gesture	GG1 point	1	.1%
MM Manipulate	MM manipulate	24	3.4%
NN Navigation	NN navigate	16	2.3%
	NN1 forwards	8	1.1%
	NN2 round	1	.1%
	NN3 up	8	1.1%
	NN31 up and down	2	.3%
	NN4 down	4	.6%
	NN41 down slope	1	.1%
NP Navigation to position the VB	NP general	12	1.7%
	NP1 closer	50	7.1%
	NP12 through	7	1.0%
	NP2 spot-on	47	6.7%
	NP21stop in front	2	.3%
	NP3 backwards	55	7.8%
	NP31 back into	4	.6%
	NP32 back through	10	1.4%
	NP4 position to left A	8	1.1%
	NP5 position to right B	4	.6%
	NP6 circle to position	7	1.0%
SS Scanning the CVE space	SS scan	2	.3%
	SS1 scan A B A	8	1.1%
	SS2 full circle	4	.6%
	SS3 view left A	29	4.1%
	SS4 view right B	26	3.7%
	SS5 follow object	1	.1%
	Total	**705**	**100.0%**

Table 8.6: Scores for observed sub-categories.

In order to increase our understanding of the actually observed acts, which seem typical to occur a look at each act group and their constituent sub groups separately, is presented below. Section 8.3.2.1 deals with all communication issues. Section 8.3.2.2 deals with all navigation issues. Section 8.3.2.3 deals with all scanning issues.

8.3.2.1 Communication Issues

The communication issues considered in this section are all the verbal communication acts that have been observed. To be precise, all communication acts which were considered to be pure communication acts (i.e. those that seemed to be verbal utterances of CVE participants) have been included in this part of the analysis. As evoked before, (see figure 8.2), communication acts which serve to verify something ("CV"), are the most frequent type of communication act. In order to understand this type of communication act better, a more detailed analysis has been made (see table 8.7).

	Count	%
CV general	56	29.5%
CV5 happening	50	26.3%
CV6 giggle	25	13.2%
CV4 acknowledge	22	11.6%
CV61 laughter	12	6.3%
CV1 self	10	5.3%
CV3 inaudible other	6	3.2%
CV2 audible self	4	2.1%
CV11 noise	2	1.1%
CV51 scream	2	1.1%
CV21 other	1	.5%
Total	190	100.0%

Table 8.7: Frequency count of all "CV communication to verify" acts.

The two most frequently observed "CV" act is a general "CV", concerned with issues of confusion, such as "what's happening?", etc. (29.5%), and CV5 (26.3%) "has it happened?". However, the next most often observed act is concerned with a "giggle to confirm that the user has observed and appreciated what happened" (CV6, 13.2%). Giggling could arguably be more likely considered to be part of the ongoing collaboration process (and thus tally under "CC communication" acts), but the instances of "giggle" that were observed seemed to be primarily an expression of slightly nervous excitement about “what seemed to be happening”. The expression of such an emotion would not seem unexpected, given the scenario of trying out a futuristic communication system using a highly advanced technology. The next most often observed verification act is a straight acknowledgement that something has happened (CV4, 11.6%). These types of acts would be the first candidates for the introduction of more particular types of feedback, striving to ultimately eliminate user needs for more confirmations of this type. The next most often observed verification act is laughter (CV61, 6.3%). Again, these acts could be construed as part of the ongoing collaboration, however, the observed incidences of laughter seemed to confirm the other users’ perception and understanding of collaboration acts gone ‘wrong’ due to a first users’ interface or application failure related problems. The author of this thesis would under no circumstances want to preach that acts of laughter should be removed from CVE collaboration. If anything, they are an indication that actually, a multi-layered rapport between the CVE participants does take place during CVE interaction; which of itself is reminiscent of what one would expect to occur during any collaboration between any given number of participants. As such, it would seem, CVEs provide a medium for human-human communication, albeit of a kind. To illustrate this point, the residue of observed verification acts is made up of several small, but highly interesting other sub groups: “CV self” (5.3%), “CV inaudible other” (3.2%), “CV audible self” (2.1%), “CV noise” and “CV scream” (1.1%), and finally, “CV other” (0.5%). These acts all concerns themselves with letting people know that one has arrived in the CVE, whether one can be heard, “have I heard you correctly?”, and making various noises to acknowledge and test each other’s ‘presence’ in the CVE, etc.

Apart from communications to verify something, pure communication acts, which are part of the collaboration process have been observed. In order to understand these different types of communication acts better, a closer look at the observed sub categories has been attempted (see table 8.8). The table shows the frequencies for all remaining observed sub category communication acts.

	Count	%
CC1 progress	95	61.7%
CC general	44	28.6%
EC outside talk	8	5.2%
CC2 text	5	3.2%
CE swap to RL	2	1.3%
Total	154	100.0%

Table 8.8: Frequencies for all observed sub category communication acts.

The most often observed communication act is “CC1 progress” (61.7%), which is to be expected from a collaboration activity. Textual communications (“CC2”) are perhaps rather low, considering the added value of initiating and maintaining sub-group communications available from a textual channel inside a CVE. However, possibly those parts of the experiments that provided the data for this analysis did not deal with interactions that could be considered to demand more textual communication.

8.3.2.2 Navigation Issues

Referring back to table 8.3: “Navigate” (total 246, right hand column), is the next most often occurring type of act (after communication), of all predicted collaboration activities. To gain a better understanding of the type of navigation acts that CVE users seem to perform, a more detailed observation of the navigation acts has been performed (see table 8.9).

	Count	%
NP3 backwards	55	22.4%
NP1 closer	50	20.3%
NP2 spot-on	47	19.1%
NN navigate	16	6.5%
NP general	12	4.9%
NP32 back through	10	4.1%
NN1 forwards	8	3.3%
NN3 up	8	3.3%
NP4 position to left A	8	3.3%
NP12 through	7	2.8%
NP6 circle to position	7	2.8%
NN4 down	4	1.6%
NP31 back into	4	1.6%
NP5 position to right B	4	1.6%
NN31 up and down	2	.8%
NP21stop in front	2	.8%
NN2 round	1	.4%
NN41 down slope	1	.4%
Total	246	100.0%

Table 8.9: Frequency count of all observed navigation acts.

The most frequently observed act is “NP3 backwards” (22.4) and a close second is “NP1 closer” (20.3%). Both acts are concerned with a desire to change what is seen on the screen: more (NP1) or less (NP3) detail. Moving backwards and closer unfortunately also means moving into (NP31, 1.6%), and through (NP32, 4.1%) objects such as walls, other users, and game-tables. Generally acts of type “NP31 moving into object” and sometimes acts of type “NP32 falling through object” seemed to be deliberate on the users part, but often seem to be accompanied by CC communications from the active user, and CVs from the other users. Sometimes the remarks address the invasion of personal space, sometimes they are considered ‘laughable’ acts, it may create concern for the other users, or it may create annoyance for other users. Making walls and objects solid, so that one cannot move ‘through’ them is in itself a solution, although there is some evidence that when walls are solid, users will find the rooms “too small”; probably due to the small field of view that a desktop CVE provides. The third most frequently observed act of navigation is "NP2 spot-on (19.1%), which indicates the type of alignment CVE users consider to be worthy of navigating their embodiment for.

The residue of navigational acts is made up of "NN navigate" (6.5%), and "NP general" (4.9%), both of which would be expected to be general user acts during a collaboration. These scores are closely followed by "NP32 back through" (10 4.1%), which really signifies how much this problem occurs compared to intentional navigation acts. This high incidence should immediately place it high on the list of CVE development priorities. The next most often occurring navigation acts concern themselves with moving forward (NN1, 3.3%), up (NN3, 3.3%) and to the left (NP4, 3.3%).

In order to gain a better understanding of precisely what type of pure navigation acts do seem to occur (excluding navigation acts which are aimed at positioning (NP), a more detailed analysis has been made of the observed navigation acts on their own (NN only). See table 8.10.

	Count	%
NN navigate	16	40.0%
NN1 forwards	8	20.0%
NN3 up	8	20.0%
NN4 down	4	10.0%
NN31 up and down	2	5.0%
NN2 round	1	2.5%
NN41 down slope	1	2.5%
Total	40	100.0%

Table 8.10: Frequency count of all low-level rough navigation acts.

The most often occurring navigation act is “NN navigate” (40%). Some of these navigation acts could be defined more precisely: “NN1 forwards” (20%) and “NN3 up” (20%). A number of observations of type “NN3 up” may be attributable to a clumsily laid out navigation device, however, occurrences of deliberately moving up and down (NN31, 5%) and moving down with a slope, thus providing a birds-eye view of the CVE (NN41, 2.5%) have also been observed and could be construed as evidence that some acts to move up (NN3) are deliberate. Finally, the acts of “NN31 up and down” (5%), and “NN2 round” (2.5%), could be interpreted as a certain type of verification. Moving up and down could be interpreted as an attempt of the user to test the reaction time of interface-command vs. body-movement. Moving round could be interpreted as an act of orientation, thus providing for a similar need as the birds-eye view.

Looking at all fine tuned navigation (NP) acts a bit more closely provides a similar picture to the one presented for all navigation (NN) acts (see table 8.11).

	Count	%
NP3 backwards	55	26.7%
NP1 closer	50	24.3%
NP2 spot-on	47	22.8%
NP general	12	5.8%
NP32 back through	10	4.9%
NP4 position to left A	8	3.9%
NP12 through	7	3.4%
NP6 circle to position	7	3.4%
NP31 back into	4	1.9%
NP5 position to right B	4	1.9%
NP21stop in front	2	1.0%
Total	206	100.0%

Table 8.11: Frequency count of all fine tuned navigation acts.

The most often occurring “NP” act is “NP3 backwards” (26.7%), closely followed by “NP1 closer” (24.3%), and “NP2 spot-on” (22.8%). The high incidence of “NP3 backwards”, is tell-tale for the fact that the field of view for desktop CVE is comparatively small, since this act increases the field of view. Acts of “NP1 closer” and NP2 spot-on” are to be expected for collaborations, and are a definite candidate for automation. The residue is made up of “NP6 circle to position” (3.4%), and “NP21 stop in front” (1.0%); both indicators of high precision acts of navigation, reminiscent of real world navigation.

8.3.2.3 Scanning Issues

Finally, we look at all scanning acts a bit more closely (see table 8.12).

	Count	%
SS3 view left A	29	41.4%
SS4 view right B	26	37.1%
SS1 scan A B A	8	11.4%
SS2 full circle	4	5.7%
SS scan	2	2.9%
SS5 follow object	1	1.4%
Total	70	100.0%

Table 8.12: Frequency count of all low level scanning acts.

Most scanning acts could be said to be part of the expression of the users’ wish to gain more information about things going outside their field of view, i.e. they wish to focus their attention elsewhere. As such, scanning acts could be said to be very strong indicators of users showing tendencies to maintain the objects of collaboration in focus, and also of users’ tendencies to maintain maximum peripheral awareness. It would be impossible to predict where a particular user attention would be drawn next. However, generally we can safely assume that, any ‘next occurrence’ in a sequence of collaborative acts, would draw the attention of every collaborator. This particular incidence, of CVE users' instantly directing their view at 'any type of object/user behaviour that is not one's own', would be straightforward to automate in terms of feedback as soon as the act has occurred. Whether this would create an enormous overhead in terms of network traffic, without improving the process of collaboration, remains to be seen.

8.3.3 Patterns in Sequences of Behaviours

In order to ascertain whether there are any particular sequences to be observed in terms of collaboration acts on a microscopic level (every act occurring), an analysis has been made of how often a particular act is followed by what other acts (see table 8.13).

		Next act										Total
		CC	CV	CE	EC	EE	GG	MM	NN	NP	SS	
Preceding act	CC	51	34		1	4		1	5	35	12	143
	CV	35	75		2	5		2	12	41	16	188
	CE				1						1	2
	EC	3	1	1		1				1		7
	EE	4	8	1		3			2	2		20
	GG									1		1
	MM	3	3					13		3	2	24
	NN	4	7		1	2			8	15	3	40
	NP	29	42		1	1	1	6	8	89	25	202
	SS	13	19		1	3		2	4	19	9	70
Total		142	189	2	7	19	1	24	39	206	68	697

Table 8.13: Cross tabulation of preceding act by following act.

These data are seen in descending frequency in table 8.14 (for example a communication act (Preceding act "CC") is followed by a next act, which is also a communication (Next act "CC"), 51 times). Note that all scores, which account for less than 1% of the total observed parings, are deleted from this analysis.

Preceding act-Next act	Frequency	%
NP-NP	89	13%
CV-CV	75	10.8%
CC-CC	51	7.3%
NP-CV	42	6.0%
CV-NP	41	5.9%
CC-NP	35	5.0%
CV-CC	35	5.0%
CC-CV	34	4.9%
NP-CC	29	4.2%
NP-SS	25	3.6%
SS-CV	19	2.7%
SS-NP	19	2.7%
CV-SS	16	2.3%
NN-NP	15	2.2%
MM-MM	13	1.9%
SS-CC	13	1.9%
CC-SS	12	1.7%
SS-SS	9	1.3%
EE-CV	8	1.1%
NN-NN	8	1.1%
NP-NN	8	1.1%
NN-CV	7	1.0%

Table 8.14: The sequence in which the observed acts occurred.

These scores are an indication that the type of act “NP” is most often followed by another act of “NP” (“NP-NP”, 13%). In other words, this means that a fine-tuned positioning act is typically followed by another fine-tuning act. An act of “NP” is also, just under half as often, followed by an act of “CV” (“NP-CV”, 6%). In other words, a fine-tuned navigation act (“NP”), often seems to be followed by a request for verification of something that happened (“CV”). This could possibly point at difficulties in understanding something related to the navigation act or its results, although this is a highly speculative conclusion, if not supported by other corroborative data.

Communications to verify something (“CV”) are most often followed by another communication to verify something (“CV-CV”, 10.8%). This is indicative of conversations about the CVE or the functioning of elements of the CVE, and is certainly to be expected from user interaction in a CVE under development. It will be useful to know more about the type of confirmation CVE users are giving each other, since these could be candidates for better feedback design. Communications to verify something are followed by an act of “NP” (“CV-NP”) in 5.9% of the cases. This could suggest that once users receive confirmation about something going on in the CVE, they direct their focus in a certain place, however, again this is highly speculative.

Communication acts (“CC”) are also often followed by another communication act (“CC-CC”, 7.3%), which is to be expected of human-human collaboration and is indicative of conversations about the task at hand, going on inside the CVE. Communications are followed by an act of fine-tuned navigation (“CC-NP”) 5.0% of the time. This is indicative of confirmations that ongoing collaborations are taking place. Collaborations involve the continuous re-definition of the area of focus, so that one would expect a communication about the task at hand often to be followed by an adjustment in the positions of the users. Vice versa, fine-tuned navigation acts (“NP”) are also often (4.2%) followed by communication acts (“CC”); in fact nearly as often (“NP-CC”, 4.2%) as a communication act is followed by a fine-tuned navigation act (“CC-NP”, 5%).

Communications are also followed by acts of communication to verify something (“CC-CV”, 4.9.%). This is indicative of conversations breaking up either through bad audio reception, application performance problems or other types of user struggles with the interface for which they give each other confirmations.

Interestingly, scanning acts are not very often followed by another scanning act ("SS-SS", 1.3%), compared to the high frequencies for "NP-NP", "CV-CV", and "CC-CC" (all higher than 7%). However, higher frequencies are observed for a scanning act to be followed by a fine-tuned navigation ("SS-NP", 3.6%), a communication to verify something ("SS-CV", 2.7%), and a general communication ("SS-CC", 1.9%). Also, scanning acts are more likely to be preceded by a communication to verify something ("CV-SS", 2.3%) and general communication ("CC-SS", 1.7%). This is highly indicative of the importance of scanning acts during CVE interaction, and the integral part they play in the continuation of the collaboration process.

Another score that is notably low is "NN-NN" (1.1%), a navigation act followed by another navigation act. The low incidence can be explained by the fact that navigation acts that are general movements ("NN") have been displayed separately from navigation acts ("NP"), that are fine-tuned positioning acts ("NP-NP", 13%) so that a total score for navigation acts following another navigation act could be said to be 14.1%. The reason for the low incidence of "NN" observations could also be found in that the observations concerned CVE users interacting in small spaces; CVE rooms, so that the observed navigation acts are reminiscent of movements in small spaces in the real world: small adjustments rather than large movements. Navigation acts are followed by fine-tuned positioning acts 2.2% of the time and fine-tuned positioning acts are followed by a navigation act 1.1% of the time. Approaching an object seems to be a gross navigational movement towards the object followed by fine-tuning the position, and if the user is not satisfied with the final position, they can be seen to make another attempt at arriving at the object with a new gross navigational movement.

8.3.4 Statistical Prediction of Observation Patterns

In order to statistically assess whether acts follow other acts randomly, or with a certain pattern that could be predicted, a cross tabulation has been made for the preceding act-next act. Based on the number of observations for each cell (expressed in table 8.19 as a number for "Count"), a statistical prediction of the frequency of occurrence for each act is made (expressed in the table as "Expected Count", for example the expected count for CC-CC is 29.1), using the assumption that the acts are not linked to each other, but occur randomly. The 'standardized residual' (expressed in the table as "Std. Residual, for example, the residual for CC-CC is 4.1), is calculated (formula: (Observed count - Expected Count) / Expected Count / standard deviation of Expected Count), in order to provide an "ad-hoc" statistical assessment of the extent to which the occurrence of any given act is independent of the preceding one. The standardised residual expresses a normalised measure of the size of the difference between the predicted and the observed counts. The difference equals zero if the predicted count is equal to the observed count, which means that the relationship between act and next act is random. Precisely what the meaningful relationship is, has to be interpreted afterwards. However, a negative difference is associated with a lower count of observed acts than predicted, and a positive difference is associated with a higher count of observed acts than predicted. A standardized residual is deemed "interestingly" large if it is greater than two only. All cells related to an act that has a count higher than two, are highlighted in red in table 8.15. All cells that show interesting residuals are shaded.

			Next act										Total
			CC	CV	CE	EC	EE	GG	MM	NN	NP	SS	
Preceding act	CC	Count	51	34	0	1	4	0	1	5	35	12	143
		Expected Count	29.1	38.8	.4	1.4	3.9	.2	4.9	8.0	42.3	14.0	143.0
		Std. Residual	4.1	-.8	-.6	-.4	.1	-.5	-1.8	-1.1	-1.1	-.5	
	CV	Count	35	75	0	2	5	0	2	12	41	16	188
		Expected Count	38.3	51.0	.5	1.9	5.1	.3	6.5	10.5	55.6	18.3	188.0
		Std. Residual	-.5	3.4	-.7	.1	-.1	-.5	-1.8	.5	-2.0	-.5	
	CE	Count	0	0	0	1	0	0	0	0	0	1	2
		Expected Count	.4	.5	.0	.0	.1	.0	.1	.1	.6	.2	2.0
		Std. Residual	-.6	-.7	-.1	6.9	-.2	-.1	-.3	-.3	-.8	1.8	
	EC	Count	3	1	1	0	1	0	0	0	1	0	7
		Expected Count	1.4	1.9	.0	.1	.2	.0	.2	.4	2.1	.7	7.0
		Std. Residual	1.3	-.7	6.9	-.3	1.9	-.1	-.5	-.6	-.7	-.8	
	EE	Count	4	8	1	0	3	0	0	2	2	0	20
		Expected Count	4.1	5.4	.1	.2	.5	.0	.7	1.1	5.9	2.0	20.0
		Std. Residual	.0	1.1	3.9	-.4	3.3	-.2	-.8	.8	-1.6	-1.4	
	GG	Count	0	0	0	0	0	0	0	0	1	0	1
		Expected Count	.2	.3	.0	.0	.0	.0	.0	.1	.3	.1	1.0
		Std. Residual	-.5	-.5	-.1	-.1	-.2	.0	-.2	-.2	1.3	-.3	
	MM	Count	3	3	0	0	0	0	13	0	3	2	24
		Expected Count	4.9	6.5	.1	.2	.7	.0	.8	1.3	7.1	2.3	24.0
		Std. Residual	-.9	-1.4	-.3	-.5	-.8	-.2	13.4	-1.2	-1.5	-.2	
	NN	Count	4	7	0	1	2	0	0	8	15	3	40
		Expected Count	8.1	10.8	.1	.4	1.1	.1	1.4	2.2	11.8	3.9	40.0
		Std. Residual	-1.5	-1.2	-.3	.9	.9	-.2	-1.2	3.9	.9	-.5	
	NP	Count	29	42	0	1	1	1	6	8	89	25	202
		Expected Count	41.2	54.8	.6	2.0	5.5	.3	7.0	11.3	59.7	19.7	202.0
		Std. Residual	-1.9	-1.7	-.8	-.7	-1.9	1.3	-.4	-1.0	3.8	1.2	
	SS	Count	13	19	0	1	3	0	2	4	19	9	70
		Expected Count	14.3	19.0	.2	.7	1.9	.1	2.4	3.9	20.7	6.8	70.0
		Std. Residual	-.3	.0	-.4	.4	.8	-.3	-.3	.0	-.4	.8	
Total		Count	142	189	2	7	19	1	24	39	206	68	697
		Expected Count	142.0	189.0	2.0	7.0	19.0	1.0	24.0	39.0	206.0	68.0	697.0

Table 8.15: Cross tabulation of Top category by Next top category, with expected and observed values. Note: red print signifies the valid cases for this analysis; shaded cells signify interesting scores.

Just looking at residual values bigger than 1.5, there are a number of observations that can be made. The values of the residuals for “MM-MM” (13.4), “CC-CC” (4.1), “NN-NN” (3.9), and “NP-NP” (3.8) immediately stand out. Additionally, residual values for “NP-CC” (-1.9), “NP-CV” (-1.7) are noteworthy. The likelihood of a manipulation being followed by another manipulation is 13.4 times greater than predicted. The likelihood that a communication is being followed by another communication is 4.1 times greater predicted. Similarly, the likelihood of a navigation act to be followed by another one is 3.9 times greater than predicted, and the likelihood of a fine-tuned navigation act to be followed by another fine-tuned navigation act is 3.8 times greater than predicted. Manipulation, communication, navigation and fine-tuned positioning are obviously all regular activities of the collaboration process, and if CVEs need to be improved those acts would be the first to be subject to a more detailed analysis in order to gather information for a proper user requirements analysis. The residual values for "NP-CC" and "NP-CV" are both close to –2. This means that a navigation act is less likely to be followed by a communication act than expected. Possibly this could mean that when a user is busy navigating, they are less likely to speak, which could point at the fact that they are concentrating on the task of navigation.

Finally, it pays to look at what type of acts one actor are aims at (what) other actors (see table 8.16). The first actor in column 1, is the 'acting' actor and the second actor is the actor 'acted upon'. The columns under the "top category" label all present the number of times a first actor has aimed each possible act, for each actor 'acted upon'. Actor 0 is the code for the whole group. All participants (1^{st} actor 0) reacted twice with a communication to verify something (CV, 2) to all other participants (2^{nd} actor). Having looked up these particular instances in the data set, the author can confirm that these acts refer to laughter that was shared by the group members. Actors 1, 2, and 3 tend to talk to the group more than to one particular individual in the group, which is to be expected from a collaborative setting. The other actors frequencies are not all complete observations as they were out of the field of view of the actor from whose screen the observations were taken.

1st ACTOR			Top category									Total
			CC	CV	CE	EE	GG	MM	NN	NP	SS	
0	2nd ACTOR	0		2								2
		3		1								1
	Total			3								3
1	2nd ACTOR	0	16	28	2					17	4	67
		1	1	1							1	3
		2	11	25					3	22	11	72
		3	9	18		1				16	10	54
		4	1	1						2		4
		8							1	1	1	3
		9									1	1
		10								2	1	3
	Total		38	73	2	1			4	60	29	207
2	2nd ACTOR	0	26	23						5	1	55
		1	6	19					1	12		38
		2	1									1
		3	5	4					1	3		13
		4	6	2								8
		7								1		1
		10	1	4								5
	Total		45	52					2	21	1	121
3	2nd ACTOR	0	5	15					1	9	2	32
		1	12	8				1		3		24
		2	4	3						1		8
		3		1								1
	Total		21	27				1	1	13	2	65
4	2nd ACTOR	0	4	1								5
		1		1								1
		2	11	3								14
		3					1					1
	Total		15	5			1					21
5	2nd ACTOR	4								1		1
	Total									1		1
6	2nd ACTOR	2	1									1
		99	1									1
	Total		2									2
8	2nd ACTOR	2	1									1
		9									1	1
	Total		1								1	2
10	2nd ACTOR	1							1	1		2
		2	3	1					1			5
	Total		3	1					2	1		7
991	2nd ACTOR	2									1	1
	Total										1	1

Table 8.16: What acts are aimed at which actor.

It has to be noted that the data for these scores were collected from the actor whose screen the observations are taken from (actor 1) and each next actor is somebody that actor 1 engages with in an interaction. The table gives an indication at what type of interactions actors might engage in, with what frequencies, during a small group collaboration in a CVE.

8.3.5 Comparison between Beginning, Middle and End Sections

To explore the possibility that during different times of the collaboration process different collaborative activities are employed more than others, a look at the differences in observed acts between the beginning, the middle and the end of a collaboration is called for. To this end, the data in the WhoDo set have been scored for the observed acts, occurring in each time-slice (see table 8.17, the three columns "beginning", "middle" and "end" under main top column "period").

			PERIOD			Total
			beginning	middle	end	
Top category	CC	Count	12	42	35	89
		% within PERIOD	14.1%	35.9%	42.2%	31.2%
	CV	Count	18	18	28	64
		% within PERIOD	21.2%	15.4%	33.7%	22.5%
	CE	Count	2			2
		% within PERIOD	2.4%			.7%
	EC	Count	7			7
		% within PERIOD	8.2%			2.5%
	EE	Count	2	3	1	6
		% within PERIOD	2.4%	2.6%	1.2%	2.1%
	GG	Count	1			1
		% within PERIOD	1.2%			.4%
	MM	Count		1		1
		% within PERIOD		.9%		.4%
	NN	Count	4	9		13
		% within PERIOD	4.7%	7.7%		4.6%
	NP	Count	24	29	13	66
		% within PERIOD	28.2%	24.8%	15.7%	23.2%
	SS	Count	15	15	6	36
		% within PERIOD	17.6%	12.8%	7.2%	12.6%
Total		Count	85	117	83	285
		% within PERIOD	100.0%	100.0%	100.0%	100.0%

Table 8.17: Observed acts cross tabulated with time slice in which they occurred.

This can also be presented as a graph:

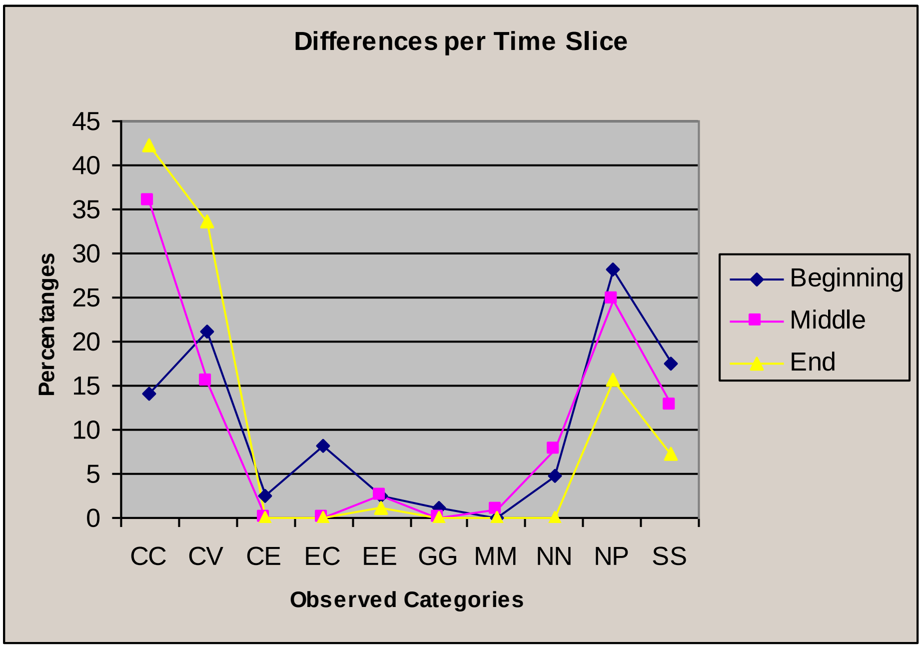

Figure 8.4: Differences in percentages for each observed category per time slice "beginning", "middle", and "end".

Additionally, an analysis of the low level observed acts can be made using the same statistical measures, for more detail about the type of acts occurring for each time slice (see table 8.18).

			PERIOD			Total
			beginning	middle	end	
Low level acts	CC general	Count	4	7	20	31
		% within PERIOD	4.7%	6.0%	24.1%	10.9%
	CC1 progress	Count	5	35	15	55
		% within PERIOD	5.9%	29.9%	18.1%	19.3%
	CC2 text	Count	3			3
		% within PERIOD	3.5%			1.1%
	CV general	Count	1	1		2
		% within PERIOD	1.2%	.9%		.7%
	CV1 self	Count	2	2	1	5
		% within PERIOD	2.4%	1.7%	1.2%	1.8%
	CV11 noise	Count	1			1
		% within PERIOD	1.2%			.4%
	CV2 audible self	Count	1			1
		% within PERIOD	1.2%			.4%
	CV21 other	Count	1			1
		% within PERIOD	1.2%			.4%

	CV3 inaudible other	Count		2		2
		% within PERIOD		1.7%		.7%
	CV4 acknowledge	Count	3	6	6	15
		% within PERIOD	3.5%	5.1%	7.2%	5.3%
	CV5 happening	Count	4	4	2	10
		% within PERIOD	4.7%	3.4%	2.4%	3.5%
	CV51 scream	Count			2	2
		% within PERIOD			2.4%	.7%
	CV6 giggle	Count	2	2	12	16
		% within PERIOD	2.4%	1.7%	14.5%	5.6%
	CV61 laughter	Count	3	1	5	9
		% within PERIOD	3.5%	.9%	6.0%	3.2%
	CE swap to RL	Count	2			2
		% within PERIOD	2.4%			.7%
	EC outside talk	Count	7			7
		% within PERIOD	8.2%			2.5%
	EE desktop	Count	1			1
		% within PERIOD	1.2%			.4%
	EE1 game controls	Count	1	3	1	5
		% within PERIOD	1.2%	2.6%	1.2%	1.8%
	GG1 point	Count	1			1
		% within PERIOD	1.2%			.4%
	MM manipulate	Count		1		1
		% within PERIOD		.9%		.4%
	NN1 forwards	Count	1	3		4
		% within PERIOD	1.2%	2.6%		1.4%
	NN2 round	Count		1		1
		% within PERIOD		.9%		.4%
	NN3 up	Count	1	3		4
		% within PERIOD	1.2%	2.6%		1.4%
	NN31 up and down	Count	1	1		2
		% within PERIOD	1.2%	.9%		.7%
	NN4 down	Count	1			1
		% within PERIOD	1.2%			.4%
	NN41 down slope	Count		1		1
		% within PERIOD		.9%		.4%
	NP1 closer	Count	8	9	3	20
		% within PERIOD	9.4%	7.7%	3.6%	7.0%
	NP12 through	Count			1	1
		% within PERIOD			1.2%	.4%
	NP2 spot-on	Count		4		4
		% within PERIOD		3.4%		1.4%
	NP21stop in front	Count			2	2
		% within PERIOD			2.4%	.7%
	NP3 backwards	Count	9	9	5	23
		% within PERIOD	10.6%	7.7%	6.0%	8.1%
	NP31 back into	Count	1		1	2
		% within PERIOD	1.2%		1.2%	.7%
	NP32 back through	Count	1		1	2
		% within PERIOD	1.2%		1.2%	.7%
	NP4 position to left A	Count	3			3
		% within PERIOD	3.5%			1.1%
	NP5 position to right B	Count	2			2
		% within PERIOD	2.4%			.7%
	NP6 circle to position	Count		7		7
		% within PERIOD		6.0%		2.5%
	SS1 scan A B A	Count	2	1		3
		% within PERIOD	2.4%	.9%		1.1%

	SS2 full circle	Count			1	1
		% within PERIOD			1.2%	.4%
	SS3 view left A	Count	7	6	3	16
		% within PERIOD	8.2%	5.1%	3.6%	5.6%
	SS4 view right B	Count	6	8	2	16
		% within PERIOD	7.1%	6.8%	2.4%	5.6%
Total		Count	85	117	83	285
		% within PERIOD	100.0%	100.0%	100.0%	100.0%

Table 8.18: Cross tabulation of low level acts vs. the time period in which it took place (beginning, middle or end).

8.3.6 Novice vs. Expert

To see in what way experts and novices differ from the total observed cases, a comparison of the percentages of acts of novices and experts with the total of observed top category acts is made (see table 8.19).

			Expertise		**Total**
			Novice	**Expert**	
Top category	**CC**	Count	62	27	89
		% within expertise	45.6%	18.1%	31.2%
	CV	Count	43	21	64
		% within expertise	31.6%	14.1%	22.5%
	CE	Count	2	0	2
		% within expertise	1.5%	0%	.7%
	EC	Count	7	0	7
		% within expertise	5.1%	0%	2.5%
	EE	Count	2	4	6
		% within expertise	1.5%	2.7%	2.1%
	GG	Count	0	1	1
		% within expertise	0%	.7%	.4%
	MM	Count	1	0	1
		% within expertise	.7%	0%	.4%
	NN	Count	3	10	13
		% within expertise	2.2%	6.7%	4.6%
	NP	Count	8	58	66
		% within expertise	5.9%	38.9%	23.2%
	SS	Count	8	28	36
		% within expertise	5.9%	18.8%	12.6%
Total		Count	136	149	285
		% within expertise	100.0%	100.0%	100.0%

Table 8.19: Comparison of the percentages of acts of novices and experts with the total of observed top category acts.

This can also be presented as a graph:

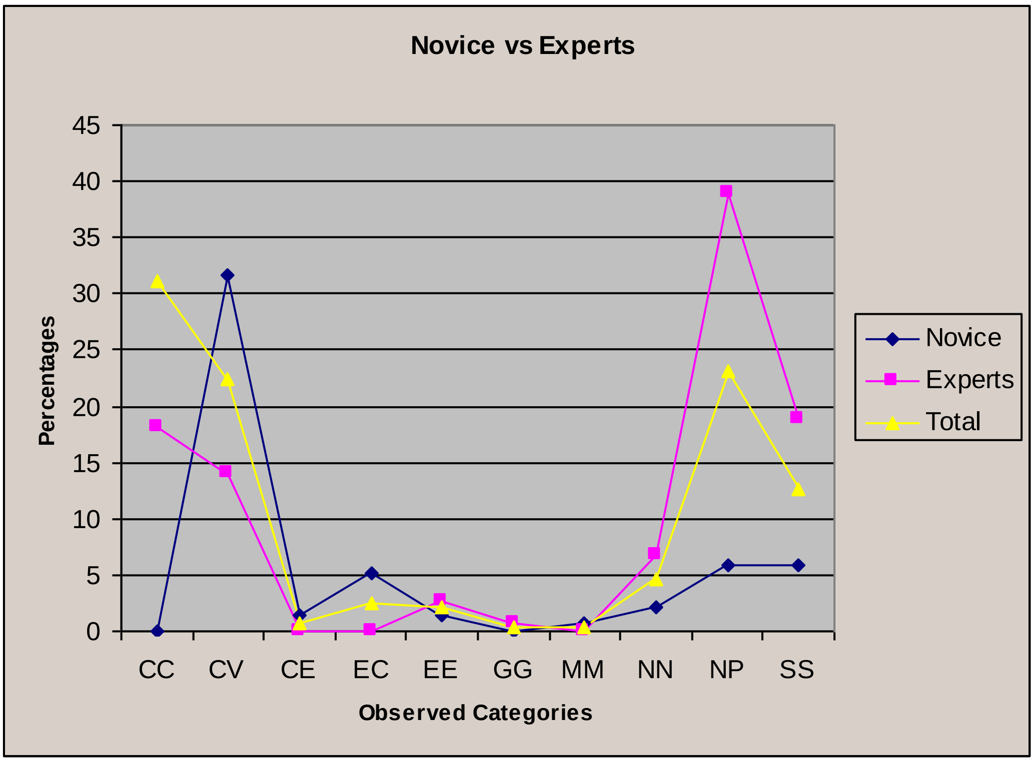

Figure 8.5: Differences between novices and experts for the percentages of observed categories.

Novices are much more likely to communicate (CC, 46.5%, CV 31%, CE 1.5%, EC 5.1%), than experts (CC 18.1%, CV14.1%, CE 0%, EC 0%). Experts are more likely to navigate (NN 6.7%, NP 38.9%), than novices (NN 2.2%, NP 5.9%). Experts are also more likely to perform a scan of the CVE (SS 18.8%), than novices (SS 5.8%). The fact that novices are more likely to communicate and experts more likely to navigate and scan, suggests that navigation and scanning activities are rather complicated and beyond the novices' competence and immediate concern, whilst communications serve to establish mutual trust, which could be said to be perceived by the novices as more important than the experts because they already know each other.

It is also interesting to look at any differences between novice and expert for the parings of act-next act scores. For convenience, patterns of novice and expert scores are presented in two tables (table 8.20 for the scores of the novices, and table 8.21 for the scores of the experts). The most notably higher scores are printed in red, notably low scores are printed in shaded cells.

		Next top category										**Total**
		CC	**CV**	**CE**	**EC**	**EE**	**GG**	**MM**	**NN**	**NP**	**SS**	
Top category	CC	28	20		1	1		1	1	6	3	61
	CV	19	14		2				2	1	4	42
	CE				1						1	2
	EC	3	1	1		1						6
	EE	1		1								2
	GG											0
	MM	1										1
	NN		2							1		3
	NP	5	2		1							8
	SS	3	4		1							8
Total		60	43	2	6	2	0	1	3	8	8	133

Table 8.20: Novices act-next act cross tabulation.

		Next top category										**Total**
		CC	**CV**	**CE**	**EC**	**EE**	**GG**	**MM**	**NN**	**NP**	**SS**	
Top category	CC	6	7			1			2	9	2	27
	CV	5	6			1			1	4	5	21
	CE											
	EC											
	EE	3							1			4
	GG									1		1
	MM											
	NN	2								6	2	10
	NP	5	5			1	1		3	24	16	55
	SS	6	3						3	14	2	28
Total		27	21	0	0	2	1	0	10	58	27	146

Table 8.21: Experts act-next act cross tabulation.

It can be seen that compared to experts, novices are much more busy talking, not bothering with scanning or fine-tuning their position often, while the experts are much more likely to fine-tune their view and navigate into position more precisely.

Finally, the differences between experts and novices in terms of the beginning (see table 8.22), the middle (see table 8.23), and the end of a collaboration (see table 8.24) are considered.

PERIOD				Expertise		Total
				Novice	Expert	
Beginning	Top category	CC	Count	7	5	12
			% within expertise	15.2%	12.8%	14.1%
		CV	Count	16	2	18
			% within expertise	34.8%	5.1%	21.2%
		CE	Count	2		2
			% within expertise	4.3%		2.4%
		EC	Count	7		7
			% within expertise	15.2%		8.2%
		EE	Count	1	1	2
			% within expertise	2.2%	2.6%	2.4%
		GG	Count		1	1
			% within expertise		2.6%	1.2%
		NN	Count	3	1	4
			% within expertise	6.5%	2.6%	4.7%
		NP	Count	2	22	24
			% within expertise	4.3%	56.4%	28.2%
		SS	Count	8	7	15
			% within expertise	17.4%	17.9%	17.6%
	Total		Count	46	39	85
			% within expertise	100.0%	100.0%	100.0%

Table 8.22: Novices vs. Experts, top category acts, beginning of collaboration.

In the beginning of the collaboration, novices communicate to verify a lot more often than the experts (34.8% vs. 5.1%). Novices also receive outside help (EC 15.2%), while experts do not. Experts navigate a lot more often (56.4%) than novices (4.3%). However, both groups scan an almost equal amount of the time (17%) during the beginning of a collaboration.

PERIOD				Expertise		Total
				Novice	Expert	
Middle	Top category	CC	Count	32	10	42
			% within expertise	64.0%	14.9%	35.9%
		CV	Count	10	8	18
			% within expertise	20.0%	11.9%	15.4%
		EE	Count	1	2	3
			% within expertise	2.0%	3.0%	2.6%
		MM	Count	1		1
			% within expertise	2.0%		.9%
		NN	Count		9	9
			% within expertise		13.4%	7.7%
		NP	Count	6	23	29
			% within expertise	12.0%	34.3%	24.8%
		SS	Count		15	15
			% within expertise		22.4%	12.8%
	Total		Count	50	67	117
			% within expertise	100.0%	100.0%	100.0%

Table 8.23: Novices vs. Experts, top category acts, middle of collaboration.

During the middle of the collaboration, novices communicate a lot more often than experts, but novices navigate and scan a lot less than the experts.

PERIOD				Expertise		Total
				Novice	Expert	
End	Top category	CC	Count	23	12	35
			% within expertise	57.5%	27.9%	42.2%
		CV	Count	17	11	28
			% within expertise	42.5%	25.6%	33.7%
		EE	Count		1	1
			% within expertise		2.3%	1.2%
		NP	Count		13	13
			% within expertise		30.2%	15.7%
		SS	Count		6	6
			% within expertise		14.0%	7.2%
	Total		Count	40	43	83
			% within expertise	100.0%	100.0%	100.0%

Table 8.24: Novices vs. Experts, top category acts, end of collaboration.

At the end of a collaboration novices still communicate more often than experts, but they do not scan or navigate at all, whereas the experts show a gradual decline in scanning and navigation acts.

Only during the beginning of a collaboration do the novices communicate almost as much as the experts, but during the middle and end the novices communicate a lot more often. Only during the beginning of a collaboration do novices scan as often as experts, during the middle and end they do not scan at all.

8.3.7 Time Between Connected Events

In order to analyse how much time it takes for acts to be performed, an analysis is made for the time lapsed between the beginning and the end of observed acts. The data for this analysis consists of all observed acts from the 30.06.99 experiment (147 items). In table 8.25, time is presented in seconds.

		Time lapsed for observed acts											**Total**
		.00	**1.00**	**2.00**	**3.00**	**4.00**	**5.00**	**7.00**	**13.00**	**15.00**	**44.00**	**> 60.00**	
Low level acts	CC general		7	1	2	1	2				1		14
	CC1 progress	1	4	2	1	1		1		1			11
	CC2 text								1			1	2
	CV1 self	1	2	1									4
	CV11 noise				1								1
	CV3 inaudible other		1										1
	CV4 acknowledge	2	4			1							7
	CV51 scream	1											1
	CV6 giggle	1		1	1								3
	CV61 laughter	2	1										3
	EE desktop											1	1
	EE1 game controls		1	1			1						3
	GG1 point						1						1
	NN1 forwards			2	1								3
	NN2 round	1											1
	NN3 up		3										3
	NN31 up and down		1	1									2
	NN41 down slope		1										1
	NP1 closer		13	3	1								17
	NP12 through		1										1

	NP2 spot-on		3										3
	NP21stop in front	1			1								2
	NP3 backwards	1	13	3		1	2						20
	NP31 back into		2										2
	NP32 back through	2											2
	NP4 position to left A		2										2
	NP5 position to right B		1										1
	NP6 circle to position	1	4	2									7
	SS1 scan A B A	1	1	1									3
	SS2 full circle		1										1
	SS3 view left A	1	7		1		2						11
	SS4 view right B	4	7			2							13
Total		20	80	18	9	6	8	1	1	1	1	2	147

Table 8.25: Cross tabulation of low level acts vs. time lapsed for each act.

The 20 acts seemingly taking less than a second (.00) are acts that are part of a more or less continuous activity, for instance a scan, a navigation and a fine-tuned position act almost rolled into one continuous intentional act. During the scoring process the movements appeared distinct enough to be scored as separate acts, but so quick that they really take less than a second. Indeed, most acts seem to take only about a second to start and finish (80 items). Although some acts take longer than a second, almost all of them take less than a minute, with two exceptions in the observations; communicating by writing text (CC2, > 60 seconds) and dealing with external activities on the desktop (EE, > 60 seconds), however, this is as would be expected. Fine-tuned navigation acts mostly seem to take between one and two seconds, although navigating backwards and scanning sometimes seem to take up to 5 seconds. Communication acts seem to vary most in terms of their duration, which is as would be expected, although it is noteworthy that most of the observed communication acts actually are so short in duration. It would seem that the collaboration process really does show many phatic exchanges.

Another interesting conclusion can be drawn by looking at how long it takes for one user to react to another user who is directing a query of some sort at them (see table 8.26). Most acts take about 1 second (7 observations) to 2 seconds (6 observations) to receive a response. General conversation has a slower turn-around (equal or bigger than 5 seconds), although communications directly related to the progress of the collaboration proper tend to be a bit faster paced (one or two seconds).

		Time taken for each act to be responded to								**Total**
		.00	**1.00**	**2.00**	**3.00**	**5.00**	**8.00**	**10.00**	**13.00**	
Low level acts	CC general					1	1	1	1	4
	CC1 progress		1	2		1				4
	CC2 text		1							1
	CV1 self		1							1
	CV4 acknowledge		2	1	1					4
	CV6 giggle		1	1						2
	CV61 laughter	1								1
	NN31 up and down	1								1
	NP1 closer		1	1						2
	SS4 view right B			1						1
Total		2	7	6	1	2	1	1	1	21

Table 8.26: Cross tabulation of observed low level acts vs. time taken for each act to be responded to.

Although the total number of observations that qualified for this analysis was only 21 items, they still do confirm that the observed CVE users could react to each other quickly, and within its own seemingly fairly natural pace.

8.4 Conclusions

Hypotheses 2 and 4 have been positively confirmed through the research presented in this chapter. General patterns of CVE user collaboration acts, lie in the realm of continuous small adjustments in viewpoint, triggered by the happenings in the shared space. The data analysis in this chapter discusses the usability problems novice and expert CVE users experience. Although hypothesis 4 has only been tested for a CVE before explicit collaboration support had been incorporated, the analysis of the actual usability problems observed has provided a rich source of information for more precise hypotheses and subsequent experimental designs.