Chapter 7 Hierarchical Task Analysis of Collaboration

H2	*General patterns of collaboration can be predicted.* Hierarchical task analysis of collaboration.

H3	*Design Properties for collaboration can be predicted.* Predictions from hierarchical task analysis of collaboration.

7 Hierarchical Task Analysis of Collaboration

This chapter consists of a hierarchical task analysis of collaboration, created by the author of this thesis in order to improve our understanding of the atomic tasks involved in collaboration between multiple users in a CVE.

7.1 Introduction

This chapter presents a hierarchical task analysis (HTA) of a generic collaborative task in a CVE. It describes and discusses the effects of human collaboration needs on the usability of CVEs. The HTA of collaboration is by no means exhaustive in its description of each branch and node of the total collaboration task, but rather consider in pertinent detail each action that leads to and seems to be part of shared work mediated by a CVE. This approach has been adopted in order to clearly identify the collaborative actions that are supported by state-of-the-art CVEs, at the time this thesis is produced. Furthermore, the HTA is used to create predictions about usability breakdown in current CVEs. The aim of this chapter is to test hypotheses 1 and 2, and make explicit the consequences of current design solutions on the one hand and current knowledge on what the collaboration needs are for CVEs on the other hand, in order to describe the type of collaboration support that is needed, and discuss the open issues as regards usability of current CVE technology.

The next section presents how the hierarchical task analysis of collaboration was created (section 7.2), followed by a section that presents the hierarchical task analysis of collaboration (section 7.3), and a section that draws out any predictions that can be made from the hierarchical task analysis about the usability design properties that

seem to be essential to support collaboration in CVEs (section 7.4), and finally, conclusions are drawn with regards to the testing of hypotheses 2 and 3, and the usability design properties derived from the HTA in terms of further analyses (section 7.5).

7.2 Creation of Hierarchical Task Analysis of Collaboration

Hierarchical task analysis is a method to make sense of what people should do or what they actually do do (Diaper, 1998). The literature on task analysis introduces a number of concepts, including goals, tasks, operations, plans, hierarchies, redescription, and stopping rules. Goals are meaningful activities aimed to reach a desired outcome. In order to reach this goal, the user has to perform a certain task. The task is the manner in which people seek to attain that goal. The manner in which the user performs the task is constrained by a number of factors: the competence of the user, their preference in terms of how they think they should perform the task, and what facilities are available to the user, i.e. the functions and limitations of the system they are using. The user forms a plan to perform the task. This plan can be represented as a hierarchy of tasks and subtasks, which together present the operations that a user has to perform in order to perform the task and reach their goal. The entire plan can be presented as hierarchical task analysis. To this end the task and each operation, is described and redescribed until a certain level of detail has been reached. The task is described by the person performing the task analysis, based on several sources of information: observation of users, literature, and re-examinations of the analysis with users or experts on the type of task under analysis. The level of detail is defined by the person performing the task analysis, based on a certain stopping rule. The stopping rule is also defined by the person performing the task analysis. In order to break down

a task, the question is asked 'how is this task done?'. If a subtask exists at a lower level, the structure is extended by asking 'why is this done?'. The final result is a structure chart that shows the sequencing of activities by ordering them from left to right. This approach is illustrated in figure 7.1.

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                    │    Why?      │
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┌──────────────────┐ ┌────────────────────┐ ┌──────────────────┐
│ What happens      │ │ What is done or    │ │ What happens     │
│ before?           │ │ to be done?        │ │ next?            │
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                        │  How?    │
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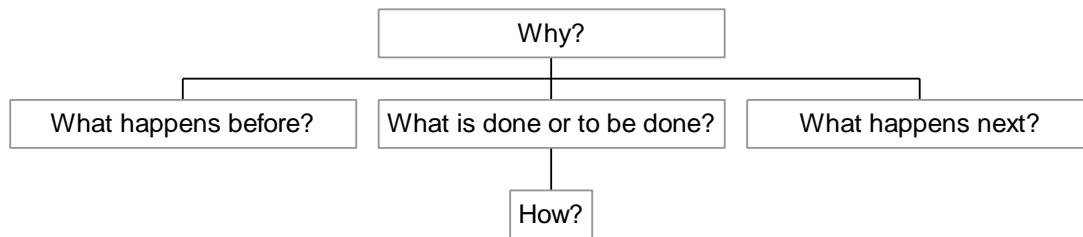
Figure 7.1: Task breakdown method (Maguire, 1997).

Each operation is numbered consistently and an accompanying written account is presented alongside the decomposition diagrams. The stopping rule for the breakdown of actions into sub-actions for the task analysis presented here is to continue until the level of detail of atomic tasks has been reached. Atomic tasks are defined by the author of this thesis as those that directly connect to interface interactions. Further breakdown of these operations would require the use and knowledge of a specific CVE interface, for which task flow diagrams could than be made. However, the aim of the task analysis presented here, is to define the generic actions that any user trying to collaborate in a CVE would have to perform; not how a particular CVE interface allows the user to collaborate. Drawing the line at 'atomic tasks' ensures that all the subtasks decompositions are treated consistently, whilst remaining generic enough to be applicable to any CVE interface. The task of collaboration in a CVE has been decomposed into high-level tasks, constituent subtasks, and operations all of which are aimed at achieving the goal of human-human CVE mediated collaboration. The resulting hierarchical task analysis of collaboration presented below, thus outlines

predicted behaviours of users in a CVE, when collaborating with other users inside that CVE.

To check the HTA, it has been presented to several researchers (Hindmarch, some of the COVEN partners and EU Commission) who were not involved in the decomposition, but who know the activities well enough to check for consistency, and their comments were incorporated in the presentation below.

Task Decomposition: Collaboration in CVE

The general goal of CVEs is to give physically remote people a common space to interact in, mediated by virtual embodiments (VBs) and an interaction space. This concerns the general capacity of the CVE to create a suspension of disbelief in its users, and become a channel of communication, an extension of them. This in itself entails a whole field of research (cf. Nichols, Haldane and Wilson, 2000).

The specific goal of users in a CVE is at best, managing multiple tasks. Depending on the goal of the application the tasks may take a different form, such as activities involved in teleconferencing, or group-way finding in a tourist application, or information visualisation and searches, etc. However, it is still possible to define these multiple tasks and more specifically, the tasks and subtasks that form CVE collaborations in general.

The next three pages show the aspects of the HTA in the larger tasks of collaboration. The tasks are described in terms of high-level tasks and decomposed into their constituent sub tasks and operations (see figures 7.2-7.7). The aim is to show the

overall structure of the main CVE user tasks and a detailed overview of the sub tasks and actions, which are specific to collaboration in CVEs. In order to remain focused on the collaborative aspect of CVE user needs, only those tasks involved in CVE specific collaboration have been broken down to the atomic level of single actions and these tasks and sub tasks are discussed in more detail than other tasks.

7.3 The Hierarchical Task Analysis of Collaboration in CVEs

In any CVE a user has to manage multiple tasks. This roughly means a user has to control their VB, navigate through the CVE, find other participants in the CVE, introduce oneself, establish relationships, observe behaviour of other participants and artefacts of the VE, and participate in a collaborative task. Thus, the main CVE user tasks are a type of meta-collaboration evoked in Chapter 3, consisting of such tasks as navigation and exploration, finding other users and objects, and the collaboration proper, where users work together on something, mediated by the CVE (see figure 7.2). It is the intention of the author to clarify what happens precisely when users try to achieve the settings for the collaboration proper, and to identify what tasks they need to get on with in order to perform the collaboration proper.

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                    │ 0. Meta Collaboration│
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│ 1.Navigate│ │2. Find other users│ │3. Find objects│ │4. Collaborate│
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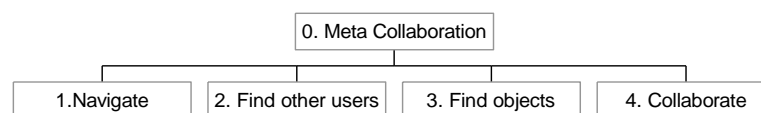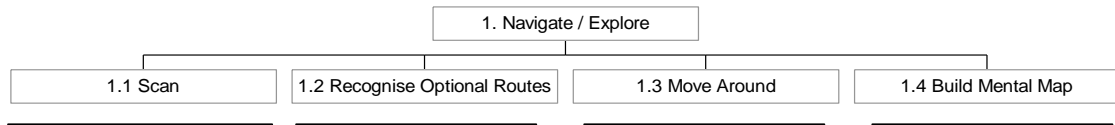
Figure 7.2: Meta collaboration.

1.   Navigate and Explore

Navigating through complex data structures is an issue that has been addressed in single user VEs as well as in hypertext systems. It has been found that users need landmarks, and global maps to help them

navigate effectively. The task of navigation can be broken down into scanning, recognising optional routes, moving around, and building a mental map of the space traversed.
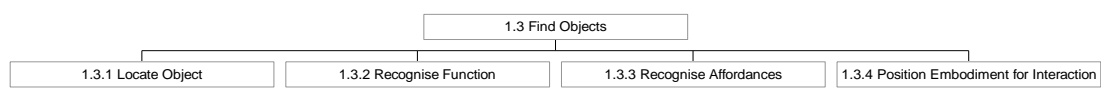
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                    ┌──────────────────────┐
                    │ 1. Navigate / Explore │
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│ 1.1 Scan │ │1.2 Recognise Optional │ │1.3 Move Around│ │1.4 Build Mental  │
│          │ │        Routes         │ │               │ │       Map        │
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2.   Finding Other Users

Finding other participants in the CVE is an issue that needs to be addressed at system level. Other then expecting users to find each other through exploration and chance, or agreements made through other communication means than the CVE, mechanisms could be build into the CVE which allow users to locate each other. The task of finding other users can be broken down into locating others, recognising individuals, establishing contact, and positioning the VB for interaction.

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                    │ 2. Find Other Users  │
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│2.1 Locate Others│ │2.2 Recognize      │ │2.3 Establish     │ │2.4 Position Embodiment for       │
│                 │ │    Individuals    │ │    Contact       │ │    Interaction                   │
└───────────────┘ └───────────────────┘ └──────────────────┘ └──────────────────────────────────┘
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3.   Find Objects

In order to find objects one has to be able to locate them and understand their function and current state (i.e. do they allow interaction, etc.). Objects need to be designed in such a way that their function is obvious or self-explanatory, i.e. the affordances are visible to the user. The task of finding objects in a CVE can be broken down into locating objects, recognising object functions, recognising object affordances, and positioning the VB for interaction with the object.

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                    │ 1.3 Find Objects     │
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   ┌──────────────┬────────────┴───────────┬────────────────────────┐
┌───────────────┐ ┌───────────────────┐ ┌──────────────────────┐ ┌──────────────────────────────────────┐
│1.3.1 Locate   │ │1.3.2 Recognise    │ │1.3.3 Recognise       │ │1.3.4 Position Embodiment for         │
│      Object   │ │      Function     │ │      Affordances     │ │      Interaction                     │
└───────────────┘ └───────────────────┘ └──────────────────────┘ └──────────────────────────────────────┘
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4.   Collaboration

As evoked in Chapter 3, collaboration between people sharing the same workspace - be it virtual or physical - involves the ongoing and seamless transition between individual and collaborative tasks. Thus collaboration can be broken down into unfocused collaboration, where the individual monitors the other participants' activities without getting involved, and focused collaboration, where individuals are closely working together.

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                  │     4. Collaboration     │
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                 ┌─────────────┴─────────────┐
┌────────────────────────────┐  ┌────────────────────────────┐
│ 4.1 Unfocused Collaboration │  │ 4.2 Focused Collaboration  │
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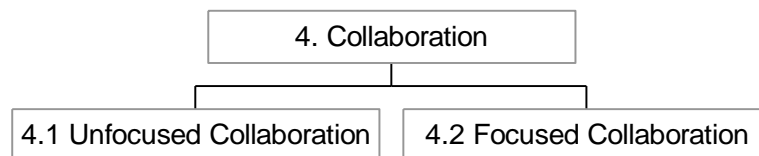
Both focused and unfocused collaboration are largely accomplished through alignment towards the focal area of activity, such as a document, where individuals coordinate their actions with others through peripheral monitoring of the others' involvement in the activity at hand.
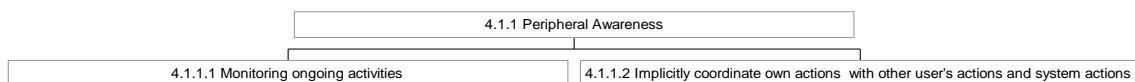
4.1   Unfocused Collaboration

As evoked in Chapter 3: "Collaboration", unfocused collaboration seems to entirely depend on peripheral awareness. Peripheral awareness is an almost invisible action, but it is essential to the seamless transition from unfocused to focused collaboration, and it needs to be broken down in more depth in order to understand the precise needs for CVE users and CVE design to support these needs.

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┌─────────────────────────────────┐
│   4.1 Unfocused Collaboration   │
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                 │
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│   4.1.1 Peripheral Awareness    │
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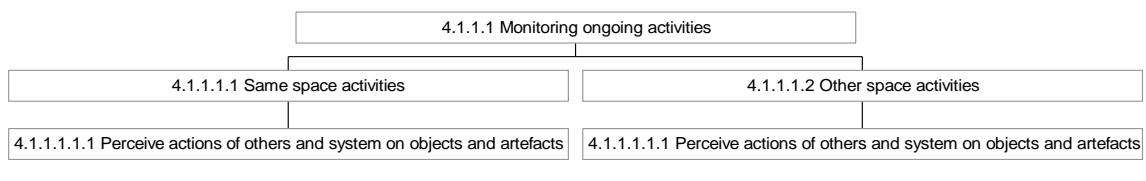
4.1.1 Peripheral Awareness

Peripheral awareness is central to many tasks that are part of the high level task of collaboration. An individual's ability to contribute to the activities of others and fulfil their own responsibilities relies upon peripheral awareness and monitoring; in this way information can be gleaned from the concurrent activities of others within the "local milieu", and actions and activities can be implicitly coordinated with the emergent tasks of others (Heath et al., 1995). Peripheral awareness in a CVE can be broken down into monitoring ongoing activities (section 4.1.1.1), and implicitly coordinating ones own actions with those of other users (section 4.1.1.2).

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┌───────────────────────────────────────────────────────────────────────────────┐
│                        4.1.1 Peripheral Awareness                             │
└───────────────────────────────────────────────────────────────────────────────┘
┌─────────────────────────────────┐  ┌──────────────────────────────────────────┐
│ 4.1.1.1 Monitoring ongoing      │  │ 4.1.1.2 Implicitly coordinate own actions│
│ activities                      │  │ with other user's actions and system     │
│                                 │  │ actions                                  │
└─────────────────────────────────┘  └──────────────────────────────────────────┘
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4.1.1.1   Monitoring Ongoing Activities

Participants' activities are mediated and rendered visible through their respective interaction with objects and artefacts. Activities in a CVE can take place in either the same space as the participant occupies or a remote space about which the participant is kept informed.

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┌───────────────────────────────────────────────────────────────────────────────┐
│                     4.1.1.1 Monitoring ongoing activities                     │
└───────────────────────────────────────────────────────────────────────────────┘
┌─────────────────────────────────┐  ┌──────────────────────────────────────────┐
│ 4.1.1.1.1 Same space activities │  │ 4.1.1.1.2 Other space activities         │
└─────────────────────────────────┘  └──────────────────────────────────────────┘
┌─────────────────────────────────────┐ ┌────────────────────────────────────────────┐
│ 4.1.1.1.1.1 Perceive actions of     │ │ 4.1.1.1.1.1 Perceive actions of others and │
│ others and system on objects and    │ │ system on objects and artefacts            │
│ artefacts                           │ │                                            │
└─────────────────────────────────────┘ └────────────────────────────────────────────┘
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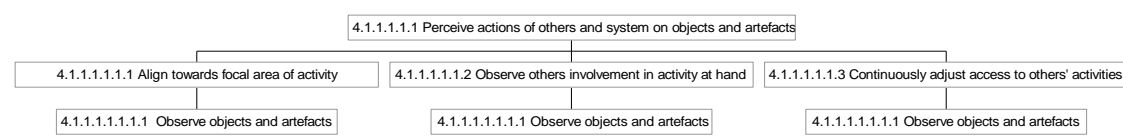
A serious problem for networked CVE mediated collaboration is that sometimes what one users sees is different to what another users sees, even though they are looking at the same thing at the same time. This can be caused by network delays, or by the fact that the CVE allows its participants personal unique views, which are not shared by the others unless they request this. This problem has been identified and discussed in Snowdon, Greenhalgh and Benford (1995).

4.1.1.1.1 Same Space Activities and Other Space Activities

Location and the notion of adjacency and neighbourhood do not strictly have the same meaning and function in a VE as in the real world. A participant could also have multiple virtual embodiments engaged in different tasks in the CVE or be virtually present in more than one CVE at a time. It is relatively easy to inform a CVE participant about activities taking place in a remote location in some form or another and this may extend and will certainly influence the options for collaboration.
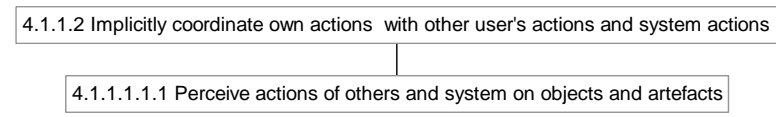
4.1.1.1.1.1 Perceive Actions of Others and System on Objects and Artefacts

4.1.1.1.1.1 Perceive actions of others and system on objects and artefacts		
4.1.1.1.1.1.1 Align towards focal area of activity	4.1.1.1.1.1.2 Observe others involvement in activity at hand	4.1.1.1.1.1.3 Continuously adjust access to others' activities
4.1.1.1.1.1.1.1 Observe objects and artefacts	4.1.1.1.1.1.1.1 Observe objects and artefacts	4.1.1.1.1.1.1.1 Observe objects and artefacts

In order to perceive actions of others and of the system on objects and artefacts in the CVE, a participant needs to be able to smoothly and perhaps automatically align their virtual embodiment towards the focal area of activity, without losing track of their own activities. The participant furthermore needs to be able to observe the involvement of the other participants in the collaborative activity that is taking place. Participants may want to be able to

automatically be informed about changes in involvement of other participants, and they may wish to alter the degree of information and the way in which they are informed.
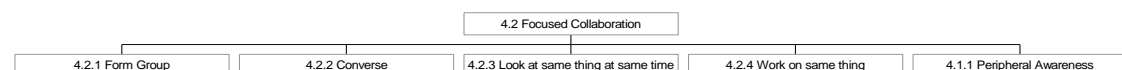
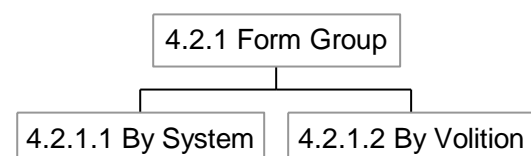### 4.1.1.2 Implicitly Coordinating One's Own Actions with Other Users' Actions and System Actions

4.1.1.2 Implicitly coordinate own actions with other user's actions and system actions
4.1.1.1.1.1 Perceive actions of others and system on objects and artefacts

In order to implicitly coordinate ones' own actions with the actions of the system and the other participants one wants to be able to perceive the actions of others and the system on objects and artefacts in the CVE. The breakdown of this task is described in section 4.1.1.1.1.1. Again the user may want the system to automatically coordinate their actions towards the focal area of activity, but the user should at all times be able decide to change or adapt this automatic behaviour.

4.2 Focused Collaboration

Once the transition from unfocused collaboration to focused collaboration has been made, the task for a CVE user can be broken down into:
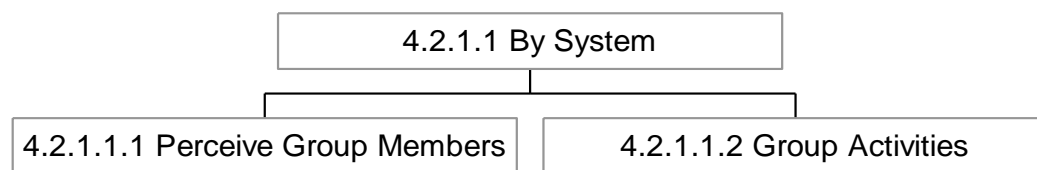
4.2 Focused Collaboration				
4.2.1 Form Group	4.2.2 Converse	4.2.3 Look at same thing at same time	4.2.4 Work on same thing	4.1.1 Peripheral Awareness

4.2.1 Form Group

4.2.1 Form Group	
4.2.1.1 By System	4.2.1.2 By Volition

A group can be formed by the system when it perceives a certain degree of adjacency between participants or a certain common interest or action. The system may then increase the awareness levels between the individuals in the group. Alternatively, the participants themselves can decide to form a group, after which their awareness levels are adjusted for the task at hand.
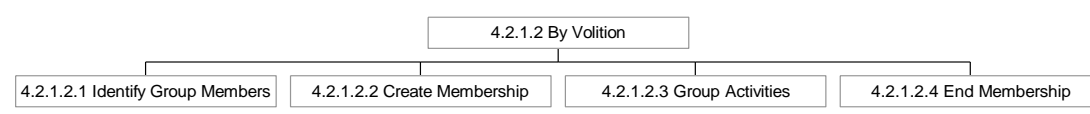
4.2.1.1   By System

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            │  4.2.1.1 By System      │
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        ┌───────────────┴───────────────┐
┌───────────────────────────┐  ┌───────────────────────────┐
│ 4.2.1.1.1 Perceive Group  │  │ 4.2.1.1.2 Group Activities│
│ Members                   │  │                           │
└───────────────────────────┘  └───────────────────────────┘
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When the system decides that certain participants must belong to a specific group, the individuals in that group should be informed of the fact that the system has changed their awareness levels and any other changes in status, and treatment. The user should be able to individually change or modify the choices made by the system. Additionally, once the user is aware of being part of a group, they become part of the groups' activities. These group activities have certain generic tasks associated with them, which can be broken down further into single actions (see section 4.2.1.2.3).

4.2.1.2   By Volition

When two or more CVE participants have decided to form a group, their task can be broken down into:

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                              │ 4.2.1.2 By Volition │
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┌──────────────────┐ ┌────────────────────┐ ┌──────────────────┐ ┌──────────────────┐
│4.2.1.2.1 Identify│ │4.2.1.2.2 Create    │ │4.2.1.2.3 Group   │ │4.2.1.2.4 End     │
│Group Members     │ │Membership          │ │Activities        │ │Membership        │
└──────────────────┘ └────────────────────┘ └──────────────────┘ └──────────────────┘
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4.2.1.2.1 Identify Group Members

The user should be able to identify which participants in the CVE are members of what group. Group membership can be made visible by the system in a variety of ways, including leaving the choice to alter the way of viewing this information up to the individual.

4.2.1.2.2 Create Membership

The users need to be able to manually create a group and decide on the degree and kind of information the system sends to the individual members of the group.
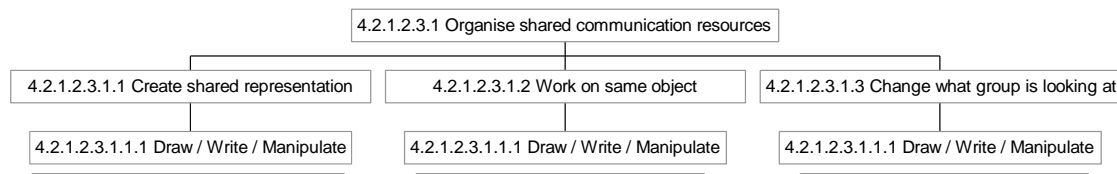
4.2.1.2.3 Group Activities

Group activities obviously depend on the nature of the group task, but generic sub tasks and actions can be isolated as follows:
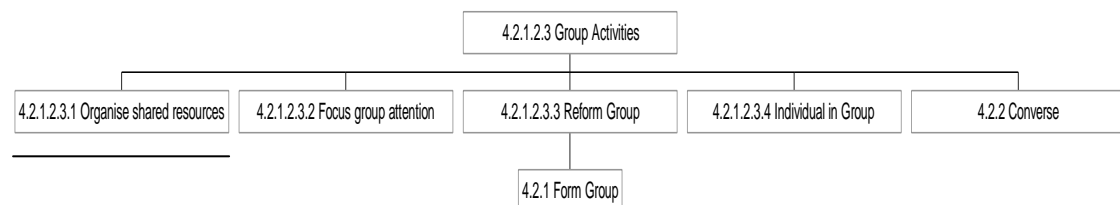
Each of these sub tasks can be broken down again into other sub tasks that are described below. The sub task of conversing not only appears here as a sub task of group activities, it is also a direct sub task of focused collaboration (section 4.2) and a break down of the tasks involved in conversing can be found in section 4.2.2. The other remaining sub tasks involved in a break down of generic CVE group activities are described in the sections directly below.

4.2.1.2.3.1 Organise Shared Communication Resources
Part of the tasks involved in group activities are organising the shared communication resources. This involves actions that alter some physical aspect of the workspace in order to make communicative resources available to be the shared focus of group activity (Robertson, 1997). The task can be broken down into the following sub tasks:

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                  │ 4.2.1.2.3.1 Organise shared communication resources │
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        ┌───────────────────────────┼───────────────────────────────┐
┌───────────────────────────┐ ┌───────────────────────────┐ ┌────────────────────────────────────┐
│ 4.2.1.2.3.1.1 Create shared│ │ 4.2.1.2.3.1.2 Work on same │ │ 4.2.1.2.3.1.3 Change what group is   │
│ representation             │ │ object                     │ │ looking at                           │
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            │                             │                                │
┌───────────────────────────┐ ┌───────────────────────────┐ ┌────────────────────────────────────┐
│ 4.2.1.2.3.1.1.1 Draw /     │ │ 4.2.1.2.3.1.1.1 Draw /     │ │ 4.2.1.2.3.1.1.1 Draw / Write /       │
│ Write / Manipulate         │ │ Write / Manipulate         │ │ Manipulate                           │
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4.2.1.2.3.1.1   Create Shared representation
The creation of shared representations is used to express ideas, add meaning to the accompanying talk and to summarise work (Robertson, 1997). Representations can be objects in the CVE, or temporal/spatial representations, which take the form of drawings, written information, and the manipulation of the view of the group members in the CVE.

4.2.1.2.3.1.1.1 Draw / Write / Manipulate
The tasks of drawing, writing and manipulation are single actions as far as a generic CVE user task breakdown is concerned (although to save space in the flow-diagram they have been put together into one box). The design issues involved in implementing these actions have to be addressed at interface level. Quite a lot of design guidelines are available for this, although most of them only address solutions for 2D environments, or single user environments.
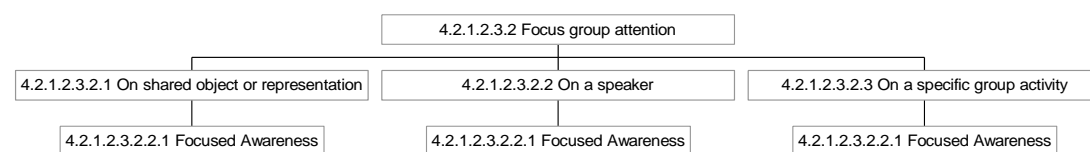
4.2.1.2.3.1.2   Work On Same Object

Group activities also involve more than one individual manipulating the same object in some way, perhaps even at the same time. The system should allow for smooth transition between ownership of the object and user rights in terms of manipulation of shared objects. The task of working on the same object can be broken down into single actions draw, write, and manipulate (see section 4.2.1.2.3.1.1.1). The task of working on the same thing at the same time is further broken down in section 4.2.4, as it is a direct sub task of focused collaboration (section 4.2).

4.2.1.2.3.1.3   Change What Group is Looking at

Any participant in a group should be allowed to change what the group is looking at, although handing down of certain rights and privileges to control the group view may sometimes have to be reserved to a group leader depending on the nature of the group task and the individuals in the group.

4.2.1.2.3.2 Focus Group Attention

Focusing group attention is used as a way of structuring the conversation, it is usually initiated by one person's actions, but the group as a group, perceives the action and reorients its attention (Robertson, 1997). The sub tasks involved seem to break down as follows:

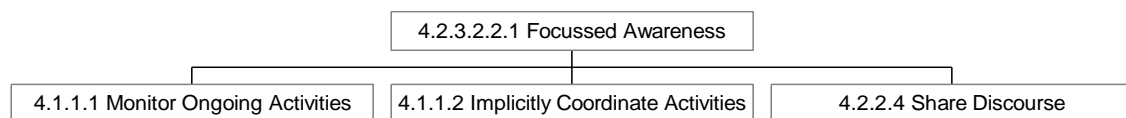| 4.2.1.2.3.2 Focus group attention		
4.2.1.2.3.2.1 On shared object or representation	4.2.1.2.3.2.2 On a speaker	4.2.1.2.3.2.3 On a specific group activity
4.2.1.2.3.2.2.1 Focused Awareness	4.2.1.2.3.2.2.1 Focused Awareness	4.2.1.2.3.2.2.1 Focused Awareness

For each sub task: focusing on a shared object or representation, on a speaker, or on a specific group activity breaking down into lower level sub-tasks means describing focused awareness, but it also has

to be noted that the system can take care of focusing group attention
and changing group attention automatically at different required
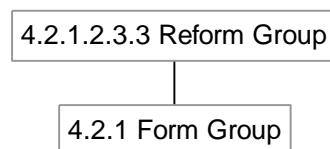degrees of control.

4.2.1.2.3.2.2.Focused Awareness

Focussed awareness is similar to the activities performed during
peripheral awareness, however, during this type of activity the actor
is not only monitoring the goings on, but also directly, and actively
involved in the goings on.

```
                    ┌──────────────────────────────┐
                    │ 4.2.3.2.2.1 Focussed Awareness │
                    └──────────────────────────────┘
        ┌────────────────────────┬─────────────────────────────┐
┌────────────────────────────┐ ┌──────────────────────────────────┐ ┌──────────────────────────┐
│4.1.1.1 Monitor Ongoing Activities│ │4.1.1.2 Implicitly Coordinate Activities│ │4.2.2.4 Share Discourse │
└────────────────────────────┘ └──────────────────────────────────┘ └──────────────────────────┘
```

For further breakdown of these tasks the reader is referred back to task trees 4.1.1.1,
4.1.1.2, and 4.2.2.4.

4.2.1.2.3.3 Reform Group

```
┌──────────────────────────────┐
│ 4.2.1.2.3.3 Reform Group      │
└──────────────────────────────┘
        │
┌──────────────────────┐
│ 4.2.1 Form Group      │
└──────────────────────┘
```
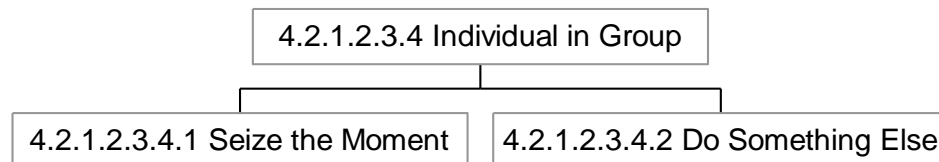
The sub task of reforming the group is based on the observation that
collaborative work sometimes requires temporarily forming smaller
groups to attend to a specific sub task and reform into a larger
group once the task has been completed (Robertson, 1997). This may
involve changes for group members, such as to be temporarily less
peripherally aware of the larger group. The task of forming a group
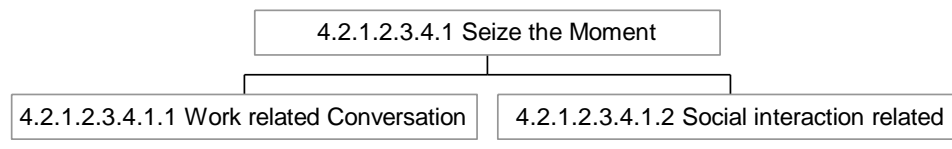has been described in section 4.2.1.

4.2.1.2.3.4 Individual to Group

The sub tasks of an individual in a group are part of the higher level task of group activities (see section 4.2.1.2.3). The observed actions of an individual involved in a group activity can be broken down into:
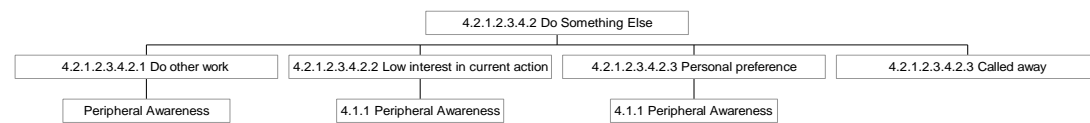
```
┌─────────────────────────────────────────┐
│      4.2.1.2.3.4 Individual in Group     │
└─────────────────────────────────────────┘
┌────────────────────────┐  ┌────────────────────────────┐
│ 4.2.1.2.3.4.1 Seize the │  │ 4.2.1.2.3.4.2 Do Something  │
│        Moment           │  │           Else              │
└────────────────────────┘  └────────────────────────────┘
```

Group members take advantage of lulls in the group activity for the opportunistic use of time they are together to do something else (Robertson, 1997).

4.2.1.2.3.4.1   Seize the Moment

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┌─────────────────────────────────────────┐
│     4.2.1.2.3.4.1 Seize the Moment       │
└─────────────────────────────────────────┘
┌──────────────────────────────┐  ┌──────────────────────────────────┐
│ 4.2.1.2.3.4.1.1 Work related │  │ 4.2.1.2.3.4.1.2 Social interaction│
│        Conversation          │  │             related               │
└──────────────────────────────┘  └──────────────────────────────────┘
```

Group members seize the moment to do something else when one or more of the others are attending to an interruption, or to some individual or subgroup work (Robertson, 1997). They might either ask a question about something to do with work, or use the time for explicit social interaction, such as discussion of movies, football, and holidays or to tell jokes. These behaviours have been observed in a natural setting, and are part of common interactions in a group. It would follow that in a CVE is must be possible for participants to exhibit this behaviour and if these behaviours spontaneously occur it would seem to confirm the transfer of natural behaviour to the CVE setting.

4.2.1.2.3.4.2 Do Something Else

		4.2.1.2.3.4.2 Do Something Else	
4.2.1.2.3.4.2.1 Do other work	4.2.1.2.3.4.2.2 Low interest in current action	4.2.1.2.3.4.2.3 Personal preference	4.2.1.2.3.4.2.3 Called away
Peripheral Awareness	4.1.1 Peripheral Awareness	4.1.1 Peripheral Awareness	

Individuals in the group can do something other than the group activity, while remaining in the same CVE space. 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. It may however also occur that the users' virtual embodiment is called away from the virtual space they share with the rest of the group, or only be called away from the audio space they share with the group, and finally they could be completely away from their machine on which the CVE is running.

4.2.1.2.3.4.2.1 Do Other Work

CVE users can do other work in the same virtual space as the other members of the group occupy. Thus allowing the other group members to be peripherally aware of the fact that their attention to the group activities is changing. However, CVE users can also work in another window and may or may not want the other group members to know about this or the extent to which they are engaged in this other activity.

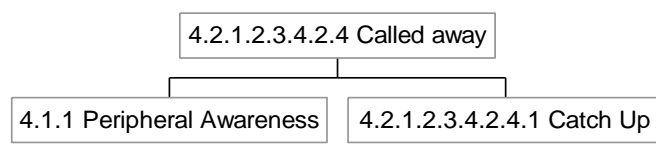### 4.2.1.2.3.4.2.2 Low Interest in Current Action

CVE users can easily monitor a virtual group activity by sharing the same audio space as the other group members. CVE group members may want to be able to both signify to the other group members that they are present as passive observer only, and about changes in their interest in the group activities by changing the visible degree of presence somehow. Perceptual clues for this category of behaviour are

that low interest is expressed by positioning the body away from the group and seen as engaged in prolonged personal use of a physical object (Robertson, 1997). A change in interest can be signified by a change in the spatial position and orientation of the virtual embodiment.

4.2.1.2.3.4.2.3   Personal Preference

A CVE user may be unwilling to participate in the group activities fully or without doing something else at the same time. It seems therefore common sense to allow the users to do this and give them the choice of letting the fact that they are sharing their attention between different activities be part of a CVE etiquette which will develop around this issue if users are left free choice in this matter. Means should be provided for users to catch up smoothly with the group activities.

4.2.1.2.3.4.2.4   Called Away

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             ┌───────────────────────────────┐
             │ 4.2.1.2.3.4.2.4 Called away    │
             └───────────────────────────────┘
         ┌──────────────────┴──────────────────┐
┌──────────────────────────┐  ┌──────────────────────────────────┐
│ 4.1.1 Peripheral Awareness│  │ 4.2.1.2.3.4.2.4.1 Catch Up       │
└──────────────────────────┘  └──────────────────────────────────┘
```

For a CVE user to be called away from the virtual group activities is as common as being interrupted in ones' real office, or perhaps even more so because the CVE is an added communication/activity source. Depending on the extent to which one is physically called away from the machine with the CVE running on it, several modalities of peripheral awareness might help the user to stay informed about the group activities. It should be made clear to the other users that this user is called away from the virtual embodiment. It should also be easy for the user to signify this to the other users because otherwise users may not always make use of this option. The user
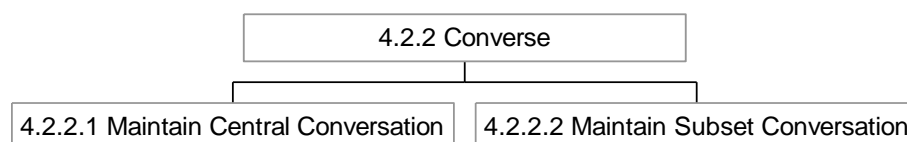
might want to leave some information behind for the other users about the estimated duration of absence from the virtual embodiment. And lastly, the user should be able to quickly catch up after a complete absence.

4.2.1.2.3.4.2.4.1 Catch Up
CVE users catch up with the events that took place in their absence by either monitoring the current group activities in order to deduce what has taken place, or by asking another group member. In order for group members to communicate with each other without dominating the group discussions, they need to be provided with a separate communication channel that can be aimed at single users (similar to the whisper-mode in real life). Additionally a user could be provided with a recording device which can be played back when the user returns. This recording device should be so quiet as to not destroy the option of having peripheral awareness of the current group activities whilst playing back
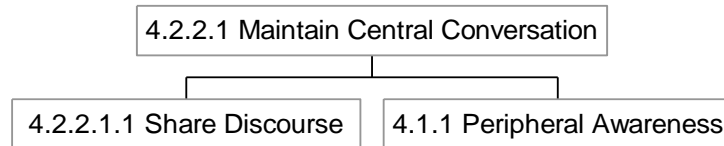
4.2.2 Converse

It has been observed that whatever work people do in meetings, this is accomplished by them talking together. Conversing is the major and essential category in the taxonomy of group activity (Robertson, 1997). It can be broken down into:

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                    ┌─────────────────────────┐
                    │     4.2.2 Converse      │
                    └─────────────────────────┘
        ┌───────────────────────────┴───────────────────────────┐
┌───────────────────────────────────┐ ┌───────────────────────────────────┐
│ 4.2.2.1 Maintain Central Conversation │ │ 4.2.2.2 Maintain Subset Conversation │
└───────────────────────────────────┘ └───────────────────────────────────┘
```

Conversing as a group activity consists of either maintaining a single conversation involving the whole group, or maintaining more than one conversation involving different subsets of the group, for
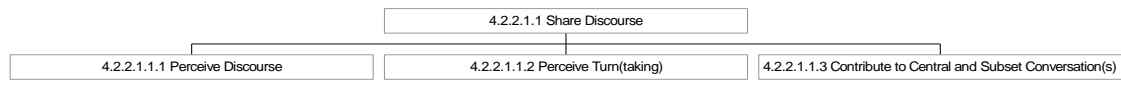
both tasks the individual involvement can vary over time (Robertson, 1997).

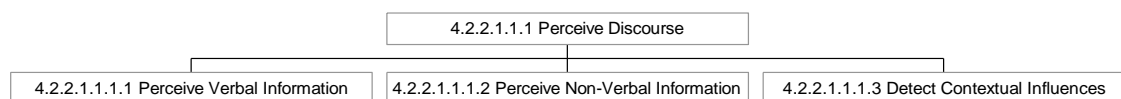### 4.2.2.1   Maintain Central Conversation

```
        ┌──────────────────────────────────────┐
        │ 4.2.2.1 Maintain Central Conversation │
        └──────────────────────────────────────┘
       ┌──────────────────┴──────────────────┐
┌───────────────────────────┐   ┌──────────────────────────┐
│ 4.2.2.1.1 Share Discourse │   │ 4.1.1 Peripheral Awareness │
└───────────────────────────┘   └──────────────────────────┘
```

In order to maintain a central conversation one has to be able to share the discourse that is taking place within the group, and one has to have a peripheral awareness of the individuals in the group and objects in the space. Peripheral awareness has already been described in section 4.1.1. The task of sharing discourse can be broken down further, see next section.

4.2.2.1.1   Share Discourse

```
                    ┌──────────────────────────────────┐
                    │     4.2.2.1.1 Share Discourse     │
                    └──────────────────────────────────┘
     ┌───────────────────────────────┼──────────────────────────────────────────────────────┐
┌───────────────────────────────┐ ┌───────────────────────────────┐ ┌──────────────────────────────────────────────────────┐
│ 4.2.2.1.1.1 Perceive Discourse │ │ 4.2.2.1.1.2 Perceive Turn(taking) │ │ 4.2.2.1.1.3 Contribute to Central and Subset Conversation(s) │
└───────────────────────────────┘ └───────────────────────────────┘ └──────────────────────────────────────────────────────┘
```

In order to share the discourse one has to be able to perceive the discourse, one has to be able to perceive turn taking in the conversation and ones' own turn so that one can contribute to the central and subset conversations. Each of these tasks can be broken down into sub tasks, although the task of perceiving turn taking (4.2.2.1.1.2) has not been broken down further.

4.2.2.1.1.1 Perceive Discourse

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                         ┌───────────────────────────────┐
                         │ 4.2.2.1.1.1 Perceive Discourse │
                         └───────────────────────────────┘
       ┌─────────────────────────────┼─────────────────────────────────────┐
┌──────────────────────────────────┐ ┌────────────────────────────────────────┐ ┌──────────────────────────────────────┐
│ 4.2.2.1.1.1.1 Perceive Verbal Information │ │ 4.2.2.1.1.1.2 Perceive Non-Verbal Information │ │ 4.2.2.1.1.1.3 Detect Contextual Influences │
└──────────────────────────────────┘ └────────────────────────────────────────┘ └──────────────────────────────────────┘
```

The task of perceiving discourse can be broken down into perceiving verbal information, perceiving non-verbal information, and detecting contextual influences.

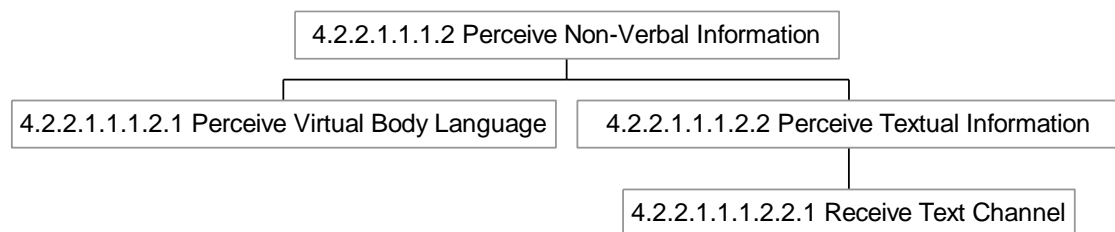4.2.2.1.1.1.1   Perceive Verbal Information

4.2.2.1.1.1.1 Perceive Verbal Information

4.2.2.1.1.1.1.1 Receive Audio Signal

In order to perceive verbal information in a CVE, one has to receive an audio signal. Audio signals sent across the network are not as reliable or as perfect as real world verbal information signals. Often a large amount of trouble with communication is caused by problematic audio connections between participants (Bowers, Pycock & O'Brien, 1995; Tromp & Snowdon, 1997; Steed & Tromp, 1998). Since receiving the audio signal is one of the lowest level tasks in collaboration, and essential to the task of conversing, it is obviously a candidate for support from other sub tasks of the higher level task of perceiving discourse.

4.2.2.1.1.1.2   Perceive Non-Verbal Information
Perceiving non-verbal information can be broken down into perceiving virtual body language, and perceiving textual information.

4.2.2.1.1.1.2 Perceive Non-Verbal Information

4.2.2.1.1.1.2.1 Perceive Virtual Body Language	4.2.2.1.1.1.2.2 Perceive Textual Information

4.2.2.1.1.1.2.2.1 Receive Text Channel

4.2.2.1.1.1.2.1 Perceive Virtual Body Language

In order to perceive virtual body language users should be able to express virtual body language and view the changes in body language of other participants in sufficient detail. They should be able to recognise the signals involved in that body language, and users should interpret body language used by others in the same way they would use it themselves. Minimalizing the degree to which users can employ virtual body language, or providing users with predetermined non-verbal communication means, such as gestures and facial expressions, obviously influences the capacity of users to smoothly transfer daily knowledge about body language to the CVE. Perceiving virtual body language is part of the lowest level of sub tasks involved in conversing and collaboration and an essential backup channel for perceiving discourse when perception of the audio channel is weak. It is therefore of obvious importance to improve the perception of virtual body language as much as possible.

4.2.2.1.1.1.2.2 Perceive Textual Information

Perceiving textual information depends on receiving the textual channel. Text messages can come to the user on several different levels, such as personal communications, group channel communications, real-time communications from another participant in the CVE, but not in the same space as this user, time-delayed information such as email messages, bulletin board messages, notes left behind for the user by another user, etc. The text channel has a different immediacy, a different persistency, and a different reliability than the audio channel, and is used accordingly by experienced users. Care most be taken to inform the user about incoming or pending textual messages because of the low immediacy of

the medium. The textual channel is an important backup channel for the audio channel (Bowers et al., 1995; Tromp, 1996).
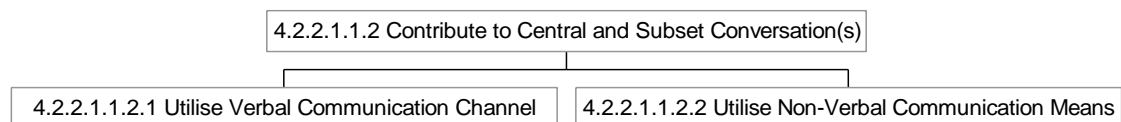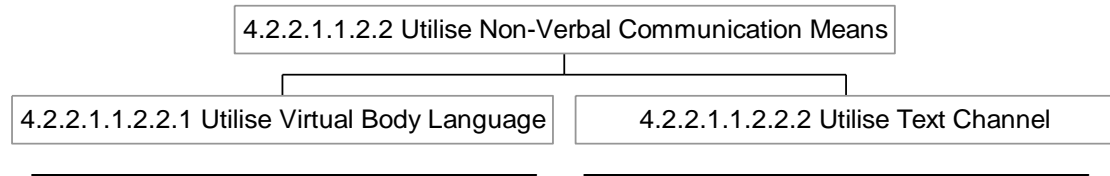
4.2.2.1.1.1.3   Detect Contextual Influences

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          ┌─────────────────────────────────────────┐
          │ 4.2.2.1.1.1.3 Detect Contextual Influences │
          └─────────────────────────────────────────┘
        ┌──────────────┴───────────────┐
┌──────────────────────────────┐  ┌──────────────────────────┐
│ 4.2.1.2.3.2.2.1 Focused Awareness │  │ 4.1.1 Peripheral Awareness │
└──────────────────────────────┘  └──────────────────────────┘
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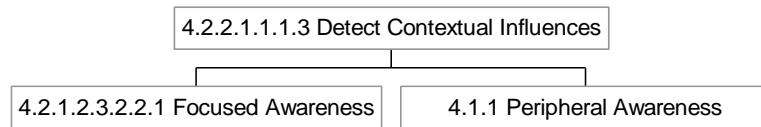
Detecting contextual influences (4.2.2.1.1.1.3) could be said to be similar to the tasks of perceiving turn-taking and focused and peripheral awareness, but is more in that it is the task of interpreting the reasons for changes in verbal and non-verbal information exchange. Each of these sub tasks has been broken down above.

4.2.2.1.1.2 Contribute to Main Conversation and Subset Conversation
In order to contribute to the central and the subset conversations, one obviously not only needs to be able to perceive them, one also needs to be able to utilise these different communication channels. Utilising the different communication channels simultaneously is obviously a demanding task and should be designed at system level in such a way that it creates the least overhead in cognitive load on the user (Steed and Tromp, 1998).

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        ┌──────────────────────────────────────────────────────┐
        │ 4.2.2.1.1.2 Contribute to Central and Subset Conversation(s) │
        └──────────────────────────────────────────────────────┘
      ┌──────────────────┴───────────────────┐
┌──────────────────────────────────────┐  ┌──────────────────────────────────────────┐
│ 4.2.2.1.1.2.1 Utilise Verbal Communication Channel │  │ 4.2.2.1.1.2.2 Utilise Non-Verbal Communication Means │
└──────────────────────────────────────┘  └──────────────────────────────────────────┘
```

4.2.2.1.1.2.2   Utilise Non-Verbal Communication Means

4.2.2.1.1.2.2 Utilise Non-Verbal Communication Means

4.2.2.1.1.2.2.1 Utilise Virtual Body Language	4.2.2.1.1.2.2.2 Utilise Text Channel

4.2.2.2   Maintain Subset Conversation

4.2.2.2 Maintain Subset Conversation

4.2.2.2.1 Maintain Same Space Subset Conversation	4.2.2.2.2 Maintain Other Space Subset Conversation
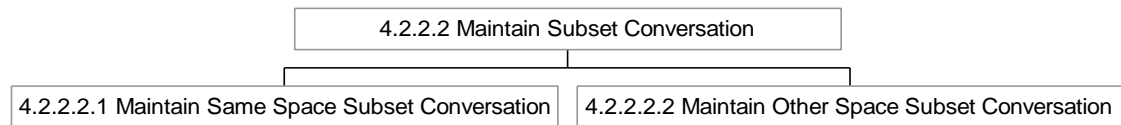
Maintaining a subset conversation in a CVE can be broken down into maintaining a same space subset conversation, where the user communicates with other users in the same virtual space, and maintaining a other space subset conversation, where the users receives communications from other users in the total CVE space who do not share their immediate surrounding virtual space. Maintaining other space subset conversations could be one of the valuable added options of virtual communication when implemented effectively.
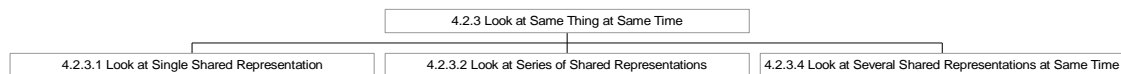
4.2.2.2.1   Maintain Same Space Subset Communication

4.2.2.2.1 Maintain Same Space Subset Conversation

4.2.2.1.1 Share Discourse	4.1.1 Peripheral Awareness

4.2.2.2.2   Maintain Other Space Subset Communication

4.2.2.2.2 Maintain Other Space Subset Conversation

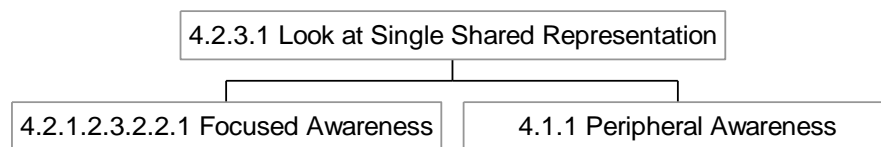| 4.2.2.1.1 Share Discourse	4.1.1 Peripheral Awareness
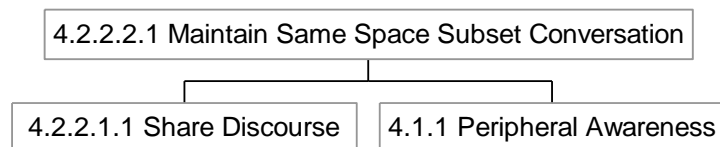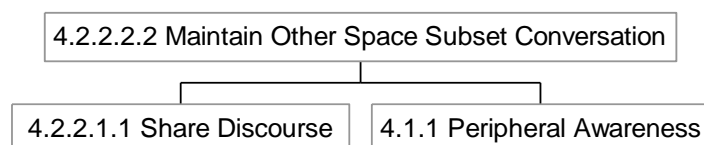
4.2.3 Look at the Same Thing and the Same Time

It has been observed that being able to look at the same thing at the same time makes the group conversation more robust by enabling the inclusion in the conversation of some aspect of what is being looked at (Robertson, 1997). As it is one of the central sub tasks of collaboration it seems an important issue for CVE implementation at system level. This task can be broken down into:

4.2.3 Look at Same Thing at Same Time		
4.2.3.1 Look at Single Shared Representation	4.2.3.2 Look at Series of Shared Representations	4.2.3.4 Look at Several Shared Representations at Same Time

4.2.3.1   Look at Single Shared Representation

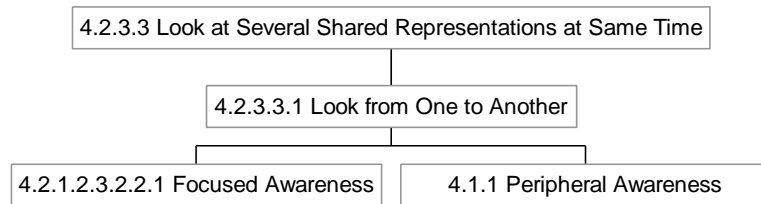| 4.2.3.1 Look at Single Shared Representation	
4.2.1.2.3.2.2.1 Focused Awareness	4.1.1 Peripheral Awareness

Users may want to look at one and the same shared representation during a conversation. In order to do this they must be able to see when and where the other users are looking.

4.2.3.2   Look at a Series of Shared Representations

4.2.3.2 Look at Series of Shared Representations	
4.2.1.2.3.2.2.1 Focused Awareness	4.1.1 Peripheral Awareness
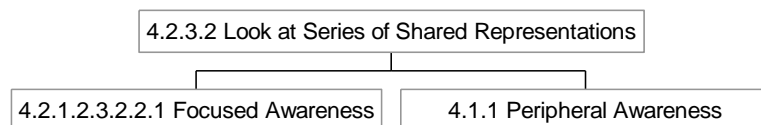
Users may want to look at a series of shared representations such as a slide show or a screen display in a CVE. Users need to be able to become aware of the changes in the shared representations at the same time these changes take place.

4.2.3.3   Look at Several Shared Representations at the Same Time
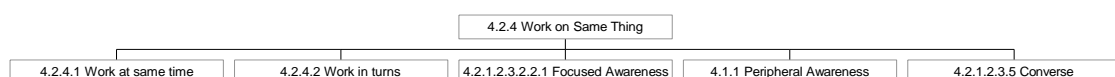
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┌──────────────────────────────────────────────────────┐
│ 4.2.3.3 Look at Several Shared Representations at Same Time │
└──────────────────────────────────────────────────────┘
                          │
            ┌─────────────────────────────────┐
            │ 4.2.3.3.1 Look from One to Another │
            └─────────────────────────────────┘
        ┌─────────────────────┴──────────────────────┐
┌──────────────────────────────┐   ┌──────────────────────────────┐
│ 4.2.1.2.3.2.2.1 Focused Awareness │   │ 4.1.1 Peripheral Awareness │
└──────────────────────────────┘   └──────────────────────────────┘
```

Users may want to look at several different shared representations at the same time in order to compare them, etc. In order to do this they have to be able to look from one to the other shared representation and they have to be aware of where the focus of attention of the others is aimed.

4.2.3.3.1   Look from One to Another

Looking from one to another shared representation might be a good candidate for semi-automatic behaviours build into the CVE at system level. This means that the system may be assigned to automatically track the users gaze between several shared representations, either based on tracking and mimicking a speakers gaze, or based on some kind of time-delay. The user could select the objects between which they want to share their view.
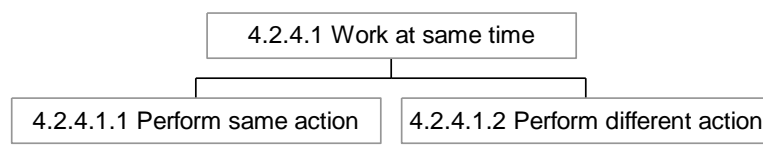
4.2.4 Work on the Same Thing

Users may be working on the same thing. This means that rules, rights and permissions to change that thing should be transferred smoothly, but also that the user should be able to control the transfer of permissions. The sub tasks involved in working on the same thing can be broken down as follows:
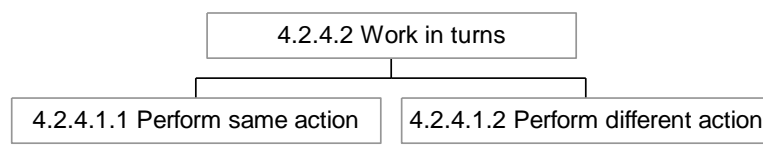
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                        ┌──────────────────────────┐
                        │ 4.2.4 Work on Same Thing  │
                        └──────────────────────────┘
 ┌──────────────────┬──────────────────┼──────────────────────┬──────────────────┐
┌───────────────┐ ┌───────────────┐ ┌──────────────────────────┐ ┌──────────────────────┐ ┌──────────────────┐
│4.2.4.1 Work at │ │4.2.4.2 Work in│ │4.2.1.2.3.2.2.1 Focused   │ │4.1.1 Peripheral      │ │4.2.1.2.3.5 Converse│
│same time       │ │turns          │ │Awareness                 │ │Awareness             │ │                    │
└───────────────┘ └───────────────┘ └──────────────────────────┘ └──────────────────────┘ └──────────────────┘
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```
4.2.4.1    Work at the Same Time
```

Working at the same time on the same thing obviously creates problems when two or more users perform the same action with a different effect and intention. If the system updates the changes, who's changes will be shown? Maybe an object should be automatically cloned when this occurs so that users can discuss the differences and decide which version to keep. This needs to be implemented at system level.

```
          ┌─────────────────────────────┐
          │  4.2.4.1 Work at same time  │
          └─────────────────────────────┘
         ┌──────────────┴──────────────┐
┌──────────────────────────┐  ┌──────────────────────────────┐
│ 4.2.4.1.1 Perform same action │  │ 4.2.4.1.2 Perform different action │
└──────────────────────────┘  └──────────────────────────────┘
```

```
4.2.4.2    Work in Turns
```

```
          ┌─────────────────────────────┐
          │   4.2.4.2 Work in turns     │
          └─────────────────────────────┘
         ┌──────────────┴──────────────┐
┌──────────────────────────┐  ┌──────────────────────────────┐
│ 4.2.4.1.1 Perform same action │  │ 4.2.4.1.2 Perform different action │
└──────────────────────────┘  └──────────────────────────────┘
```

When working in turns on the same, shared representation, object hand-over needs to be smooth and effective.

7.4 Predictions from Hierarchical Task Analysis of Collaboration

A number of issues arise from the HTA of collaboration, which point directly at potential usability breakdown during CVE collaboration, if those properties are missing or inadequately supported in a CVE interface. These issues or design properties, are listed below.

- **Navigate**

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

- **Find other users**

Mechanisms should be build into the CVE which allow users to locate each other.

- **Find objects**

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

- **Collaboration**

User should be able to align towards the focal area of activity.

- **Unfocused collaboration**

An user has to be able to monitor the activities of others whilst fulfilling their own responsibilities.

- **Peripheral awareness**

It should be possible for information to be gleaned from the concurrent activities of others within the "local milieu", and a user should be able to implicitly coordinate their own actions and activities with the emergent tasks of others.

- **Monitoring ongoing activities**

Users' activities should be rendered visible to themselves and to the other participants, through their interaction with objects and artefacts.

- **Perceive actions of others and system on objects and artefacts**

The user should be able to smoothly align their VB towards the focal area of activity, without losing track of its own activities. The user should be able to observe the involvement of the other participants in the collaborative activity that is taking place.

- **Implicitly coordinate own actions with other users' and system actions**

The user should be able to perceive the actions of others and the system on objects and artefacts in the CVE.

- **Identify group members**

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

- **Organise shared communication resources**

The users should be able to alter 'physical' aspect of the workspace so as to make communicative resources available to be the shared focus of group activity.

- **Create shared representations**

The users should be able to create shared representations to express ideas, add meaning to the accompanying talk and to summarise work.

- **Work on same object**

The system should allow for smooth transition between ownership of the object and user rights in terms of manipulation of shared objects.

- **Individual in group**

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

- **Seize the moment**

Group members should be able to seize the moment to do something else when one or more of the others are attending to an interruption, or to some individual or subgroup work.

- **Do something else**

Whilst doing something else the user should be able to remain peripherally aware of the group activities and return to focused collaboration should they wish to do so.

- **Personal preference**

The user should be able to do something else whilst maintaining peripheral awareness of goings on in CVE.

- **Called away**

The user should be able to leave some information behind for the other users about the estimated duration of absence from the virtual embodiment.

- **Catch up**

The uses should be able to deduce what has taken place while they were away, without interrupting the flow of the collaboration.

- **Converse**

The user should be able to either maintain a single conversation involving the whole group, or maintain more than one conversation involving different subsets of the group.

- **Maintain central conversation**

The user should be able to share the discourse that is taking place within the group by having sufficient peripheral awareness of the individuals in the group and objects in the space.

- **Share discourse**

The user should be able to perceive turn taking in the conversation and their own turn taking opportunities, so that one can contribute to the central and subset conversations.

- **Perceive discourse**

The user should be able to perceive verbal information, non-verbal information, and be able to detect contextual influences.

- **Perceive verbal information**

The user should be able to receive the audio signals clearly.

- **Perceive non-verbal information**

Perceiving virtual body language, and perceiving textual information.

- **Perceive virtual body language**

Users should be able to view the changes in body language of other participants in sufficient detail, recognise the signals involved in that body language, and interpret body language used by others.

- **Perceive textual information**

The user must be informed about incoming or pending textual messages because of the lower immediacy of the medium.

- **Detect contextual influences**

The user must be able to interpret the reasons for changes in verbal and non-verbal information exchange.

- **Contribute to main conversation and subset conversations**

The user must be able to utilise the different communication channels simultaneously.

- **Maintain subset conversation**

The user must be able to communicate with other users in the same virtual space, and receive communications from other users in the total CVE space who do not share their

immediate surrounding virtual space.

- **Look at the same thing at the same time**

The user must be able to look at the same thing at the same time.

- **Look at single shared representation**

The user must be able to see when and where the other users are looking.

- **Look at series of shared representations**

The user must be able to become aware of the changes in the shared representations at the same time these changes take place.

- **Look at several shared representations at the same time**

The user must be able to look from one to the other shared representation and be aware of where the focus of attention of the others is aimed.

- **Look from one to another**

The user must be able to find and select the objects between which they want to distribute their attention.

- **Work on the same thing**

The rules, rights and permissions to change that thing should be transferred smoothly; and the user should be able to control the transfer of permissions.

- **Work at the same time**

The users must be made aware of who's changes will be shown if they are working in the same thing at the same time.

- **Work in turns**

Object hand-over needs to be smooth and effective.

7.5 Conclusions

The usability design properties are predictions about usability breakdown in CVE interactions and will be discussed and compared to the research data (see Chapter 10, section 10.2.2). Hypotheses 2 and 3 have been positively confirmed through the construction of the HTA for collaboration as presented in this chapter. The HTA shows each step of the task of collaboration in a CVE, as far as it can be predicted based on an understanding of collaborative activities in the real world, and an understanding of the CVE as a communication medium. The description that accompanies each act identified in the HTA leads to the formulation of design properties for CVEs, which in their absence are predicted to contribute to usability problems.