JYVÄSKYLÄ STUDIES IN COMPUTING 29

Samuli Pekkola

Multiple Media in Group Work

Emphasising Individual Users in Distributed and Real-time CSCW Systems

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UNIVERSITY OF JYVÄSKYLÄ

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ABSTRACT

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Computer supported co-operative work (CSCW) is a multidisciplinary research discipline studying technological solutions to support different kinds of works in social contexts. During the past years, particular interest has been laid on distributed and real-time works. Systems to support these are numerous ranging from videoconferences and tele-meetings to mobile connections. But, technologies are usually designed from the organisational viewpoint, for a purpose. Changing work practices and individual users' preferences are often not considered enough so the systems are unusable in varying situations or purposes. In this dissertation, the focus is on individual users and on support of their dissimilar work practices. In addition, no definite context, situation or purpose is emphasised. Instead, the aim is to study generic situations so that the CSCW system can be used in various ways in multiple different cases. As a hypothesis, it is assumed that this can be achieved by combining multiple communication and collaboration media, for instance audio, video, text chat, and whiteboard, into an aggregate. In this dissertation, it will be studied why, how, and in what way can these media be integrated, and furthermore, whether such aggregate improves individual users' work practices. Theoretical bases are derived from CSCW studies. An application is built and introduced into two different organisations where it is evaluated by using both quantitative and qualitative research methods. Consequently, the dissertation reports the results of a constructive research process. The main contributions can be divided into three categories: the proving of the hypothesis and other theoretical suggestions; technically-oriented suggestions, such as integrating the media at the presentation level; and development problems because of the disparity of CSCW and information systems development (ISD) disciplines. This study, first, suggests that future CSCW systems should combine multiple communication and collaboration media into an aggregate, second, it proposes how it can be done, and third, shows a need for ISD methods from the individual users' viewpoint.

Keywords: CSCW, multiple media, users, group work, awareness, groupware

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I have had the privilege of working closely with two distinguished scholars, Prof. Mike Robinson and Prof. Jukka Heikkilä (aka Jups), both who have had a significant impact on my work in its different phases. Mike's enthusiasm really impressed me and got me doing research in the first place. Jups, on the other hand, provided a more feet-on-the-ground approach and pushed me through the final writing and polishing phase. Both of them have also provided constructive comments, criticism, instructions, guidance, support, reflection of ideas, and encouragement throughout the research.

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During most of the time spent completing the dissertation, I have been working as a senior lecturer in the Department of Computer Science and Information Systems at the University of Jyväskylä. However, I also made an odyssey as a project manager at the Information Technology Research Institute, and

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Jyväskylä, May 2002
Kristiansand, February 2003

CONTENTS

Vaarille

(To my grandfather)

PART ONE: INTRODUCTION AND OVERVIEW

1 INTRODUCTION

This is a multidisciplinary dissertation on computer science and information systems. To be more precise, this is about computer supported co-operative work and the technologies and products that make it possible. It will be discussed why, how and in what way multiple communication and collaboration technologies can be integrated into an aggregate, and furthermore, how it improves individual users' work processes.

Computer supported cooperative work (CSCW) is a relatively recent discipline within computer science; the term was introduced back in 1984, and the first conference was held in 1986 (according to (Bannon and Schmidt 1989) and (Greenhalgh 1999)). However, as such, there is no single definition either for the term or the discipline, but several attempts (e.g. Bannon and Schmidt 1989; Hughes *et al.* 1991; Lyytinen and Ngwenyama 1992; Robinson 1992; Schmidt and Bannon 1992; Baecker 1993). Schmidt and Bannon (1992, p.11) proposed that "CSCW should be conceived of as an endeavour to understand the nature and requirements of co-operative work with the objective of designing computer-based technologies for co-operative work arrangements". Baecker (1993), on the other hand, took a more technology-oriented approach to define the discipline through the applications and systems, which support co-operative work. He summarised that:

> "Groupware and CSCW systems thus represent a paradigm shift for computer science, one which emphasizes *human-human* rather than human-machine coordination, communications, and problem solving. CSCW systems can integrate voice and video communication with *shared digital workspaces* and can support work that occurs both synchronously and asynchronously. Thus groupware technology enables an expansion of both the concept of a *meeting* and that of *collaborative work*, allowing participants to transcend the requirements of being in the same place and working together at the same time."
>
> [ibid. p. 2.]

These two quotes also point out the difference between the concepts of groupware and CSCW, as they are often confused. CSCW can be referred to by the

term groupware so that CSCW can be seen as a focus on the design of software that supports group work, that is, groupware (Schmidt and Bannon 1992).

Collaborative virtual environments (CVEs) are one type of groupware. CVEs originate from a multidisciplinary research by combining virtual reality (VR) technologies with general findings and suggestions from the CSCW field. Hence, it can be said that a CVE is a distributed (often 3D) virtual reality that is designed to support collaborative activities. As such, it provides "a potentially infinite, geographically realised digital landscape within which multiple geographically separated or collocated collaborators can interact with each other and with different kinds of data representations" (Churchill and Snowdon 1998, pp. 3). Consequently, CVEs are designed to support distributed, usually synchronous co-operative work, where multiple people (users) work together via computer generated user interface in a 3D landscape[1].

To further classify groupware applications, first Johansen (1988) and later Ellis et al. (1991) introduced a "Same time, same place – Different times, different places" –taxonomy, illustrated in Table 1.1. In this dissertation, the approach is solely limited to the "Same time – Different places" category, although the same theoretical discussions and system descriptions can also be applied to the "Same Time – Same Place" category, as collocated activities can be supported by the same systems as distributed activities. Applications and devices to support synchronous and distributed interactions include telephone, videoconferencing systems and the aforementioned CVEs. In this thesis, it will be discussed how those technologies can be enhanced so that multiform and multifaceted group work could both be aided by, and take place through, them.

TABLE 1.1 Dimensions of time and space applied to CSCW systems adapted from Johansen (1988) and Ellis *et al.* (1991).

	Same Time	**Different Times**
Same Place	synchronous interaction *face-to-face meeting*	asynchronous interaction *bulletin board*
Different Places	synchronous distributed interaction *telephone*	asynchronous distributed interaction *letter, email*

It will be shown later (in Part II) that group work is complex and multiform, hence it can be considered to be extremely difficult to be supported by a single

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1 Often, CVEs are also considered to include all kinds of virtual environments where collaboration takes place. These range from text-based MUDs (MultiUser Dungeon) and MOOs (MUD, Object Oriented) to three-dimensional graphical environments. However, in this dissertation, the term CVE refers solely to 3D virtual environments for collaboration. The term MUD is used to indicate text-based virtual environments respectively.

technology – which has typically been the approach[2]. Here it will be argued that group work can better be supported not only by one, but by many alternative and complementary technologies. The focus is on individual users and supporting their activities as a member of a group – rather than on groups and organisations, and their change. Also, since this study originated itself from the CVE application development and research, it will be discussed, as a corollary to the first hypothesis, how CVEs should and could be extended as a fully cooperative system.

In other words, the hypotheses consider how to improve computer-aided group work (process). Hence, if and when a software prototype is built to test out the hypothesis, Information Systems Development (ISD) methodologies also need to be addressed as CSCW is design-oriented just for making proposals and requirements for the systems' design (Bannon and Schmidt 1989), not for guiding how to implement one. Consequently, in this thesis, systems requirements are first derived from CSCW and then applied and exploited when designing an information system. On the other hand, although ISD methodologies are numerous (Iivari *et al.* 2001), they do not address the change in the information system itself when it is introduced into an organisation, or when the organisation or its environment changes (Lyytinen 1986; de Michelis *et al.* 1998) – issues which are found central in CSCW literature respectively (Bannon and Schmidt 1989; Schmidt and Bannon 1992). It can even be said that the information systems development begins when it is introduced into an organisation (Nurminen and Forsman 1994).

In this thesis, this paradigm of two related but conceptually and fundamentally separate disciplines is taken for granted, and both its impact on the research process and its implications to the adaptation of the prototype by the end-users, are recognised. However, as the emphasis is on the group work process[3] and its improvement from the individual users' point of view, detailed analyses of the ISD methodologies and their failures, organisations, and organisational change are neglected, although again their impact, environmental boundaries and limitations are acknowledged.

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2 Commonly groupware applications are designed to support some specific task or process, as it was proposed e.g. by Briggs et al. (1999). However, as will be shown later, office work, or generally group work, is much more complex thus to support it and its multiple forms such an approach is not appropriate. Chapter 5 presents a comparison of different applications to visualise the usual approach.

3 Group work process is significantly different to ISD process. For instance in Lyytinen's framework for information systems development as a social action (Lyytinen 1986), the process is understood as a set of activities taken by the development group to turn the requirements (objectives) into a system (target) within a set of environments and constrains. For the group work process, for instance, the objectives and targets could be initially unknown or blurry (Schmidt and Bannon 1992). Fundamental assumptions beneath the processes are significantly different hence the methodologies cannot be exploited as such.

Moreover, both to elucidate the viewpoint of the dissertation, and to give some reasons for the chosen approach, Grudin's 'Rings' of the computer systems development and the principal customers of the resulting technology are adapted and reprinted as Figure 1.1 (Grudin 1994a). Each ring includes different groupware technologies, their target users and the most closely related research discipline. The outer ring represents

> "major systems and applications, primarily mainframe and large minicomputer systems designed to organisational goals […]. The inner ring represents applications designed primarily for individual users of PCs and workstations […]. The two rings between these represent large projects and small groups."
>
> (Ibid. p. 20).

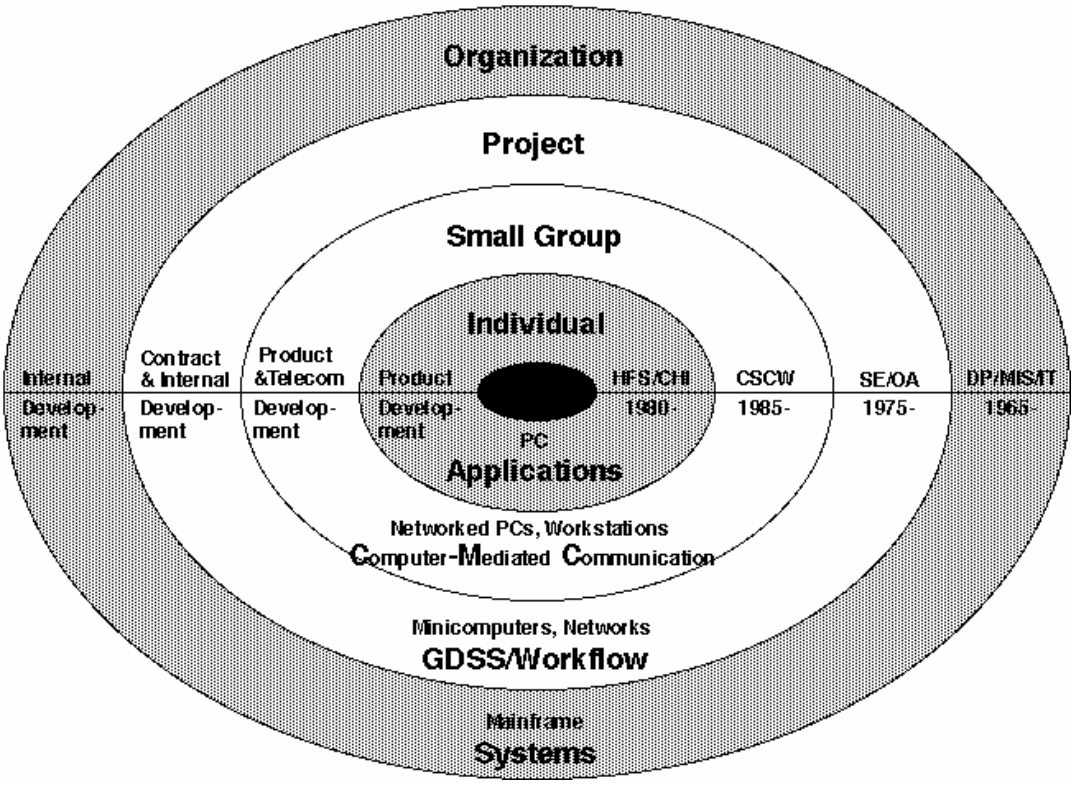

FIGURE 1.1 Grudin's 'Rings' of CSCW research and development contexts (Grudin 1994a, p.21).

Although CSCW research is most strongly tied with small groups, it in fact spans the boundaries and has its implications in every other 'ring' as individual, group, project, and organisational activities are fundamentally intertwined (Grudin 1994a). This fact is acknowledged, but as the focus of the dissertation relies on the group work process from the individual users' point of view, the emphasis is clearly more on the inner 'rings', and the outer ones are conse-

quently considered with less interest[4]. This approach has other implications too. For example the adaptation of groupware at an organisational level is mostly ignored, but discussed on the personal level instead. Similarly the ISD methodologies turn out to be unusable as they usually focus on the designing of information systems on the organisational level.

Throughout the dissertation, discussion about alternative and complementary technologies takes place. These are referred to as media, which are any type of technologies or technological tools used for communication and/or cooperation between two or more participants. This definition differs significantly from the human communication interpretation where the term is often considered to cover different types of (non-verbal) signals the participants produce. Hence, in this context, the media include, for example, audio, video, virtual reality, text chat, shared whiteboard, co-authoring, and email.

As in traditional CSCW research, proposals for the systems design are also studied and reported in this dissertation. In addition, those proposals are tested and validated by implementing and evaluating a prototype. Hence, this thesis reports the results of a constructive research process. A starting point was to develop a CVE application, "VIVA – virtual reality virtual office application", where interactions were assumed to be launched from and take place inside a 3D virtual reality environment. However, it was soon realised from detailed theoretical analyses, which were later proved by empirical evaluations, that this was not the correct approach (see Part II as a whole, and Article VI). The value of the VR interface is often overrated and it should be treated solely as a medium among others, not as an ultimate, central interface around which all activities take place (as discussed in Article VI). Realising this expanded the focus of the research away from the CVEs to distributed and synchronous groupware in general (see research objectives and questions in section 3.1).

VIVA[5] supports real-time communication and co-operation among a physically dispersed group of users. It combines several/numerous media (audio, text chat, short message, shared whiteboard, rudimentary co-authoring tool, file transfer, email and a simple document database) into an aggregate. This allows users to choose a medium, or multiple media at once, which best supports their intended activities. It was also observed that users used VIVA to indicate their presence to other users, similarly to Active Badges (Harper 1996)

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4 This means that some traditional IS research areas, which lie on the "outer" rings and focus on organisational issues, are excluded. They include, for example, MIS (Management Information Systems) and data processing.

5 In addition to indicating the software prototype, VIVA was also a name for a research project. VIVA, virtual reality virtual office application for TCP/IP and ATM networks, when meaning the research project, was funded by Tekes (National Technology Agency in Finland) and participating companies. The project started with a feasibility study in autumn 1997, and lasted until the end of the year 2001. Here, the term VIVA usually connotates the software. When it relates to the research project, it is indicated either by the explicit word "VIVA-project" or implicitly by the context.

or instant messaging systems (Nardi *et al.* 2000), so that other devices or methods (telephone, personal visit) could have been applied (Article VII). Technically, VIVA utilises both client-server and peer-to-peer network topologies so that each client is continuously connected to an awareness server, while direct point-to-point connections between clients or dedicated media servers are established only when appropriate (benefits of such an approach are discussed, for instance, in Greenhalgh 2001 and Pekkola and Robinson 1997a). Later, more detailed descriptions about the design, implementation and evaluations of the system will be provided.

The dissertation is divided into five interwoven parts each contributing to different sections of the study, as illustrated in Figure 1.2. Part I, i.e. this part, provides an introduction to and overview of the topic. Also, background and motivation are illustrated. This is followed by a presentation of research objectives and methodological basis, and an overview of included articles and their relation to the whole. In the final section of Part I, related groupware applications are classified, analysed and compared so that the relationship between the VIVA prototype and the state-of-the-art systems is explicitly illustrated.

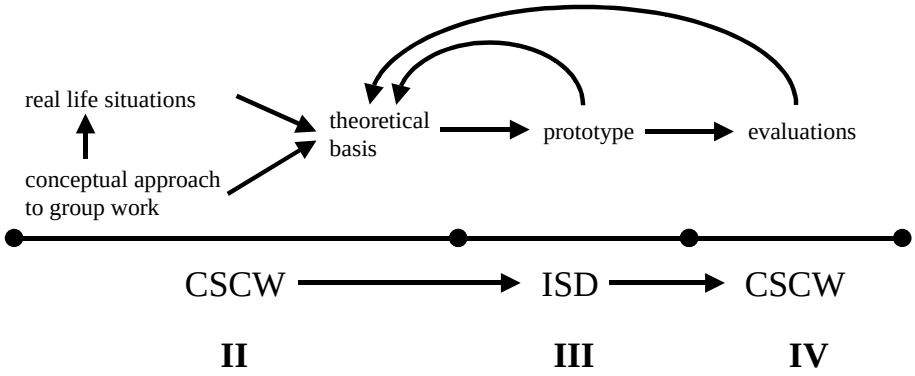

FIGURE 1.2 Relationships between different parts of the dissertation, and their research disciplines.

Part II forms a theoretical basis for the prototype by first making a conceptual approach to group work (Article I), and then analysing two different situations in which collaboration takes place (Articles II-III). Part II is solely derived from the CSCW discipline. Part III is more traditional information systems development oriented and describes the software prototype and its design rationale (Articles IV and V). Part IV puts CSCW issues back on the drawing board and presents an evaluation section of the study in the form of discussions about the role of VR in general, and of some findings of the use of the VIVA prototype in real work settings (Articles VI and VII). These articles provide some feedback to the theoretical basis-part. Finally, Part V gathers all the threads together again and summaries the contributions and conclusions of the dissertation as a whole.

2 BACKGROUND

A well-known phrase “to understand the present, one must know the history” describes the idea of this chapter. First, some general issues and problems with CVEs are summarised. These set a starting point, and an initial approach for the VIVA project. The change in the approach is then described in terms of the basic concepts and design principles, which were applied throughout the research project so that they are concretised in the prototype. However, as this Part is an introduction and overview to the topic, profound discussions, theoretical explanations, and actual theory building are taken up elsewhere in the appropriate chapters and articles.

2.1 A starting point i.e. the motivation

During the past decade, or, in fact, as long as CVEs have existed, the focus of CVE research has been on the collaboration in the virtual environment. However, it is astonishing to realise that collaborative activities are assumed to take place *inside* a virtual reality space. This means that to be able to co-operate or just to chat with others, people must first enter the VR environment, find the right person there, and then launch the medium they need – no matter whether they need VR itself to accomplish their task or activity. However, this is not always a problem, since the task is usually tailored to 3D VR, and can as such be best accomplished there (e.g. (Hindmarsh *et al.* 1998; Pycock *et al.* 1998a; Pycock *et al.* 1998b; Smith and O'Brian 1998; Huxor 2001)). Nevertheless, when generalising the issue, this ‘VR centricity’ becomes problematic. If another application, or tool, or medium would be more suitable or appropriate, or could provide more accurate information for that very moment or situation, it must be opened and used completely separately, and in isolation, to a CVE. There is no linkage between those applications and a CVE (i.e. the VR) – a feature, which obviously limits the usage of CVEs as a fully collaborative tool.

Basically, all traditional CVEs approach collaboration by combining other media with the VR. For example, different versions of MASSIVE (Benford *et al.*

1997a; Greenhalgh 1997; Greenhalgh *et al.* 2000), DIVE (Carlsson and Hagsand 1993; Hagsand 1996; Frécon and Stenius 1998), or Onlive Traveller[6] all support audio communication in the VR. Some others have added video by allowing 'video faces' on avatars (some variants of DIVE, FreeWalk (Nakanishi *et al.* 1998), or CU-SeeMe VR (Han and Smith 1996)) or integrating the video picture onto a wall inside the VR (Koleva *et al.* 2000). Text chat is included in almost every application, perhaps because it is relatively easy both to accomplish and to use. Occasionally some (very) limited document handling and management tools have been utilised (Frécon and Stenius 1998; Huxor 1999). These include, for example, a shared whiteboard and document sharing ability so that participants can place documents on the table to publish them (Benford *et al.* 1995). There are even prototypes, where the structure of a Web-site with its numerous links is used to generate a VR environment (Benford *et al.* 1996).

Lately, the development of CVEs have evolved and moved on, and started to explore so-called 'mixed realities'[7] where VR is embedded into real world settings such as the theatre stage (Benford *et al.* 1997b) or TV performances (Benford *et al.* 1999). However, in these contexts, mixed realities are considered to be a mixture of VR technology and real world settings (where participants mostly act as observers) rather than a mixture of multiple media with real world settings.

Yet, in all these applications and approaches, the common theme is the obligatory use of virtual reality. It is even presumed that the VR interface is central to everything and that most of the activities take place inside the VR environment, or at least that the VR interface is utilised (see Figure 2.1). In fact, it is essential to open the VR interface on a client machine: it is not possible to move into the VR from another application, or vice versa, from VR to another application – such as the Web or a Word document, or an audio 'chat' – if wanted or preferred. Instead, the VR interface must be used no matter whether it is needed or not. Figure 2.1 illustrates the conceptual principles of these two alternative approaches; VR centric (left) and distributed (right) as discussed earlier.

The notion of being 'inside' the VR when accomplishing activities is very important. It reveals the main problem with current CVEs; all actions must be performed in the VR environment as stated earlier. However, in real life, people tend to use the medium, which is the most appropriate for them at that very moment (Reder and Schwab 1990; Heath and Luff 1991; Ehrlich and Cash 1999). The task may not require the utilisation of a 3D environment but involves the use of some other media instead. Workers also switch from one medium to another smoothly if the other one is more appropriate for their current work (Reder and Schwab 1990). For example, customer support analysts and librarians use different tools and methods (telephone, databases, notebooks, consult-

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6 http://www.onlive.com (referenced March 2002).

7 About the topic in general and related technical issues, see e.g. (Ohta and Tamura 1999).

ing other people) simultaneously and move between them seamlessly to find the appropriate information (Ehrlich and Cash 1999). Each medium suits best its own purposes, and helps a skilful person to combine information with other information provided by different media. This parallels with a claim by Hollan and Stornetta (1992), who stated that each medium has its own affordances; some media are better for a particular task at that particular moment, others better for other tasks or at other times. Consequently, it can be said that the VR is just a medium among many. Any user may start from *any* medium that they happen to be using, and wish to add or move to *any* other, as seen in Figure 2.1 (right).

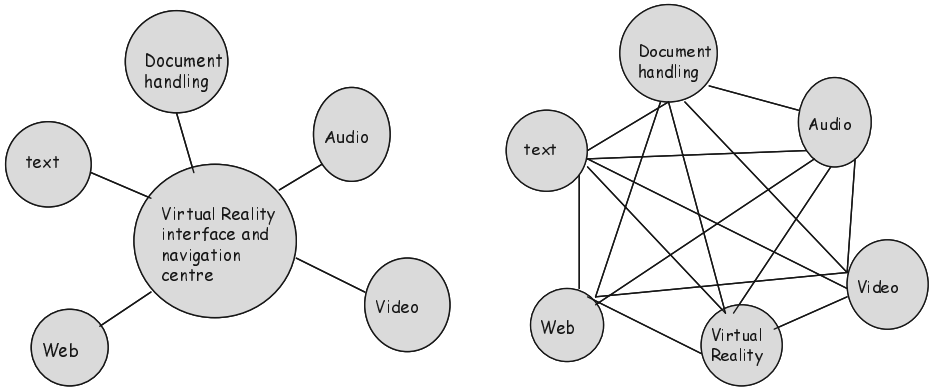

FIGURE 2.1 Conceptual architectures for CVEs: VR centric (left) and distributed (right)[8].

Realising this led to the development of the VIVA software prototype in the VIVA project.

2.2 VIVA virtual reality virtual office application

The VIVA, VIrtual reality Virtual office Application, project began with the aim of developing both a virtual office, where people may work collaboratively, and a virtual warehouse, where they may shop with their fellow shoppers in a 3D environment. The original goal was to design a virtual reality (3D) interface to manage and handle multiple interactions and work processes through multiple media (VR, video, audio, text, graphics, documents), and to design and construct the prototype to support such actions. VR interface was regarded as a navigation and transition point between media and communication modalities, i.e. it followed the aforementioned approach of virtual reality centric systems. In other words, a user could open video or text communication from VR (as it is possible with other existing VR applications) but could not do this the other

8 Thanks to Mike Robinson for the pictures.

way round. Similarly video or a document could be opened from or within VR, but not vice versa. Intuitively this was not right. This kind of limitation to VR-centricity was unnecessary and a result of history more than design – as was discussed in the previous subsection 2.1.

The overall vision was revised in the light of reflection and lessons learned from CSCW. This led to a partial redesigning and revisiting of the goals of the VIVA project – away from VR centricity towards a distributed and flexible combination of multiple media. In fact, the VR interface was abandoned from the final prototype versions completely, thus, for instance, there are no user evaluations either of its utilisation, or of its relationship to every other media. The incident took place after two years of intensive prototype development, after the first prototype version was introduced to the end-users. Reasons are profoundly discussed in Article VI.

The research process of the VIVA project, illustrated in Figure 2.2, roughly followed the principles and methods of participatory design (PD) (Kyng 1991; Bødker *et al.* 1993; Ehn 1993; Kyng 1994; Crabtree 1998; Kensing and Blomberg 1998) and of evolutionary prototyping with three iterative development cycles (McConnell 1996). First, a CSCW literature review was performed to gather a list of design requirements and principles (requirement specification phase in ISD terms (McConnel 1996)). This was followed by the first version of the software prototype (with software design, implementation and testing phases). The prototype was used as a basis for discussions in several workshops that were organised to further develop it and potential use scenarios. Fourth, the second version of the prototype was developed and delivered to users. While they were using it, i.e. prototyping it in PD terms, more workshops, additional use scenarios and alternative user interfaces (mock-ups) were held, designed and investigated. In the sixth phase, the third and the final prototype version was developed and evaluated. The results of these evaluations are presented in Article VII.

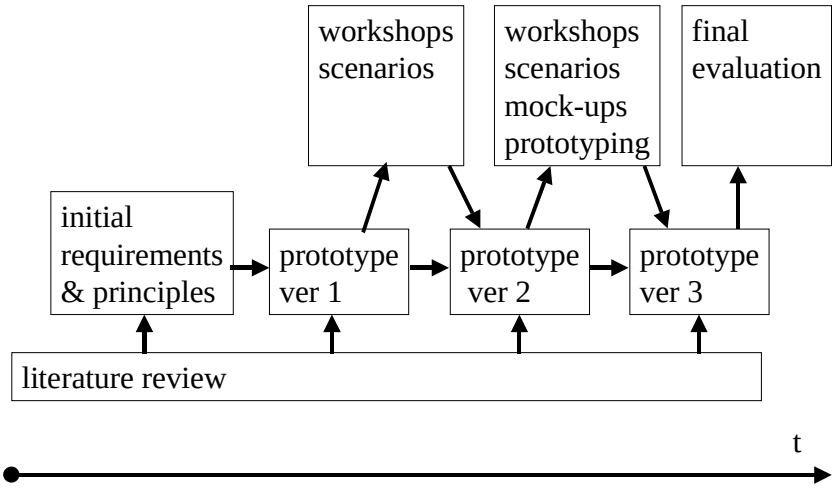

FIGURE 2.2 The research process of the VIVA project.

Works before the VIVA project included a set of design principles for the virtual offices and their facilities (Pekkola and Robinson 1997b; Robinson *et al.* 1998). These principles, which, as mentioned, were derived from CSCW, acted as guidelines throughout the project thus they are reflected in the design of the VIVA prototype respectively. Briefly, the principles are flexibility, common artefact, and 'beyond being there'.

Flexibility. Application constraints (over and above those constraints of the medium itself) should not be based on anticipated use (Keil-Slawik 1992; Robinson 1993). For instance, usually the quality of audio needs to be higher than the quality of video to maintain smooth communication (Tang and Isaacs 1993), but there are circumstances were the opposite will apply (e.g. when reviewing a picture). It is therefore a mistake to assume any perpetual importance of audio over video, or similarly with any other media. Instead, users should be allowed to tailor their virtual workspace, and respectively rank audio and video the way they prefer, and further to choose tools or media they wish to use. This requirement for flexibility and tailorability reflect a large volume of CSCW research on the importance of contingent and ad hoc activities (see Articles II-III, and for instance Gerson and Star (1986), Suchman (1987) and Bowers *et al.* (1995)).

Common artefacts are usually considered to be taken for granted, inconspicuous, and trivial. The idea was originally illustrated by an example of a hotel key rack (Robinson 1993):

> "Guests can leave and collect their keys: can see which other guests are in or out, and leave messages in the pigeonholes. Hotel staff uses it to communicate with their colleagues, and place bills, faxes, etc. to be given out to guests. The presence of keys, or contents of pigeonholes, conveys information, and may be the subject of questions or discussion. Some operations are considered legitimate, while others are not: usually only receptionist can place keys or messages; keys have to be hung over appropriate numbers; etc. The keyrack is a model of the hotel, mapping the rooms. A glance at late night evening gives an overview of the hotel occupancy.
>
> Yet this keyrack is not foolproof, nor is it 'active'. There is nothing to prevent keys being hung in the wrong places, or lost. It can be used in many idiosyncratic ways – probably violating the recognised procedures. Conversely, there are certain things about a keyrack that are fixed, like to positions of the hooks. It is simply not possible to hang a key between two hooks, as there is nothing to hang it on. So potential uses are a result of physical properties, local conventions and rules, and situated activities."
>
> [ibid. pp. 190-191]

Common artefacts have several characteristics, which need to be considered when designing them (Robinson 1993). Common artefacts are both predictable and dependable to the people using them, and provide an overview on a work-world, which would not otherwise be available. They are often used in situations, where peripheral awareness (e.g. being aware of colleagues and their activities) is essential for accomplishing the task (Heath and Luff 1991; Heath *et al.* 1993). Common artefacts not only convey information but also provide further

contexts for both implicit and explicit communications (Harper *et al.* 1989; Robinson 1991; Robinson 1993). Those types of communication should not be seen as alternatives, but complementary and mutually supportive. Robinson's widely acknowledged model, the 'Double Level Language', conceptualises the issue at two levels; cultural and formal (Robinson 1991). The formal level provides a common reference point for participants, while the cultural level supports interactions and communications upon it. Robinson argued that "the formal level is meaningless without interpretation, and the cultural level is vacuous without being grounded" (Robinson 1991, p. 43). Thus, it can be concluded that the levels complement and support each other.

The last of the design principles is '**beyond being there'**, which was originally identified by Hollan and Stornetta (1992). They argued that simulating face-to-face co-presence was the objective of most tele-application designers (back in the early 90's): to produce environments that were as close as possible to 'being there'. This does not parallel experience, since a phone call or an email is often better, more effective, or more appropriate than a visit to another's office or a conversation. The authors argued that each medium has its own affordances, and that mere approximation to face-to-face is a bad design objective, which is unattainable and does not mirror reality. 'Beyond being there' was adapted as a quality principle for VIVA. It was assumed that an application has quality if and only if there are circumstances in which people prefer it to a physical presence.

By bearing these principles in mind, the elaboration of theoretical issues and the design of the VIVA prototype were ready to begin. VIVA was designed to support multiple work practices and types of works (flexibility) without forgetting the context and environment where the work is supposed to take place (common artefact and double level language). 'Beyond being there' provided the basis for evaluating the quality of the application.

Part II provides profound theoretical discussions and some implications to multiple media application design in general. Part III presents the VIVA prototype, some general but detailed requirements for multiple media applications, i.e. making the design principles concrete, and some hypothetical use scenarios. The focus is on the implementation and integration of media. Part IV then takes a more user-oriented approach and illustrates both the VIVA user interface and users' experiences when the design principles were applied. The evaluation of the realisation of flexibility, common artefact, and 'beyond being there' is discussed in the conclusions in Part V.

3 RESEARCH OBJECTIVES AND APPROACHES

In this chapter, research objectives, questions and methodologies will be discussed. Also, the validity of the research will be considered.

3.1 Research objectives and questions

The main objective of this research is to study *why, how and in what way multiple communication and collaboration media can be integrated into an aggregate*. In other words, the objective is to analyse and propose possibilities to improve computer supported group work. Theoretical discussions are derived from two intertwined viewpoints; experiences from real-life (working) situations and from a human communicational perspective. These highlight, first, the reasons why multiple media applications are needed after all, and second, how the use of multiple media improves different work situations in contrast to the utilisation of just one medium. Also, a prototype to evaluate the theoretical issues and proposals is presented. This brings up several new points, such as scalability in different directions and the integration of media, which are not considered in the human-centric theoretical analysis, but which are highly relevant to the systems design. Naturally, the prototype also presents an example how those issues can be considered in the design and implementation of distributed and synchronous groupware.

Another minor objective, as a corollary to the first one and because of the initial research origin, is to study *how collaborative virtual environments should and could be extended as a fully co-operative system.* The issue is addressed from theoretical and practical points of view by briefly analysing some current CVEs and their weaknesses through the scope of the aforementioned theoretical discussions (chapter 2.1). Both objectives are tightly interrelated thus they are discussed concurrently.

In CSCW literature, there are three themes that are identified as central to this dissertation. They are: (working) *process*, *awareness,* and *scalability and boundaries.* Process covers all the different kinds of methods and practices of

how people may work or otherwise perform co-operative activities together, for example, in underground or air traffic control rooms (Heath and Luff 1991; Filippi and Theureau 1993; Heath and Luff 1996; Thereau and Filippi 2000), financial institutions (Heath *et al.* 1993; Harper 1998; Hughes *et al.* 1999), law firms (Suchman 2000), libraries (Ehrlich and Cash 1999), shops (Pekkola *et al.* 2002), and paper mills (Auramäki *et al.* 1996; Kovalainen *et al.* 1998; Robinson *et al.* 2000). In all these situations, people use, or could use, computers or other technologies as tools for the tasks they are trying to accomplish. Awareness of other users and their activities has been identified to be essential for the process (Heath and Luff 1991; Heath *et al.* 1993; Heath and Luff 1996). In this dissertation, the concept of awareness is approached from the situation awareness viewpoint, which refers to the degree of accuracy by which observers' perceptions of their current environment mirror reality (Adams *et al.* 1995; Gilson 1995). Situation awareness can be considered to consist of two elements: user awareness and workspace awareness. User awareness represents direct actions occurring in the workspace; for example, who is around, whether they are available, and what they are doing, while workspace awareness is more activity-oriented. It means the understanding of other people's interactions, such as tasks, activities and communications, within a shared workspace (Gutwin and Greenberg 1997). The final theme, scalability and boundaries, is more technically sound than the other two. When people are working together with a computer-support, there are several boundaries: between users, between each user and his or her computer, between users and the objects they are working on, and between different parts of the computer-generated environment, to mention a few (Star and Griesemer 1989; Star and Ruhleder 1996). Technically, scalability refers to how those boundaries can be crossed or annihilated without excessive influence on the process and awareness.

Objectives and themes can be gathered and summarised into the following four research questions:

1. As a hypothesis, it is assumed that combining multiple media into an aggregate makes groupware more useful and flexible in different and varying situations so that when multiple media are incorporated, or are at least available, the (work) situation is improved in comparison to cases when just one medium is utilised. The first and the most important question is to prove this hypothesis.
2. What are the benefits and what are the failings of each medium?
3. How can multiple media be best integrated? This question can be further divided into several sub-questions: How to support the awareness of other users and their actions in the whole media space? How to manage different boundaries between media? How to ensure scalability in different directions?
4. How should and could CVEs be extended as a fully co-operative system?

Detailed descriptions of each part of the dissertation (as illustrated in Figure 1.2) and their chapters will be presented later. However, in Table 3.1, the research questions and their corresponding sections of the thesis are summarised. As seen, Question 4 is more or less discussed implicitly everywhere, but not answered explicitly until the conclusions and contributions chapter in Part V.

TABLE 3.1 Research questions and the corresponding Parts of the thesis.

	Question 1	**Question 2**	**Question 3**	**Question 4**
Part II	√	√	√	√
Part III			√	√
Part IV (rethinking VR)		√		√
Part IV (evaluation)	√		√	

3.2 Research approach

Bearing the aforementioned hypothesis of the benefits of multiple media in mind, and considering the fact that available systems did not satisfy the requirements of the research (see chapters 2 and 5), it was obvious that a prototype to evaluate the theory needed to be built (Järvinen 2001, p. 92). Hence prototyping and a constructive approach to the research was a self-evident choice.

CSCW attempts to make design proposals (Bannon and Schmidt 1989) while the ISD usually considers not only how to convert those proposals into technical implementation but also how to manage the whole systems development lifecycle from the requirement specification to design, implementation and testing of the prototype (Blokdijk and Blokdijk 1987). Consequently, as a prototype was required to be built, and as CSCW contributes to requirement specification[9], the research process described in the dissertation partly follows ordinary information systems development, which in turn enables the adaptation of the ISD methods as a guideline for the research.

According to Nunamaker et al., systems development can be considered as a multi-methodological approach, which proceeds through an incremental and iterative cycle of observation, theory building, experimentation, and systems development (Nunamaker *et al.* 1991a, pp. 94-95). Observation relies on research methods such as case studies, field studies and surveys. Theory building includes the development of new ideas and concepts, and construction of conceptual frameworks, new methods or models. Theories can suggest a research hypothesis, guide and enable research. Experimentation includes research methods such as action research, laboratory, field and simulation ex-

9 CSCW also contributes to concept development, and systems development and their empirical evaluations, but does not address systems development process for which ISD methods focus.

periments. It may attempt to validate theories, or look at issues of acceptance and technology transfer. Its results can be used to refine theories and further improve systems. Systems development consists of five phases, which correspond to overall systems development research methodologies. These are concept design, architecture construction, prototyping, product development, and technology transfer.

The same authors continue by stating that systems development research must conform to the following five criteria (Nunamaker *et al.* 1991a, p. 101):

- The purpose is to study an important phenomenon in areas of information systems through system building.
- The results make a significant contribution to the domain.
- The system is testable against all the stated objectives and requirements.
- The system provides a better solution to IS problems than existing systems.
- Experience and design expertise gained from building the system can be generalised for future use.

The systems development approach is described as "a critical contributor among the methodologies available" (Nunamaker *et al.* 1991a, p.93). As this research fulfils the five criteria above, and the methodology otherwise provides a good framework, the aforementioned systems development research methodology by Nunamaker et al. will be adopted in this thesis both to describe the research, and also to motivate and direct the research itself.

3.3 Validation of the research approach

Prototyping is used as a part of the research method. In such a case, the question of validity necessarily becomes the focus of special inspection. There are two common approaches for ensuring the validity of constructive research. First, for an earlier validated theory, prototyping may be used to demonstrate the feasibility of a proposed implementation. There formalisation is an important part of validation. Second, prototyping may be used as a means for theory validation. Then, the prototype must be tested in the laboratory or field to test its usability. Claims for the validity of the theory are based on the results of those experiments. (Koskinen 2000). In this study, prototyping is used both ways, although the latter approach is largely emphasised. Only when proposing some fine-grained details of the system's implementation is the first approach chosen.

By applying Nunamaker et al.'s (1991a) systems development research methodology, the validity of the research approach can be discussed. The introductory part of the thesis (especially chapters 2 and 5) looks at the existing systems, situations, and encountered problems, and outlines the current needs for

development in the field. These are considered to be observations. In addition, some preliminary theories and hypothesis are also built. Part II takes a step further into the theory building. First, the problems with current systems, devices and approaches, and reasons why they occur are illustrated through the adaptation of the concept of human communication, and making a conceptual approach to group work. Second, some real-life situations of collaboration are analysed by empirical observations and speculative discussions. In Part II, some suggestions for the design and implementation, i.e. for the systems development, are also proposed. The results of the systems development of VIVA are thoroughly discussed in Part III. It also presents some technically oriented hypotheses, which are evaluated and experimented by computer simulations. The results of the actual experiments of using VIVA as a prototype system, and utilising multiple media are reported in Part IV. Those experiments include first some experiences and theoretical discussions about the value of virtual reality and second a collective case study (Yin 1994; Stake 2000), where VIVA prototype is brought into two distinct organisations. For the case study, both qualitative (interviews) and quantitative (log-file analysis) research methods are used to allow the use of triangulation for improved analysis (Gallivan 1997). The validity of individual research methods and experiments is discussed in the appropriate chapters.

As shown, this research has followed a multi-methodological systems development approach, as advocated in Nunamaker *et al.* (1991a), in terms of the phases of the research and the use of the different strategies to support, motivate and build on each other. All four research strategies have been used, although the emphasis in this thesis has been on theory building with slightly less attention paid to systems prototyping. To date there have been only a few ’real‘ situations where multiple media were incorporated. This is partly because of the progress of the research thus observations and wide-scale experiments are just becoming possible. These will respectively form dominant strategies in research in the near future, as the current cycle of incremental systems development is concluded and the next cycle begins.

4 OVERVIEW OF ARTICLES

This chapter briefly describes the research objectives, methods, and results of each of the seven articles attached to this dissertation, and declares their logical interrelationships that are not always self-evident in the articles themselves. The articles were published, submitted for publication, or written otherwise in a similar manner as individual pieces of research in two journals, four conferences, and one chapter written particularly for this dissertation. The bibliographical details of the articles are also presented. The division of labour and my contribution in the co-authored articles are clarified in subsection 4.8.

4.1 Article I: "Characteristics of Computer-Supported Group Work: Conceptual Analysis"

Pekkola, S. (submitted). Characteristics of Computer-Supported Group Work: Conceptual Analysis. *Submitted for publication to a journal.*

4.1.1 Research problems and methods

The first article in Part II takes a conceptual approach to group work. In general, any group work situation or session (or generally speaking, any situation in which interpersonal communication and/or collaboration takes place) can be roughly divided into two interrelated and parallel elements; human communication and co-operation upon artefacts (or especially documents). In the article, these elements are further divided into detailed components to provide a schematic picture of an overall situation. However, it should be noted that although the group work session is conceptually divided into several layers to help theoretical analysis, the situation is much more complex in real life, and such a division cannot be made. Yet, such a division assists the discussion about characteristics of group work, and different media and their support for group work. Also, at the same time, it reveals the potential benefits and failings of each medium.

Discussions are based on literature reviews and experiences gained and observations drawn from different applications. Human communication is analysed by identifying its main components through appropriate literature review. Co-operation is respectively approached through the aforementioned concepts of double level language and situation awareness, and by adapting Paivio's (1986) dual coding theory to illustrate and explain the relationship between the levels of double level language.

4.1.2 Content and results

The article discusses the issues arising from the characteristics of human communication, and from the fine-grained distinctions of different types of co-operation. First, group work is approached by analysing human communication and its' multifaceted characteristics. The emphasis is on nonverbal communication. Second, the role and use of documents and other reference materials, and other types of co-ordinated actions (overhearing, pointing, etc.) in relation to human communication are investigated. Technologies and media to support identified aspects of group work are mirrored in appropriate chapters to provide detailed analysis of their benefits and downsides in different situations.

The main conclusions and contributions of the article can be shortly summarised. From the human communication point of view, the claim by Hollan and Stornetta (1992) that every medium has its own affordances, is acknowledged and proven right, and benefits and failings of each medium are discussed. Consequently, to support people and their different work practices (and not their use of computers (Grudin 1994b)), a system must support and combine multiple communication and collaboration media, respectively. Also, those media need to be seamlessly integrated so that the actions taken by the fellow co-workers can be correctly interpreted – no matter which of the media one is using. It is argued that either this kind of absence of appropriate media for a situation, or their improper integration, is one of the reasons why the most current groupware fail and are often unusable in real life situations.

4.1.3 Relation to the whole

The VIVA prototype to be presented later on is based on the theoretical analysis from this article. It continues with the initial research settings presented in chapter 2 such as background information and motivation behind the study, and provides erudite discussion on the issues risen. It also answers two original research questions (Question 1 and Question 2) thus, as a whole, its contribution to the thesis is significant.

The article addresses all themes, although it mainly deals with process and awareness. Scalability and boundaries are touched as restrictive, limiting, and constraining factors, which are caused by the isolation and incompatibility of different technologies. Methodologically the article contributes to theory building and systems development.

4.2 Article II: "Launching Multi-Modal Interaction on an EC-Site"

Pekkola, S., J. Heikkilä & V.K. Tuunainen (2002). Launching Multi-Modal Interaction on an EC-Site. Proceedings of 35th Annual Hawaii International Conference on Systems Sciences (HICSS'35). Internet and the Digital Economy track: Communities in the Digital Economy: Concepts, Models and Platforms. January 6-10 2002. Big Island, Hawaii, USA. IEEE Computer Society. CD-ROM.

4.2.1 Research problems and methods

The article discusses the weaknesses of current electronic commerce (EC) applications and approaches. These are their lack of support given to the customers to recognise other people and to communicate with them when desired, i.e. the article illustrates one of the problems identified in the previous article. Discussions are based on the literature review of both EC and CSCW disciplines, and experiences drawn from real-life examples and situations of shopping for goods or services. The paper also briefly presents an application (or a platform), which attempts to solve some of the problems presented.

4.2.2 Content and results

First, the current situation of EC-sites and applications is sketched. This is followed by the identification of some problems through three examples of real-life situations. The problems include the impossibility of asking for help, which is caused by the inability to recognise other people and further interact with them, a lack of support for unexpected negotiations, and a lack of deixis, i.e. the ability to indicate objects, e.g. by pointing, to others. It is argued that these problems are caused by the fact that the current approach to EC application and site design and development is transaction-oriented, when it rather should be communication and interaction-oriented to support people's natural need to communicate.

The second part of the paper briefly presents an application (or a platform), PeopleAwarenessEngine (PAW), which tries to overcome the identified downsides (for detailed description, see (You and Pekkola 2000; You and Pekkola 2001), neither attached here because of the focus). PAW is a tool for visitors (or users or customers or vendors) to observe others on a Web site and to communicate with them through text chat. So PAW allows visitors, first, to recognise others, and second, to start ad hoc communication anytime they wish. Awareness and deixis are supported indirectly by informing others about each visitor's location (i.e. about the Web page the visitor currently is on) so that the context (the page) the person is looking at is implicitly visible. It is proposed that this sort of mechanism to improve awareness facility would be beneficial to EC-sites in general.

4.2.3 Relation to the whole

The paper is the first of two articles investigating the features and characteristics of group work, and their realisation in practise. As the paper deals with electronic commerce, it compliments the previous view of office work (discussed for instance in chapter 2 of the introductory part) to group work by stretching it in a new direction. Despite the fact that the paper does not mention VIVA or multiple media, the application, PAW, is very closely related to VIVA. PAW can be used as a VIVA extension to connect VIVA users to others in the Web sites, and vice versa. From the VIVA point of view, PAW can be regarded either as a medium among others or as a downwards scalable platform, as is discussed in subsection 4.5 and in Article V.

The paper deals with all the themes: awareness, process, and scalability and boundaries in decreasing order of importance. Awareness is central in the paper with the revisions from the process. Scalability and boundaries are tackled indirectly in the introduction of the PAW system. Methodologically the paper contributes to observations, theory building and systems design respectively.

4.3 Article III: "Mobile Phones, Refrigerators, Bar Code Readers, Cameras, The Web and – People"

Pekkola, S., Y. You & M. Robinson (2000). Mobile Phones, Refrigerators, Bar Code Readers, Cameras, The Web and – People. In: H. Fägerlind, T. Lindroth, U.Lundh-Snis, M. Magnusson, L. Svensson, C. Sørensen and C. Östlund (Eds.) Proceedings of the 23rd Scandinavian Research Seminar on Information Systems (IRIS): Doing IT together. Vol. II. University of Trollhättan / Uddevalla, Sweden. pp. 1065 - 1072.

4.3.1 Research problems and methods

The paper examines the awareness of other people in the context of mobility, consumer electronics, and the Web. The topic is approached from the future multimedia homes' point of view by taking some technologies and analysing how they can be extended, and potentially utilised in a home environment. A list of challenging and problematic issues is presented. The paper is purely visionary, although the discussions are based on existing technologies and their usefulness (or occasional uselessness) through a CSCW literature review.

4.3.2 Content and results

The concepts of situation awareness and Double Level Language are used to analyse the challenges and problems with net-refrigerators and other technolo-

gies to support co-ordinated interactions at home. The paper begins by identifying some problems with current technologies; that is, that the users are not even aware of each other within a medium, which in fact means that the awareness issue is not considered at all. An extension to the technological context is then proposed to illustrate a potential solution for some of the problems. For the conclusions the paper combines a list of issues, which need to be considered when designing ubiquitous systems. They are: synchronicity and remote access; ability to attract attention; interface, which is intuitive and easy to use; problems caused by heterogeneity of equipment and networks; a need for automated actions; problems with identifying people, i.e. user awareness; and connectivity to other devices and domestic items. As seen, the list is quite generic and can also be applied to any type of group work, or generally to situations in which technology aids (or hampers) communication and collaboration.

4.3.3 Relation to the whole

The paper is the other of two articles investigating the characteristics of group work. As seen, many of the issues raised in the previous chapter are still valid, although the context has changed. This time it is a home environment. These two articles complement each other by providing alternative viewpoints to the topic. This paper contributes to the dissertation by sketching a simple situation, which becomes extremely complex when new technologies are introduced. Also, it shows how different kinds of boundaries can be exceeded. The themes addressed are awareness, and scalability and boundaries. In this paper a methodological contribution is made to theory-building.

4.4 Article IV: “Collaborative Virtual Environments in the Year of the Dragon”

Pekkola, S., M. Robinson, M.-J. O. Saarinen, J. Korhonen, S. Hujala & T. Toivonen (2000). Collaborative Virtual Environments in the Year of the Dragon. In: E. Churchill & M. Reddy (Eds.) Proceedings of the ACM Conference on Collaborative Virtual Environments. ACM Press pp. 11-18.

4.4.1 Research problems and methods

The paper tackles the problem of how to construct an environment or a system in which the integration of multiple media can be demonstrated and tested, and further evaluated by the users. The concept of multiple media is used as a basis for designing the architecture of the VIVA prototype. The VIVA architecture and its theoretical background are briefly described. In addition to the integration of multiple media, the paper focuses on awareness and scalability in differ-

ent directions. Because of the publication forum, special emphasis is placed on the virtual reality in general, and on the partitioning of the VR environment.

4.4.2 Content and results

In the paper, it is suggested that the next generation of CVEs should pay more attention, than they currently do, to the issues of awareness of others, multiple media and scalability in different directions. Scalability in different directions constitutes upward scalability, i.e. a support for large crowds; downward scalability, i.e. tailorability down to different devices, terminals and / or over limited network connections; and horizontally, i.e. allowing users to move both between the worlds and reconfigure the environment as they find appropriate. Although all the concepts are discussed in the context of CVEs, they can be generalised to cover any groupware – as shown elsewhere in this dissertation.

The general VIVA architecture, its theoretical background and design principles on a concrete level are also presented. The VIVA prototype was mostly implemented as is described in the paper, although, at the time of writing, some media and features were still considered more as conceptual models and examples than fully implemented and tested tools and functionalities.

Special attention is paid to the scalability of the virtual reality environment for large crowds, i.e. upward scalability. A partitioning algorithm to dynamically divide the VR environment into smaller manageable parts is presented with some initial results from the computer simulations.

4.4.3 Relation to the whole

Articles I-III provided the theoretical background upon which the VIVA prototype is based. The prototype therefore forms an empirical, constructive part of the whole research process. The prototype, or its implementation, is not optimised in a technological sense, and as there are no measured results about its technological performance, the description should be conceived as an example of a concept of how such systems could be implemented, not necessarily how different details should be considered. The paper addresses themes of awareness and scalability and boundaries, and contributes to the systems design, theory building, and experimentation.

4.5 Article V: “Multimedia Application to Support Distance Learning and Other Social Interactions in Real-time”

Pekkola, S., M. Robinson, J. Korhonen, S. Hujala & T. Toivonen (2000). Multimedia Application to Support Distance Learning and Other Social Interactions in Real-time. *Journal of Network and Computer Applications.* Vol. 23, No. 4 (2000) pp. 381-399.

4.5.1 Research problems and methods

Article IV presented the VIVA prototype with a focus on CVEs. Here the description of the VIVA prototype continues by illustrating how the system can be adapted to the Web and distance learning contexts. PeopleAwarenessEngine (also described in Article II) is again presented, with conceptual principles of how to connect it to the VIVA prototype.

4.5.2 Content and results

The paper begins with a description of the VIVA architecture. Then, the PAW architecture is presented, but in more depth than in Article II. It is then shown how these independent systems can be linked, connected, and combined. However, unfortunately this was not accomplished in practice, instead the principles of how it can be done are described. Basically, from the VIVA point of view, the Web can be treated solely as a medium among others, so the principles of combining PAW and VIVA can be generalised to cover any medium. But the PAW also provides another viewpoint, it supports downward scalability by allowing people with different terminals (that is Web browsers) to connect to others with the whole VIVA system.

Instead of focusing solely on scalability, the paper discusses VIVA through the concepts of flexibility, process, and awareness. Here flexibility is considered both as freedom to choose the medium where the activities can be started, and as a process to support both formal and ad hoc work practises.

4.5.3 Relation to the whole

The paper complements Article IV by presenting an extension to the VIVA prototype, and the principles how any new media can be technically added and integrated. Also, an alternative view to the preceding article is presented. The paper deals with the themes of scalability and boundaries and awareness. Methodologically the paper solely contributes to systems development.

4.6 Article VI: “Critical Approach to 3D Virtual Realities for Group Work”

Pekkola, S. (2002). Critical Approach to 3D Virtual Realities for Group Work. In: Proceedings of the Second Nordic Conference on Human-Computer Interaction (NordiCHI 2002). ACM Press, pp. 129-138.

4.6.1 Research problems and methods

A virtual reality interface was abandoned from the VIVA project after two years of prototype development. In this paper, the value of 3D virtual reality for group work is critically evaluated through the discussions of reasons why its development was interrupted and discontinued. Discussions are based on the analyses of the VIVA project and some public 3D chats, and conceptualising the group work in a similar manner as in Article I. The notion of distinction between space and place by Harrison and Dourish (1996) is adapted to situate and formalise the concept. The distinction is as follows: space can be regarded as a reflection of the real, physical world, while place is "[…] a space, which is invested with understanding of behavioural appropriateness, cultural expectations, and so forth." (Harrison and Dourish 1996, pp. 69).

4.6.2 Content and results

The paper begins by discerning the benefits of 3D VR for information visualisation and visualisation of co-operative activities. Next, experiences and lessons learned from the VIVA project and 3D VR chats are presented. It is shown, by the thorough analysis carried out in the paper, that the value of virtual reality interface is not great in such cases, as other media are usually regarded as much more important. Instead of a visually rich VR interface and an ability to examine a 3D model together, users prefer the availability and quality of the relevant information – the users already knew the context and the other people, they did not need a 3D image for it. After adopting the characteristics of non-verbal communication and the aforementioned space-versus-place concept, it is argued that 3D VR has only a minimal value for distributed and computer-supported meetings, and for group work in general. This leads to the revision of the above-mentioned benefits of the 3D VR. It is concluded that the value of VR for group work is often exaggerated, and overemphasised and overrated. This is because of its self-centricity – as also discussed in subsection 2.1 about the media centric approach.

4.6.3 Relation to the whole

The paper is in some ways different within the context of the thesis as VIVA and other central concepts are either considered only as an example of bad design or are completely neglected or ignored. However, since the research and the VIVA project arose and were based on the VR centric research (as mentioned in chapter 2), it is essential to sketch and justify why the VR interface was abandoned in the first place. Although the reasoning in this paper is not meaningful to the context of the thesis as a whole, it provides, with other examples and with a little help from the discussions taken in Article I, enough evidence for the claim of the overestimated value of VR. Virtual reality should be solely considered as a medium among others.

Despite the disparity of the paper, it addresses the themes of scalability and boundaries and awareness. There are several boundaries in and through the VR interface, which, in fact, impair the illusion of place. Similarly, the awareness issues are touched indirectly through the distinction between the place and space. As the illusion of the place is generated by people's actions in each person's mind (Harrison and Dourish 1996), the perception of awareness of others is implicitly assumed. Methodologically the paper contributes to observations and theory building.

4.7 Article VII: "VIVA as a Tool for Communication and Co-operation: A research report"

Pekkola, S. (2003). VIVA as a Tool for Communication and Co-operation: A research report. *A chapter for the PhD thesis.*

4.7.1 Research problems and methods

The final article of the thesis presents some initial results from the evaluation of the VIVA prototype. The purpose is to study how and in what kind of situations was the prototype used in real-life as a part of employees' casual work practices. Two distinct case organisations are studied as a collective case study (Stake 2000). The prototype was used between two to seven months in a paper machine factory (for a group of 22 users) and in a university workplace (25 users), after which a total of 24 users were interviewed and their log-files were gathered and analysed. Triangulation rationale was adapted for the analyses of qualitative (by interviews) and quantitative (log-file analysis) findings to increase the reliability of the research (Yin 1994; Gallivan 1997).

4.7.2 Content and results

First, the VIVA user interface is presented to give an overview of functions and features elaborated during the project. For example, by looking at two figures (Article V, Figure 10.2 and Figure 12.1 in this article, reprinted here as Figure 4.1), the evolution of the user interface is clearly visible. Second, research settings, case organisations and methods how the study was conducted are presented. This is followed by in-depth discussions of the findings from the interviews and log-file analyses, and general conclusions about the success and partial failure of the study and VIVA respectively.

The evaluation shows that the VIVA prototype was mainly used for testing its features, unfortunately (thus the goal of the study partially failed). Different media were seldom purposefully utilised when accomplishing formal work tasks through VIVA, although there are several examples when such circumstances occurred. However, as users logged in to the system regularly and

often spent significantly long time online, they also (subconsciously) adopted the practice of using VIVA as an advanced instant messaging system. That is, the users used VIVA to see whether a co-worker had logged in, which consequently indicated that the person was in the workplace and respectively reachable through some traditional medium like face-to-face. Also, some media were occasionally utilised for social communication such as greeting others or telling a joke. It is argued that this lack of real use is caused by the novelty of the application area in general; users have not yet adapted new work practises, which are required to gain full benefits of new features (c.f. Grudin (1989), Orlikowski (1992), Grudin (1994b), and Bandram 1996)).

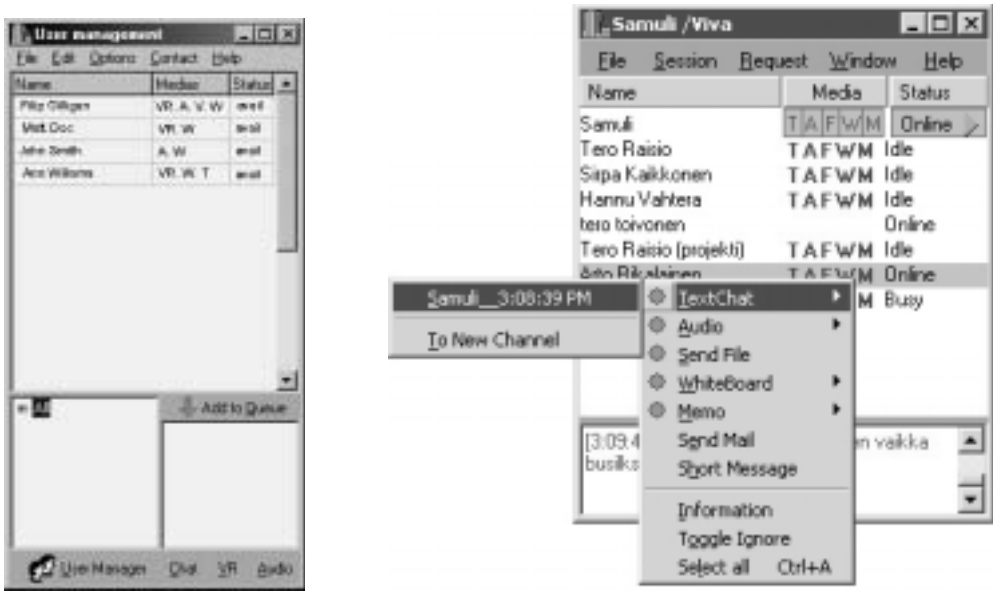

FIGURE 4.1 An evolution of VIVA user interface; the first evolution (left), and the third evolution (right).

Despite the scarce amount of reported real usage, it was found that some media are regarded to be more suitable and acceptable for socially oriented situations (e.g. text chat and short messages) while the others were considered more as work-related (whiteboard, memo, and — audio, surprisingly). Also, it was found that the combination of multiple media improves the work process, thus the hypothesis of the benefits of multiple media is addressed, and proved right.

This article contributes to the specific research question (Question 1) by illustrating the flexibility of the VIVA prototype. It is shown that the system can be used in many different ways in many different situations with many different purposes and intentions. However, it is often difficult to identify certain situations, cases or patterns, where VIVA was, and would be, incorporated. Instead, it was often embedded into casual work processes and situations, and used as an invisible background awareness supporting tool or an advanced instant messaging system.

4.7.3 Relation to the whole

This article is the second chapter for the evaluation of the VIVA prototype, which was presented in Articles IV and V. The first evaluation chapter, Article VI, explained the reasons why the project was refocused and why the VR interface was abandoned. Hence, in this article no VR or its evaluation as a medium is accomplished. Theoretical foundations are derived from Articles I-III and then their realisation into practice is elaborated. Consequently, the article can be regarded as very significant, similarly as Article I, to the concepts of the thesis.

The article mainly deals with the themes of process and awareness. Methodologically, its main contribution is to the experimentation category with less emphasis on observations and theory building.

4.8 About the joint articles

The research presented in this dissertation has been carried out in a research group where several researchers study largely overlapping issues. The greatest benefit of such an environment is obviously that it supports collective evolution of ideas and helps essentially in the development of the prototype. The setting is ideal for the prototype development and testing, but it makes life problematic when compiling and defending a doctoral dissertation. For example recognising each other's contributions and one's own work for presentation are impossible.

However, in this work, I have attempted to reduce the problem by selecting papers in which my contribution is more substantial. First, the core contribution in each paper concerns my personal research work. Second, in all papers, I have either been the only author or the first author responsible for writing and editing the major parts of the paper. Third, I have included an independent article as chapters especially for the thesis (Articles VII), a submitted manuscript (Article I) and a conference paper (Article VI), all written by me. Fourth, my role in the VIVA project has been centralised mostly on project management and overall guidance, therefore my ideas of design, implementation and the research in general are well accepted and employed. However, at the same time, this obviously limits my effort and contribution to particular details and their realisation. Next, detailed discussions about the division of labour and my contribution in each article will be presented.

Although Article I was written solely by me, its section on human communication presents a rewritten and refocused version of a subsection of an article I have co-authored earlier (Heiskanen *et al.* 2001).

Writing Article II was an extremely long process, which evolved through several draft versions. Also, as it was written in a collaborative manner, it is difficult to identify each author's individual contributions. For the article included in the thesis, I was in charge of editing and compressing the final version, and of the sections on PeopleAwarenessEngine and other technologies, and identi-

fying problems with the lack of deixis and their theoretical reasoning. Jukka Heikkilä and Virpi Kristiina Tuunainen invented the original idea for the paper and grounded it on the discipline of electronic commerce.

For Article III, I was the main author. I developed the initial concept with Yu You, but wrote the first version completely alone. Mike Robinson provided help on restructuring and re-elaborating the second version, which was published and is consequently attached here.

I was also the main author of Article IV. I held the main responsibility for guiding the research in general (as a project manager) and requesting contributions from my co-authors. Writing the theoretic foundations –subsection and editing the final version was done together with Mike Robinson. Markku-Juhani O. Saarinen developed the partitioning algorithm and performed its computer simulations. Jonni Korhonen, Saku Hujala and Tero Toivonen designed, implemented, and wrote the first draft of the VIVA architecture. I then rewrote the corresponding sections for the paper.

Article V was written in a similar manner as Article IV. I was the main author and invented the original idea, although the distance learning context was proposed by the editor of the journal. I also gathered the subsections from the co-authors and composed the paper. Again, Mike Robinson contributed to theoretical foundations and the edition of the final version. Jonni Korhonen, Saku Hujala and Tero Toivonen wrote drafts for the VIVA architecture and comparison to related system, which were later revised by me. PeopleAwarenessEngine was reproduced from You and Pekkola 2000 but rewritten and tailored to fit the context.

For Article VII, I was responsible for the work, with contributions from Pasi Pohjola and Niina Kaarilahti, who made interviews in one organisation (I interviewed the other), and from Tero Toivonen and Arto Rikalainen, who collected the data I needed from the log-files. They all worked under my tight supervision and collaboration. Plans for guiding the research and doing the data analyses and interpretations were my duty. The report attached here is written by me alone.

5 RELATED SYSTEMS

One of the criteria the systems development research must conform to is that it provides a better solution to IS problems than existing systems (Nunamaker *et al.* 1991a, see also subsection 3.2). Hence, a comparison to related systems is accomplished in this chapter to see whether the VIVA development provides new insights to the topic.

There exist a vast number of different groupware applications, which support distributed and synchronous group work. In this chapter, some of those will be reviewed in the light of themes addressed in the thesis. Applications, which support asynchronous group work (e.g. BSCW (Bentley *et al.* 1997), Lotus Notes or Microsoft Exchange), collocated group work (e.g. Groupsystems (Nunamaker *et al.* 1991b)), or which are very limited in the number of supported media (for instance telephone; audio only) are excluded.

First, a framework for analysis is created. Then, several systems and their main features are reviewed. Third, a comparison of applications is accomplished through the framework. Fourth, a summary of how the systems mirror the themes of the thesis, and a brief analysis of VIVA versus others, are presented.

5.1 A framework for analysis

The framework focuses on the scalability -theme of the thesis. As the process is more user-oriented, it makes it more difficult to analyse without introducing applications into organisations and grounding them in a certain context, thus not addressing the theme. When scalability in different directions is evaluated awareness is also considered, as it is one of the factors that support sideways scalability.

Different directions of scalability obviously set different requirements for the groupware. For upward scalability, network topology and the server performance become the most significant factors (Greenhalgh 2001), while for downward scalability, network topology and the method selected to integrate

the media are critical. Integration allows certain communication or collaboration media to be separated, or connected, so that they can operate over the limited bandwidth and with powerless devices. Sideways scalability includes, in addition to awareness, other variables such as the number of media, type of integration of the media, and connectivity to other applications. These factors both allow and support different work practices and ways to use the groupware.

Media include, as defined earlier, video, audio, text chat, shared whiteboard, co-authoring system, 3D virtual reality interface, and file transfer, to mention a few. Basically, it can be said that a medium is a tool, which aids communication and / or collaboration.

The concept of awareness is again approached from the **situation awareness** point of view by organising it into two categories: **workspace awareness** and **user awareness** (see subsection 3.1 for the definition). However, in the multiple media context, situation awareness can be considered to cover not only the awareness information about the presence of users and their activities within a medium, but also across different media. For example, numerous windows, each handling a medium, are open. One could be fully aware of the users and their activities inside a single window, but not between multiple windows and across media. Thus, an additional character to describe such a feature is engaged. It is simply regarded as **awareness across media**.

Integration of media can be done at the **presentation** (interface) level and / or at the **data** level (Mandviwalla and Khan 1999). Consider a WWW browser for instance, it supports several different media – hyperdocuments, text, graphics, sound, and video. The integration is done at the presentation level as the underlying data points to different files, which can be potentially further downloaded from different servers. A counterexample is a video conferencing application where sound and video are interrelated and integrated at the data level, and processed as an aggregate over the network.

Network topology and the use of different protocols are significant factors for upward and downward scalability (Pekkola and Robinson 1997a; Pekkola *et al.* 2000; Greenhalgh 2001). Network topologically, systems can be categorised into **peer-to-peer** (or point-to-point) systems, **client-server** systems, or **hybrids**, which somehow combine the first two. **Multicast** network protocols can be utilised regardless of the network topology, but they play a significant role in the upward scalability as appropriate choices may reduce the network load remarkably.

Sideways scalability requires that the users are allowed to utilise any media they find the most appropriate in the current situation. This may mean tools or media, which are not originally integrated into the groupware, hence a variable, **connectivity to other application**, is needed to identify such a feature.

The above-mentioned issues are now gathered together in Table 5.1 to form a framework for the analysis.

TABLE 5.1 Framework for analysing synchronous groupware.

Media	Text chat, audio, video, VR, whiteboard, email, co-authoring system, etc.	
Awareness	Situation awareness	User awareness
		Workspace awareness
	Awareness across media	
Integration	Presentation level	
	Data level	
Networking	Peer-to-peer, client-server, hybrid	
	Multicast	
Connectivity	Connectivity to other applications	

5.2 Distributed and synchronous groupware

There are many applications, which can be classified as both synchronous and distributed. To reduce their number and to clarify the analysis in general, these will be arranged into four categories, in which other applications not yet discussed here may also fall into. Each category constitutes of 2 to 4 systems making the size of the reviewed systems 12. VIVA, and how it is reflected to the framework, is discussed later in section 5.4.

The sample includes both commercially available applications and research prototypes. They were chosen by their relevance (number of supported media, distribution mechanism) and popularity. Applications, which may otherwise fulfil the requirements, but are generally used with some other technology (for instance decision support system with video conferencing) or which are rather toolkits to compose new systems than full applications themselves (e.g. Habanero[10], Access Grid[11]) are excluded. Also, if two applications are very similar either in their design or implementation or by their use, only one is included. Respectively numerous other applications, e.g. Blaxxun, and Active Worlds, which are quite similar to the ones included, are not considered here.

5.2.1 Video conferencing systems

Often, if one is asked to define a synchronous distributed group-support application, video conferencing is named. In this context, the term video conferencing is intended to cover all kinds of applications, which combine video and audio. Although these systems are numerous, only the three most popular ones are included:

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10 http://habanero.ncsa.uiuc.edu/habanero/ (referenced March 21 2002).

11 http://www-fp.mcs.anl.gov/fl/accessgrid (referenced March 21 2002).

- Microsoft Netmeeting[12] is perhaps the most widely used collaboration and communication environment for Windows platforms. It is introduced as a video conferencing application, although other media are also supported. Netmeeting is quite advanced in the number of different media (video, audio, text, whiteboard, file transfer, and application sharing are supported), but they are only linked loosely together. Awareness information can therefore be considered to be insufficient, since users are listed only in the main window, and they are generally not aware of other users' activities. From the network topology point of view, Netmeeting incorporates both peer-to-peer and client-server topologies so that peer-to-peer connections are used for two participant sessions and client-server for multiparty communication.
- Click-to-meet (formerly known as CUSeeMe)[13], similarly to Netmeeting, supports multiple media, but in a greater number; audio, video, text chat, file transfer, whiteboard, application sharing, instant messaging, calendar, and walkthroughs (guided Web tours). Awareness information is again limited to only rudimentary user awareness. Click-to-meet utilises client-server architecture.
- Lotus Sametime[14] is designed to improve and extend Lotus Notes by providing tools for real-time communication and collaboration. Although it is not a pure video conferencing system, it is introduced here because of strong support for video. In addition, Lotus Sametime also supports instant messaging (text chat), audio, whiteboard, and screen sharing. Situation awareness is limited solely to user awareness. Network topologically Lotus Sametime imitates Lotus Notes by utilising a client-server architecture.

5.2.2 Collaborative virtual environments

CVEs are the second category of applications. Here only the four common ones are analysed.

- MASSIVE (Greenhalgh and Benford 1995; Benford *et al.* 1997a; Greenhalgh *et al.* 2000) is one of the most advanced CVE. As it originally is a traditional VR application, where all actions are assumed to be taken either in or through the VR environment, there is no need for a support for awareness between media. Instead, user awareness and workspace awareness inside the VR environment are adequately supported. MASSIVE utilises audio and multiple output and input devices. Net-

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12 http://www.microsoft.com/windows/netmeeting (referenced March 21 2002).

13 http://www.cuseeme.com (referenced March 21 2002).

14 http://www.lotus.com/home.nsf/welcome/sametime (referenced March 21 2002).

work topologically MASSIVE is a peer-to-peer system, although MASSIVE-II & -III adapt servers for some dedicated tasks such as for managing different areas of the virtual environment.

- DIVE (Hagsand 1996; Frécon and Stenius 1998) is a loosely-coupled heterogeneous distributed system, which combines audio, document handling and the Web with VR. It supports peer-to-peer network communication without any central server, and a 3D-user interface in which users are represented as avatars. Awareness of other users and their activities are presented, similarly to MASSIVE, inside the VR environment and through audio channels.
- NPSNet (Zyda *et al.* 1993; Macedonia *et al.* 1994) is a networked VR system designed for military training and simulation with the goal of supporting a (very) large number of participants. It aims to create realistic simulations with a realistic modelling of smoke, fire, and terrain by utilising a server-based network topology.
- NetEffect (Das *et al.* 1997) is similarly designed to support and manage large, media-rich 3D worlds used by several thousands of dispersed users. Users see others through a 3D interface, and communicate by using either text chat or audio. Network topology makes NetEffect interesting; there is an additional level of servers – a master server for managing the environment as a whole and numerous peer servers, which administrate a section of the environment and the users located there. Clients are thus connected to an appropriate peer server. For audio communication, clients are allowed to establish direct point-to-point connections.

5.2.3 Multiple media applications

Both videoconferencing applications and CVEs combine multiple media to some extent. However, as the default, there is a medium (video or VR), which is central and around which all activities are assumed to take place (as discussed in subsection 2.1). Here some systems, which adapt a decentralised (or distributed) approach where any medium could be a starting point, are reviewed.

- COWS (Mandviwalla and Khan 1999) concentrates on the use of 2D style documents with session-based collaboration by supporting text chat, pre-defined lists and tables, and a workflow-style shape creator. Awareness of other users and their actions is illustrated in frequently and automatically updated user lists. Human interaction occurs only through text-based communication, and document and object manipulations. COWS utilises client-server communication.
- DIVA (Sohlenkamp and Chwelos 1994) brought multiple media into the context of an office so that people, documents, desks, and rooms each have a certain role for collaboration. People work upon documents on the table (i.e. work context) in a room (area where awareness informa-

tion is presented). Collaboration occurs through audio, video, notes, and a shared whiteboard. When a person enters the room, audio and video communications are immediately activated. This resembles video conferencing somewhat, but as the underlying philosophies differ significantly, DIVA supports situation awareness extremely well. For example, similar to real life situations, people can glance into other rooms, whisper to people in the same room, and group documents so that one can see who is working with whom and with which document. Network topologically DIVA is a client-server system.

- Groove[15] is a tool for small group interaction. Audio, text chat, instant messaging, newsgroup-type threaded discussions, file transfer, application sharing, co-authoring, group calendar, and walkthroughs (guided Web tours) are supported. Groove is advanced in combining numerous media, but weak in supporting situation awareness within and across them. Only user awareness is supported. Activities across media, or even within a medium, are not visible thus workspace awareness is clearly insufficiently supported. However, Groove uses cleaver network connections as the default, peer-to-peer connections are used, but occasionally routing through a server is activated to optimise bandwidth and connectivity constraints (that is, firewalls, for instance).

5.2.4 Instant messaging applications and awareness widgets

During the last couple of years, instant messaging applications have become very popular. With them, users may create 'buddy'-lists and see whether their friends are online. Communication usually takes place through text chat and text based instant messages, which are sent to the receiver when they are online, i.e. the practice resembles short messages in mobile phones.

- ICQ[16] is one of the oldest and most popular instant messaging systems. In addition to the usual user awareness information, it supports instant messages (text), text chat, email, file transfer, Web tours (walkthroughs), and connectivity to external applications. ICQ can also be embedded into Web sites, so that the visitors can discuss with others either on the Web or in ICQ. This is similar to the discussions presented in Article V when combining VIVA with PAW. Still, without the use of any external tool, ICQ is just a simple communication application with client-server architecture.

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15 http://www.groove.net (referenced March 21 2002).

16 http://www.icq.com (referenced March 21 2002).

- Microsoft Messenger[17], similarly to ICQ, supports instant messages (text, only with three friends), email and file transfer, but adds new media such as audio (with one person only), emoticons (icons for different emotions) and connectivity with other Microsoft products. Awareness information is limited to user awareness only, which is distributed from one server to all clients.

As one can see, instant messaging systems, either Web-based or stand-alone, are numerous. The aforementioned PeopleAwarenessEngine (Articles II and V and You and Pekkola 2000 and You and Pekkola 2001) provides awareness information about other people in the same Web-site and support text-based communication with them, while AREA (Fuchs 1999) supports user awareness across different applications. On the other hand, NESSIE (Prinz 1999) supports workspace awareness by transmitting notifications of events taken in other applications, while Elvin (Fitzpatrick *et al.* 1999) takes a more limited approach and only sends notifications of users' chosen interests. Yet, all these systems are very limited in the number of media – they only support one or two (in addition to awareness information) thus they cannot be classified as multiple media applications. However, as they can also be used in parallel with other applications, they are worth mentioning.

In addition to stand-alone applications, there exist some research protocols, which may be used with other applications. For example, the one in widest use is WebDAV[18] (Whitehead and Goland 1999), which approaches collaboration from the network protocol point of view. Although it is tailored to co-authoring in the Web, it can be used elsewhere, since general techniques for supporting group work (e.g. node locking, and namespace management) are implemented. Another research protocol is PSI (Platform for Shared Interaction (Palfreyman *et al.* 1999)), which provides a more complete platform and protocol for supporting collaborative work, but, at the same time, is more complex as it requires more servers and supporting services making it therefore more difficult to utilise.

5.3 Comparison of groupware

A comparison of different media is illustrated in Table 5.2. As seen, almost every application supports both audio and text chat communication. This is obvious, since audio is natural for human communication (i.e. when no technology is used) and text chat when some technology is utilised. People are also

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17 http://messenger.msn.com (referenced March 21 2002).

18 see also: http://www.webdav.org.

TABLE 5.2 Comparison by media.

	Media												
	text	audio	video	VR	white Board	email	ftp	application sharing	instant messaging	calendar	web-walkthroughs	co-authoring	other
Net-meeting	√	√	√		√		√	√					
Click-to-meet	√	√	√		√	√[19]	√	√	√	√[19]	√		
Lotus Sametime	√[20]	√	√		√			√	√	√	√		
MASSIVE	√	√	(√)	√									
DIVE	√	√		√							√		
NPSNet		√	√	√									physically-based modelling (e.g. smoke)
NetEffect	√	√		√									
COWS	√				√[21]								workflow creation, predefined lists & tables
DIVA	√[22]	√	√		√								
Groove	√	√			√	√	√	√	√	√	√	√	threaded discussions, power-point guided tours
ICQ	√[20]					√	√		√		√		file sharing
Messenger	√	√				√	√	√	√				emoticons, connectivity with other MS products

familiar with them. Other media are supported more occasionally; the only clear pattern is the combination of whiteboard and video – if one is supported then the other one is usually supported too. Co-authoring and virtual reality interfaces are the rarest. This might be due to the fact that they are still mainly researched as an independent medium, and as such not ready for commerciali-

19 Tight integration with such tools. They are not integrated as the default, but this is assumed.

20 Through instant messaging, i.e. text chat is integrated with instant messaging.

21 Workflow creation tool, similar to whiteboard.

22 Notes can be drafted to others thus they support very rudimentary text-based communication.

sation or to be combined with the others. Other seldom-supported media, in this context, are calendar and email services, but those are usually adequately supported and utilised by dedicated applications.

Applications can be compared by examining their support for different media Simply by counting the number of media from Table 5.2, it can be seen that commercial applications, such as Click-to-meet and Groove (10 supported media), Lotus SameTime (8) and Microsoft family (Netmeeting (6) and Messenger (6) can be combined) support most of them. However, the number of supported media does not reveal the usefulness (or uselessness) of an application at all. More remarkable is the awareness aspect – if a user is not aware of others and their activities in the virtual space, i.e. in the work environment, it has diminishing implications on the work process (as is discussed in Articles I-III).

TABLE 5.3 Comparison by types of application, awareness and integration.

	Type of application		**Type of awareness**[23]			**Type of integration**	
	commercial application	research prototype	user	workspace	across media	presentation level	Data level
Netmeeting	√		√	√[24]		√	√
Click-to-meet[25]	√		√			?	?
Lotus Sametime	√		√	√[26]		√	
MASSIVE		√	√	√[27]	√[28]	√	
DIVE		√	√	√[27]		√	
NPSNet		√		√			√
NetEffect		√	√	√		√[29]	√
COWS		√	√				√
DIVA		√	√	√	√		√
Groove	√		√			√	
ICQ	√		√				√
Messenger	√		√			√	

23 Video as a medium is ignored in the workspace awareness review, because it supports it as the default. Thus only when the workspace awareness is supported in some other way than by video, is it considered in the table.

24 Inside whiteboard only.

25 Technical details were not available for analysis thus the type of integration is unknown.

26 Text only.

27 Within VR interface only.

28 Across physical and virtual space.

29 Audio only.

Table 5.3 summarises the types of awareness and integration of media, and shows the status of commercialty. Every application supports user awareness (except NPSNet, but as it is a military simulation application such information is obsolete and could occasionally be even deleterious). User awareness can be easily supported by, and observed from, a list of users online. More difficult, but equally important, is the workspace awareness. This is rarely supported in this sample[30] as only CVEs and some multiple media applications address it. With CVEs this is obvious, since all activities are assumed or forced to be taken inside the 3D environment. Netmeeting and Lotus Sametime support workspace awareness within some medium only. It can be argued that workspace awareness is considered properly only in DIVA. Awareness across media is seldom addressed.

As there are benefits in both approaches of integrating the media, they are utilised equally often. Presentation level integration provides new approaches to collaborations involving arbitrary combinations of different media, while data level integration allows subjective and changing views of the same data or media. The difference can be illustrated by an example of information, which is composed from multiple media. If it is observed or produced from varying combinations of media, presentation level integration is preferred. But when the combination remains basically the same, and the way the information is presented may change from time to time or from person to person, data level integration is preferred as it provides adequate and congruent views. So this approach is more reliable, because, for instance, synchronisation problems between the media can be avoided. However, solely from the technical point of view, presentation level integration is preferred, since it allows better scalability to a number of client terminals, platforms or media, and much greater flexibility (Articles IV and V).

Networking and connectivity aspects are summarised in Table 5.4. Network topologically both client-server and peer-to-peer architectures are used. With the client-server approach, the server end forms a bottleneck (Pekkola and Robinson 1997a; Greenhalgh 2001). When the number of clients increases, either the server itself or its nearby network connection becomes overloaded, which, in turn, dramatically decreases the performance of the system as a whole. The issue can be partly solved by increasing both computational power and network bandwidth. Those can be added up to a certain point, after which the technique of replicating the servers can be applied. However, there are few exceptions when such a solution is not recommended as its utilisation either does not solve the problem, or, on the other, it just creates some new ones (Greenhalgh 2001). These circumstances include, for example, situations when bandwidth-consuming media (video, audio) are used, or when a lot of compu-

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30 There exist some dedicated applications where workspace awareness is considered (e.g. Gutwin and Greenberg 1998). However, usually the issue is not approached from the multiple media context.

tational power is needed (e.g. for calculating regions (Benford *et al.* 1997a)). On the other hand, with a peer-to-peer approach such bottlenecks can be avoided, since there is no centre point, a server, through which all packets should be passed through. But, in this case the number of transmitted packets increases rapidly when the clients start to communicate directly. To minimise this effect, multicasting can be used, but this is rarely done as seen from Table 5.4. The most beneficial approach would be to combine both approaches into a hybrid network topology. This is implemented in NetEffect, MASSIVE, and Groove so that the servers are used for user and/or region management, and peer-to-peer connections for audio and/or other bandwidth consuming media. Netmeeting employs peer-to-peer connections for two party sessions only.

TABLE 5.4 Comparison by scalability.

	Networking			**Connectivity**
	peer-to-peer	client-server	multi-cast	connectivity to other applications
Netmeeting	√[31]	√		through ActiveX
Click-to-Meet		√		to workflow environment
Lotus Sametime		√		Lotus Notes database, programming & configuration interface, and through ActiveX
MASSIVE	√	√	√	programming interface
DIVE	√		√	programming interfaces
NPSNet	√		√	
NetEffect	√[32]	√		
COWS		√		
DIVA		√		
Groove	√	√		programming interface & registration of applications
ICQ		√	√	registration of applications
Messenger		√	√	programming & configuration interfaces

Connectivity to other applications is supported well in commercial applications, but generally poorly in research prototypes. MASSIVE and DIVE are the few exceptions. As they can be also used as toolkits to test out new ideas or technical solutions, an interface to implement desired features has been developed.

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31 For two participant sessions only.

32 For direct peer-to-peer communication only.

5.4 Summary of the comparison

Earlier, twelve groupware applications were analysed. They were chosen by their relevance (number of supported media and interesting network aspects) and popularity. Consequently, the number of media was relatively high in all cases, although it is especially true with commercially available groupware. Instead, the support for awareness is generally neglected in every application. Usually only the user awareness is considered, which, however, alone is not sufficient or adequate, although it provides the first cues of presence and respectively helps group work a little.

When considering how the applications support upward scalability, the network topology becomes the most significant factor (Greenhalgh 2001). As said, there are problems with both client-server and peer-to-peer architectures, hence the most beneficial solution would be to combine them into a hybrid topology. However, as its benefits are usually achieved only with very large masses of data (or users), and as a real-time group work session usually involves only a few (tens of) collaborating users, it can be claimed that all analysed applications support upward scalability, at least at the network level.

Downward scalability means an ability to tailor the system down to technologically limited devices such as vt100 terminals, PDAs and mobile phones so that users can work together regardless of the devices. In these cases, the type of integration of media is significant. If the data level integration approach is adapted, either, or both, bandwidth and computational power are wasted, since all media-related data are transmitted to all participants no matter whether they can receive or observe it properly. This strongly proposes the presentation level integration of media. Downward scalability is, under the circumstances, addressed theoretically quite often in the sample.

Sideways scalability, as said, cannot be measured by a single variable but by a combination of many: number of media, awareness issues, type of integration and connectivity to other applications are the most remarkable factors. Multiple media and connectivity to other applications allow users to incorporate the media they find the most appropriate for certain work practices and situations. Awareness information addresses the work performance, and the type of integration considers technological scalability and the systems' ability to adapt to different tasks. In the sample, although commercial applications support both the greatest number of media and allow best connectivity to other applications, they are weak in supporting situation awareness. On the other hand, research prototypes are exactly the opposite; they support awareness reasonable well, but only a few media and no connectivity to other applications. From the sideways scalability point of view, none of the systems can be considered successful. Instead, all systems are tailored to support some specific task or process – as was proposed by Briggs et al. in the military context (Briggs *et al.* 1999). However, a much greater degree of freedom is appreciated and appropriate both for group work in the office type of environment – for which the

analysed applications are designed (with an exception), or for supporting interpersonal behaviour regardless of the context, as argued in this thesis.

When VIVA is compared to other applications, it can be claimed to be very competitive because:

- The number of media VIVA supports (8) is nearly at the same level as commercial applications, and greater than any other research prototype.
- Awareness information is sufficiently provided. User awareness is supported at the general level, and individually for each medium, and workspace awareness by simple colour codes and other indexes within each medium. Awareness across media is also addressed (see Article VII for detailed user interface description). It can be argued that situation awareness is best supported by VIVA, but only if an awareness specific prototype, DIVA, is excluded. Generally, awareness is best-supported in VIVA in the sample.
- Scalability is generally well addressed, except when examining the connectivity to other applications. Sideways scalability is not optimal, although the adaptation of hybrid network topology and presentation level integration of media support scalability in both directions. However, it can still be claimed that sideways scalability is better supported in VIVA than in any of the other applications analysed.

In this chapter, different groupware applications to support synchronous and distributed group work were analysed. It was shown that VIVA is better in supporting awareness and different directions of scalability, and consequently providing technical chances for improving the group work process. This fact, when reflecting on the systems development research criteria by Nunamaker *et al.* (1991a), proposes that VIVA, as such, makes contributions to the domain and provides a better solution in contrast to other systems for a certain problem.

References

Adams, M. J., Tenney, Y. J., and Pew, R. W. 1995. Situation Awareness and the Cognitive Management of Complex Systems. Human Factors 37 (1), 85-104.

Auramäki, E., Robinson, M., Aaltonen, A., Kovalainen, M., Liinamaa A., and Tuuna-Väiskä, T. 1996. Paperwork at 78 k.p.h. In: Proceedings of Computer Supported Cooperative Work '96 (CSCW'96), New York: ACM Press, 370 - 379.

Baecker, R. M. 1993. Readings in Groupware and Computer-Supported Cooperative Work: Assisting Human-Human Collaboration. San Francisco, CA, USA: Morgan Kaufmann.

Bandram, J. E. 1996. Organisational Prototyping: Adopting CSCW Applications in Organisations. Scandinavian Journal of Information Systems 8 (1), 69-88.

Bannon, L. and Schmidt, K. 1989. CSCW: Four Characters in Search of a Context. In J.M. Bowers and S. D. Benford (Eds.), Studies in Computer Supported Co-operative Work: Theory, Practice, and Design. Proceedings of the First European Conference on Computer-Supported Co-Operative Work (ECSCW'89), Elsevier Science Publishers, 3-16.

Benford, S., Bowers, J., Fahlen, L., Greenhalgh, C., Mariani, J., and Rodden, T. 1995. Networked Virtual Reality and Cooperative Work. Presence 4(4), 364-386.

Benford, S., Brown, C., Reynard, G., and Snowdon, D. 1996. The Internet Foyer. In: Proceedings of the Third Conference of the UK VRSIG, DeMontford University, UK, The UK VRSIG. (no page numbers).

Benford, S., Greenhalgh, C., Craven, M., Walker, G., Regan, T., Morphett, J., Wyver, J. and Bowers J. 1999. Broadcasting on-line social interaction as inhabited television. In: S. Bodker, M. Kyng, K. Schmidt (Eds.) Proceedings of the Sixth European Conference on Computer Supported Cooperateive Work (ECSCW'99), Kluwer Academic Publishers, 179-198.

Benford, S., Greenhalgh C., and Lloyd D. 1997a. Crowded Collaborative Virtual Environments. In: Proceedings of ACM CHI 97 Conference on Human Factors in Computing Systems 1997, New York: ACM Press, 59-66.

Benford, S., Greenhalgh, C., Snowdon, D., and Bullock, A. 1997b. Staging a public poetry performance in a collaborative virtual environment. In: J. A. Hughes, W. Prinz, T. Rodden, and K. Schmidt (Eds.) Proceedings of the Fifth European Conference on Computer Supported Co-operative Work (ECSCW'97), Kluwer Academic Publishers, 125-140.

Bentley, R., Appelt, W., Busbach, U., Hinrich, E., Kerr, D., Sikkel, K., Trevor, J., and Woetzel, G. 1997. Basic Support for Cooperative Work on the World Wide Web. International Journal of Human Computer Studies: Special Issue on Novel Applications of the WWW, 46(6), 827-846.

Blokdijk, A. and Blokdijk, P. 1987. Planning and Design of Information Systems, Academic Press.

Bowers, J., Button, G., and Sharrock, W. 1995. Workflow from within and without: Technology and cooperative work on the print industry shopfloor. In: H. Marmolin, Y. Sunblad, and K. Schmidt (Eds.) Proceedings of the Fourth European Conference on Computer Supported Co-operative Work (ECSCW'95). Kluwer Academic Publishers, 51-66.

Briggs, R. O., Adkins, M., Mittleman, D., Kruse, J., Miller, S., and Nunamaker, J. F. 1999. A Technology Transition Model Derived from Field Investigation of GSS Use Aboard the U.S.S. CORONADO. Journal of Management Information Systems 15 (3), 151-195.

Bødker, S., Grønbæk, K., and Kyng, M. 1993. Cooperative Design: Techniques and Experiences from Scandinavian Scene. In D. Schuler and A. Namioka (Eds.) Participatory Design: Principles and Practices. Hillsdale, New Jersey: Lawrence Erlbaum Associates, 157-176.

Carlsson, C. and Hagsand, O. 1993. DIVE — A platform for multi-user virtual environments. Computer & Graphics 17(6), 663-669.

Churchill, E. and Snowdon, D. 1998. Collaborative Virtual Environments: An Introductory Review of Issues and Systems. Virtual Reality: Research, Development and Applications 3 (1), 3-15.

Crabtree, A. 1998. Ethnography in Participatory Design. In: R. Chatfield, S. Kuhn, and M, Muller (Eds.) Proceedings of Participatory Design Conference (PDC'98), Computer Professionals for Social Responsibility in association with ACM Press, 93-105.

Das, T. K., Singh, G., Mitchell, A., Kumar, P. S. and McGee, K. 1997. NetEffect: A Network Architecture for Large-scale Multi-user Virtual Worlds. In Proceedings of the ACM Symposium on Virtual Reality Software and Technology (VRST'97). ACM Press, 157-163.

de Michelis, G., Dubois, E., Jarke, M., Matthes, F., Mylopoulos, J., Schmidt, J. W., Woo, C. and Yu E. 1998. A Three-faceted View of Information Systems. Communications of the ACM 41 (12), 64-70.

Ehn, P. 1993. Scandinavian Design: On participation and skill. In D. Schuler and A. Namioka (Eds.) Participatory Design: Principles and Practices. Hillsdale, New Jersey, Lawrence Erlbaum Associates, 41-78.

Ehrlich, K. and Cash, D. 1999. The Invisible World of Intermediaries: A Cautionary Tale. Computer Supported Cooperative Work: The Journal of Collaborative Computing, 8, 147-167.

Ellis, C. A., Gibbs, S. J. and Rein, G. L. 1991. Groupware: Some issues and experiences. Communications of ACM 34(1), 38-58.

Filippi, G. and Theureau, J. 1993. Analysing Cooperative Work in an Urban Traffic Control Room for the Design of a Coordination Support System. In: G. de Michelis, C. Simone, and K. Schmidt (Eds.) Proceedings of the Third European Conference on Computer Supported Cooperative Work (ECSCW'93). Kluwer Academic Publishers, 171-186.

Fitzpatrick, G., Mansfield, T., Kaplan, S., Arnold, D., Phelps, T., and Segall, B. 1999. Augmenting the workday world with Elvin. In: S. Bodker, M. Kyng, K. Schmidt (Eds.) Proceedings of the Sixth European Conference on Computer Supported Cooperative Work (ECSCW'99), Kluwer Academic Publishers, 431-450.

Frécon, E. and Stenius, M. 1998. DIVE: A scaleable network architecture for distributed virtual environments. Distributed Systems Engineering Journal (DSEJ): Special Issue on Distributed Virtual Environments 5, 91-100.

Fuchs, L. 1999. AREA: A cross-application notification service for groupware. In: S. Bodker, M. Kyng, K. Schmidt (Eds.) Proceedings of the Sixth European Conference on Computer Supported Cooperative Work (ECSCW'99), Kluwer Academic Publishers, 81-98.

Gallivan, M. J. 1997. Value in Triangulation: A Comparison of Two Approaches for Combining Qualititative and Quantitative Methods. In: A. S. Lee, J. Liebenau and J. I. DeGross (Eds.) Information Systems and Qualitative Research. Chapman & Hall, UK, 417-443.

Gerson, E. M. and Star, S. L. 1986. Analyzing Due Process in the Workplace. Transactions on Office Information Systems 4(3), 257-270.

Gilson, R. D. 1995. Introduction to the Special Issues of Situation Awareness. Human Factors 37(1), 3-4.

Greenhalgh, C. 1997. Analysing movements and world transitions in virtual reality teleconferencing. In: J. A. Hughes, W. Prinz, T. Rodden, and K. Schmidt (Eds.) Proceedings of the Fifth European Conference on Computer Supported Co-operative Work (ECSCW'97), Kluwer Academic Publishers, 313-328.

Greenhalgh, C. 1999. Large Scale Collaborative Virtual Environments. London: Springer-Verlag.

Greenhalgh, C. 2001. Understanding the network requirements of collaborative virtual environments. In: E. Churchill, D. Snowdon and A. Munro (Eds.) Collaborative virtual environments: digital places and spaces for interaction. London Berlin Heidelberg, Springer-Verlag, 56-74.

Greenhalgh, C. and Benford. S. 1995. MASSIVE: A Virtual Reality System for Tele-conferencing. Transactions on Computer Human Interaction 2(1), 239-261.

Greenhalgh, C., Purbrick, J. and Snowdon, D. 2000. Inside MASSIVE-3: Flexible Support for Data Consistency and World Structuring. In: Proceedings of the ACM Conference on Collaborative Virtual Environments 2000 (CVE'00), ACM Press, 119-127.

Grudin, J. 1989. Why CSCW Applications Fail: Problems in design and evaluation. Office: Technology and People 4(3), 245-264.

Grudin, J. 1994a. CSCW: History and focus. IEEE Computer 27(5), 19-26.

Grudin, J. 1994b. Groupware and Social Dynamics: Eight Challenges for Developers. Communications of the ACM 37(1), 92-105.

Gutwin, C. and Greenberg, S. 1997. Workspace Awareness. In: ACM CHI'97 Workshop on Awareness in Collaborative Systems, Position paper. Available at: http://www.cpsc.ucalgary.ca/grouplab/papers/1997/97-StudyingAwareness.CHIWorkshop/gutwin.html (referenced May 16 2002).

Gutwin, C. and Greenberg, S. 1998. Design for Individuals, Design for Groups: Tradeoffs Between Power and Workspace Awareness. In: Proceedings of the Conference on Computer Supported Cooperative Work (CSCW'98). ACM Press, 207-216.

Hagsand, O. 1996. Interactive Multiuser VEs in the DIVE System. IEEE Multimedia 3(1), 30-39.

Han, J. and Smith, B., 1996. CU-SeeMe VR: Immersive Desktop Teleconferencing. In: Proceedings of the Fourth ACM Conference on Multimedia, ACM Press, 199-207.

Harper, R. 1996. Why People Do and Don't Wear Active Badge: A Case Study. Computer Supported Cooperative Work: The Journal of Collaborative Computing, 4, 297-318.

Harper, R. 1998. Inside the IMF: An Ethnography of Documents, Technology, and Organisational Action. San Diego: Academic Press.

Harper, R., Hughes, J. A. and Shapiro, D. Z. 1989. Working in harmony: An examination of computer technology in air traffic control. In J.M. Bowers and S. D. Benford (Eds.), Studies in Computer Supported Co-operative Work: Theory, Practice, and Design. Proceedings of the First European Conference on Computer-Supported Co-Operative Work (ECSCW'89), Elsevier Science Publishers, 73-86.

Harrison, S. and Dourish, P. 1996. Re-Place-ing Space: The Roles of Place and Space in Collaborative Systems. In: Proceedings of the Conference on Computer Supported Cooperative Work (CSCW'96). New York: ACM Press, 67-76.

Heath, C., Jirotka, M., Luff, P., and Hindmarsh, J., 1993. Unpacking Collaboration: The Interactional Organisation of Trading in a City Dealing Room. In: G. de Michelis, C. Simone, and K. Schmidt (Eds.) Proceedings of the Third European Conference on Computer Supported Cooperative Work (ECSCW'93). Kluwer Academic Publishers, 163-178.

Heath, C. and Luff, P. 1991. Collaborative Activity and Technological Design: Task Coordination in London Underground Control Rooms. In: L. Bannon, M. Robinson, and K. Schmidt (Eds.) Proceedings of the Second European Conference on Computer-Supported Cooperative Work (ECSCW'91), Kluwer Academic Publishers, 65-80.

Heath, C. and Luff, P. 1996. Convergent activities: Line control and passenger information on the London Underground. In: Y. Engeström and D. Middleton (Eds.) Communication and Cognition at Work. New York, Cambridge University Press, 96-129.

Heiskanen, K., Jäkälä, M., and Pekkola, S. 2001. Communicating through Virtual Reality: Visualisation of Human Communication in Collaborative Virtual Environments. In: L. B. Rasmussen, C. Beardon and S. Munari (Eds.) Computers and Networks in the Age of Globalization. Kluwer Academic Publishers, 231-244.

Hindmarsh, J., Fraser, M., Heath, C., Benford, S., and Greenhalgh, C. 1998. Fragmented Interaction: Establishing mutual orientation in virtual environments. In: Proceedings of Conference on Computer Supported Cooperative Work (CSCW'98). ACM Press, 217-226.

Hollan, J. and Stornetta, S. 1992. Beyond being there. In: P. Baversfeld, J. Bennett, and G.Lynch (Eds.) Proceedings of the Conference on Human Factors and Computing Systems (CHI '92): Striking a Balance. ACM Press, 119-125.

Hughes, J., O'Brien, J., Randall, D., Rodden, T., Rouncefield, M., and Tolmie, P. 1999. Getting to Know the 'Customer in the Machine'. In: Proceedings of the Conference on Supporting Group Work (GROUP'99), ACM Press, 30-39.

Hughes, J., Randall, D., and Shapiro, D. 1991. CSCW: Discipline or Paradigm? A sociological perspective. In: L. Bannon, M. Robinson, and K. Schmidt (Eds.) Proceedings of the Second European Conference on Computer-Supported Cooperative Work (ECSCW'91), Kluwer Academic Publishers, 309-323.

Huxor, A. 1999. An Active Worlds Interface to Basic Support for Cooperative Working (BSCW) to Enhance Chance Encounters. Virtual Reality: Research, Development and Applications 4(1):, 4-14.

Huxor, A. 2001. The role of the personal in social workspaces: reflections on working in AlphaWorld. In: E. Churchill, D. Snowdon and A. Munro (Eds.) Collaborative virtual environments: digital places and spaces for interaction. Springer-Verlag, 282-296.

Iivari, J., Hirscheim, R. and Klein, H. K. 2001. A Dynamic Framework for Classifying Information Systems Development Methodologies and Approaches. Journal of Management Information Systems 17(3), 179-218.

Johansen, R. 1988. Groupware: Computer Support for business teams, New York: Macmillan.

Järvinen, P. 2001. On Research Methods. Tampere, Finland: Opinpajan kirja.

Keil-Slawik, R. 1992. Artefacts in Software Design. In: C. Floyd, H. Zuellighoven, R. Budde, and R. Keil-Slawic (Eds.) Software Development and Reality Construction. Berlin, Springer.

Kensing, F. and Blomberg, J. 1998. Participatory design: Issues and concerns. Computer Supported Cooperative Work: The Journal of Collaborative Computing,7: 167-185.

Koleva, B., Schnädelback, H., Benford, S., and Greenhalgh, C. 2000. Traversable Interfaces Between Real and Virtual Worlds. In: Proceedings of the Conference on Computer-human Interaction (CHI'2000). ACM Press, 233 - 240.

Koskinen, M. 2000. Process Metamodelling: Conceptual foundations and application. University of Jyväskylä. Jyväskylä Studies in Computing 7. PhD Thesis.

Kovalainen, M., Robinson, M. and Auramäki, E. 1998. Diaries at Work. In: Proceedings of the Conference on Computer Supported Cooperative Work (CSCW'98). ACM Press, 49-58.

Kyng, M. 1991. Designing for Cooperation: Cooperation in design. Communication of the ACM 24(12), 65-73.

Kyng, M. 1994. Scandinavian Design: Users in Product Development. In: Proceedings of the Conference on Computer-Human Interaction (CHI'94), ACM Press, 3-9.

Lyytinen, K. 1986. Information Systems Development as Social Action: Framework and Critical Implications. University of Jyväskylä, Jyväskylä Studies in Computer Science, Economics and Statistics 8. PhD Thesis.

Lyytinen, K. and Ngwenyama, O. K. 1992. What does computer support for cooperative work mean? A structural analysis of computer supported cooperative work. Accounting, Management and Information Technology 2(1), 19-37.

Macedonia, M. R., Zyda, M. J., Pratt, D. R., Barham, P. T., and Zeswitz, S. 1994. NPSNET: A Network Software Architecture for Large Scale Virtual Environments. Presence 3(4).

Mandviwalla, M. and Khan, S. 1999. Collaborative Object Workspace (COWS): exploring the integration of collaboration technology. Decision Support Systems 27, 241-254.

McConnell, S. 1996. Rapid Development, Microsoft Press.

Nakanishi, H., Yoshida, C., Nishimura, T., and Ishida. T. 1998. FreeWalk: A Three-Dimensional Meeting-Place for Communities. In Ishida (ed) Community Computing: Collaboration over Global Information Networks. New York, John Wiley & Sons, 55-89.

Nardi, B. A., Whittaker, S. and Bradner, E. 2000. Interaction and Outeraction: Instant Messaging in Action. In: Proceeding of the Conference on Computer supported cooperative work (CSCW'2000). ACM Press, 79-88.

Nunamaker, J. F., Chen, H. and Pardin, T. D. M. 1991a. Systems Development in Information Systems Research. Journal of Management Information Systems 7(3), 89-106.

Nunamaker, J. F., Dennis, A. R., Valacich, J. S., Vogel, D. R. and George, J. F. 1991b. Electronic meetings to Support Group Work. Communications of ACM 34(7), 40-61.

Nurminen, M. I. and Forsman, U. 1994. Reversed Quality Life Cycle Model. In: G. E. Bradley and H. W. Hendrick (Eds.) Human Factors in Organizational Design and Management IV. Amsterdam: Elsevier Science, 393-398.

Ohta, Y. and Tamura, H. (Eds.) 1999. Mixed Reality: Merging Real and Virtual Worlds, Ohmsha & Springer-Verlag.

Orlikowski, W. J. 1992. Learning from Notes: Organizational Issues in Groupware Implementation. In: Proceedings of Conference on Computer-Supported Cooperative Work (CSCW'92). ACM Press, 362-369.

Paivio, A. 1986. Mental Representations - A Dual Coding Approach, Oxford University Press.

Palfreyman, K., Rodden, T. and Trevor, J. 1999. PSI: A Platform for Shared Interaction. In: S. Bodker, M. Kyng, K. Schmidt (Eds.) Proceedings of the Sixth European Conference on

Computer Supported Cooperative Work (ECSCW'99). Kluwer Academic Publishers, 351-370.

Pekkola, S., Heikkilä, J., and Tuunainen, V.K. 2002. Launching multimodal interaction on an EC-site. In: Hawaii International Conference on Systen Sciences HICSS-35. IEEE Computer Society, CD-ROM.

Pekkola, S. and Robinson, M. 1997a. Collaborative Virtual Environments, Real-Time Video and Networking. In: Proceedings of the International Conference on Virtual Systems and Multimedia (VSMM'97). IEEE Computer Society, 26-37.

Pekkola, S. and Robinson, M. 1997b. The Jyväskylä Studio: A Mixed Reality Telematic Worksite for CSCW. In: Broadband Communications for Research and Education - Collaboration between Russia and the European Union (BBCC'97). Available at: http://www.cc.jyu.fi/~samuli/research/bbcc97.ps.gz

Pekkola, S., Robinson, M., Saarinen, M.-J. O., Korhonen, J., Hujala, S., and Toivonen, T. 2000. Collaborative Virtual Environment in the Year of the Dragon. In: Proceedings of the ACM Conference on Collaborative Virtual Environments (CVE'00), ACM Press, 11-18.

Prinz, W. 1999. NESSIE: An awareness environment for cooperative settings. In: S. Bodker, M. Kyng, K. Schmidt (Eds.) Proceedings of the Sixth European Conference on Computer Supported Cooperative Work (ECSCW'99). Kluwer Academic Publishers, 391-410.

Pycock, J., Palfreyman, K., Allanson, J., and Button, G. 1998a. Envisaging Collaboration: Using Virtual Environments to Articulate Requirements. In: D. Snowdon and E. Churchill (Eds.) Proceedings of the Conference on Collaborative Virtual Environments (CVE'98). University of Manchester, Manchester, UK, 73-79.

Pycock, J., Palfreyman, K., Allanson, J., and Button, G. 1998b. Representing Fieldwork and Articulating Requirements through VR. In: Proceedings of the Conference on Computer Supported Cooperative Work (CSCW'98). ACM Press, 383-392.

Reder, S. and Schwab, R. G. 1990. The temporal structure of cooperative activity. In: Proceedings of the Conference on Computer-Supported Cooperative Work (CSCW'90). ACM Press, 303-316.

Robinson, M. 1991. Double-Level Languages and Co-operative Work. AI & Society 5, 34-60.

Robinson, M. 1992. Computer Supported Cooperative Work: Cases and Concepts. In: R. Baecker (Ed.) Readings in Groupware and Computer Supported Cooperative Work: Assisting Human-Human Collaboration. San Mateo, CA: Morgan Kaufmann.

Robinson, M. 1993. Design for unanticipated use .... In: G. de Michelis, C. Simone, and K. Schmidt (Eds.) Proceedings of the Third European Conference on Computer Supported Cooperative Work (ECSCW'93). Kluwer Academic Publishers, 187-202.

Robinson, M., Kovalainen, M., and Auramäki, E. 2000. Diary as dialogue in papermill process control. Communications of the ACM 43(1), 65-70.

Robinson, M., Pekkola, S., and Snowdon, D. 1998. Cat's Cradle: Working with other people in overlapping real and virtual worlds through tangled strands of visual and other media. In: Proceedings of the Fourth International Workshop on Groupware (CRIWG'98), Buzion, Rio de Janeiro, Brazil, pp. 3-21. Available at: http://criwg.di.fc.ul.pt/criwg98/artigo01.pdf

Schmidt, K. and Bannon, L. 1992. Taking CSCW Seriously: Supporting Articulation Work. Computer Supported Cooperative Work: The Journal of Collaborative Computing, 1(1), 7-40.

Smith, G. and O'Brian, J. 1998. Re-coupling Tailored User Interfaces. In: Proceedings of the Conference on Computer Supported Cooperative Work (CSCW'98). ACM Press, 237-246.

Sohlenkamp, M. and Chwelos, G. 1994. Integrating Communication, Cooperation, and Awareness: the DIVA virtual office environment. In: Proceedings of the Conference on Computer Supported Cooperative Work (CSCW'94). ACM Press, 331 – 343.

Stake, R. 2000. Case Studies. In: N. K. Denzin and Y. S. Lincoln (Eds.) Handbook of Qualititative Research. Sage Publications, Inc., 435-454.

Star, S. L. and Griesemer, J. R. 1989. Institutional Ecology, 'Translations' and Boundary Objects: Amateurs and Professionals in Berkeley's Museum of Vertebrate Zoology, 1907-39. Social Studies of Science 19, 387-420.

Star, S. L. and Ruhleder, K. 1996. Step Towards an Ecology of Infrastructure: Problems in the implementation of Large-Scale Information Systems. Information Systems Research 7(1): 111-134.

Suchman, L. 1987. Plans and situated actions. The problem of human-machine communication. Cambridge, Cambridge University Press.

Suchman, L. 2000. Making a case: 'knowledge' and 'routine' work in document production. In: P. Luff, J. Hindmarsh and C. Heath (Eds.) Work-place Studies: Recovering work practice and informing system design. Cambridge University Press, 29-45.

Tang, J. and Isaacs, E. 1993. Why Do Users Like Video? Studies of Multimedia-Supported Collaboration. Computer Supported Cooperative Work: The Journal of Collaborative Computing, 1(3), 163-196.

Thereau, J. and Filippi, G. 2000. Analysing cooperative work in an urban traffic control room for the design of a coordination support system. In: P. Luff, J. Hindmarsh and C. Heath (Eds.) Work-place Studies: Recovering work practice and informing system design. Cambridge University Press, 68-91.

Whitehead, E. J. and Goland, Y. Y. 1999. WebDAV: A network protocol for remote collaborative authoring on the Web. In: S. Bodker, M. Kyng, K. Schmidt (Eds.) Proceedings of the Sixth European Conference on Computer Supported Cooperateive Work (ECSCW'99), Kluwer Academic Publishers, 291-310.

Yin, R. K. (1994). Case Study Research: Design and Methods. Sage Publications.

You, Y. and Pekkola, S. 2000. Supporting Awareness of Other People on the WWW: framework and example. In: J. Thong, P. Chau and K.Y. Tam (Eds.) Proceedings of the Fourth Pacific Asia Conference on Information Systems (PACIS 2000). Hong Kong University of Science and Technology, 44-58. CD-ROM.

You, Y. and Pekkola, S. 2001. Meeting Others - Supporting Situation Awareness on the WWW. Decision Support Systems 32(1), 71-82.

Zyda, M. J., Pratt, D. R., Falby, J. S., Lombardo, C., and Kelleher, K.M. 1993. The Software Required for the Computer Generation of Virtual Environments. Presence 2(2), 130-140.

PART FIVE: PUTTING IT ALL BACK TOGETHER

13 CONCLUSIONS AND CONTRIBUTIONS

This is the final part of the dissertation, so it aims to bind all the threads together. First, a summary of the conclusions of the main arguments of the thesis will be presented by mirroring them in the four research questions introduced in subsection 3.1. Second, some contributions to the information systems and computer science disciplines will be described. Finally, shortcomings and directions for future research will be presented.

13.1 Summary of conclusions

The main objective of this research was to study why, how and in what way multiple communication and collaboration media can be integrated into an aggregate. The issue was further divided into four separate research questions, and approached from the viewpoint of three central themes: (work) process, awareness, and scalability and boundaries. As each individual article approached the questions from their own perspective, a summary is presented to elucidate the main arguments related to the whole of the thesis.

13.1.1 Question 1: Are multiple media applications more flexible and do they improve group work?

It was assumed that combining multiple media into an aggregate makes groupware more useful and flexible in different and varying situations so that when multiple media are incorporated, or are at least available, the (work) situation is improved in comparison to cases when just one medium is utilised. This hypothesis was examined thoroughly and throughout the thesis, although it was explicitly analysed in Articles I, II, III, and VII.

Articles II and III approached group work from two different viewpoints; e-shopping and homes. The situations were dissimilar in terms of tasks, objectives, people, equipment and devices involved, processes, environments, and contexts. Article I conceptualised the issue, and understood group work to

cover any kind of activity where two or more participants try to reach some sort of consensus. These include shopping and family meetings, for instance. However, it was common in all situations that to be able to accomplish the task, no matter what it is, complex co-ordination between participants is required. But, it was shown in Article I that with computers, or technologies in general, such activities and co-ordinations are seldom supported, as essential connections between different types of communication and co-operation information are either poorly presented or completely missing. The major problem with current applications is the fact that they seldom support the characteristics of group work, identified in Article I. The media (devices, applications) are usually isolated (as illustrated in an extreme example in Article III) thus activities taken within a medium are invisible in another. However, every medium has its own affordances, context and situations in which it is at its best (as argued, e.g. Hollan and Stornetta 1992, and Article I), and which cannot be fully compensated by another. Hence, a corollary is to combine them all into an aggregate so that the users may utilise the medium they find the most appropriate at the time, and also that the media are tightly integrated.

Part II constituted of the aforementioned three articles, which have shown that the combination of multiple media would make groupware more flexible and useful, and consequently, would improve the work process – in theory. As an application was implemented alongside the study, it is possible to evaluate the theoretical claims by empirical research, and further, to prove them. This was reported in Article VII.

Although the VIVA system was often used as an awareness widget or an advanced instant messaging system, it was also studied how the system was used in numerous work-related situations. Log-file analysis and interviews revealed that different combinations of media were utilised, and more importantly, considered useful and illuminating in the work situations. VIVA can also be regarded as being flexible as it was utilised for different tasks and circumstances. Hence, to answer the appropriate research question, it can be said that when multiple media are available, or utilised, the aforementioned theoretical claims are confirmed as users perceived and regarded VIVA as useful and acknowledged that it (may) improve their work practices. To generalise the results, it can be stated that real-time groupware applications are improved, from the individual users' point of view, when multiple communication and collaboration media are integrated into an aggregate.

13.1.2 Question 2: What are the benefits and what are the failings of each medium?

Hollan and Stornetta (1992) argued that every medium has its own affordances. In Article I, their argument was acknowledged and continued by profound analytical discussions to identify those affordances. Table 6.2 of Article I summarised several communication media and their features. Here the Table is adapted and complemented by findings from Articles VI and VII, so that the

research question about the benefits and failings of different communication and collaboration medium can be answered.

Clearly, there are three media that are mostly used for communication and to complement other, more co-operation oriented, media. Audio is the only medium for spoken communication so it is often incorporated to assist the co-ordination of collaborative activities. Text chat, on the other hand, allows communication to and through technically limited terminals and networks; and importantly, supports human interactions when writing is preferred for one reason or another (Robinson and Hinrichs 1997). Also short messaging, which consists of small pieces of information (see Article VII for the difference between text chat and short messages), is considered to be textual communication. Both of them are poor in supporting the characteristics of nonverbal communication, but as their value is elsewhere, i.e. in the ability to overcome technical limitations, and in supporting written messages, their significance cannot be belittled. Generally speaking, the value of audio is at its height when using it for work-related tasks involving active participation and co-ordination, when as text-based communications (both text chat and short messages) are regarded and are better suited to socially intended activities. This behaviour parallels a study of phone conversation versus short messages (Grinter and Eldridge 2001).

Video is at its best when collaborating participants' real identities must be known, or when information from the physical world (about the objects or users there (Munro 1996) or about the (work) situation (Nardi *et al.* 1993)) is needed in collaboration or co-ordination. Olson et al. (1995) studied that the video image of users makes the video meeting more comfortable so that the work situation is improved almost to the same degree as face-to-face – although the amount of co-ordination and management were much higher. It is important to notice that the users in the study were unknown to each other and the video contributed in making the situation more natural and trustworthy – judgements by the appearance were possible. A study by Valacich et al. (2002) reveals the importance of video; people make riskier decisions in computer-mediated communication in comparison to face-to-face situations. Hence, to conclude, the value of video is in its ability to reproduce a natural, real world image, which helps people to understand the real world situation and people there.

Images and emoticons of users are integrated into some applications to provide an illustration either of the appearance, or of the emotion the user is willing to reveal. However, as some specific actions to change the emotion need to be made, images are seldom utilised as an independent medium. But as images are produced more easily and more importantly context dependently in text chat and email, they are used there instead (Becker and Mark 1998; Becker and Mark 1999). Consequently, images as an independent medium are seldom useful.

In principle, MUDs are very similar to text chat, but MUDs enhance them by supporting (primitive) proxemity, so the users could be aware of others and their locations in the virtual environment. Everything, including the environment, is described in text. CVEs, on the other hand, provide visually rich

graphical representations of the environment and people and objects there. They are good for visualising the landscape, people, and spatial relationships between people and objects. However, in generic work situations (i.e. when the situation, simulation, or case is not tailored to VR), there is seldom any need for such representations – as argued in Article VI. The communicational value of CVEs is very limited, although graphical representations may stimulate the discussion and decrease its quality among the previously unknown parties (Ahern 1993; Smith *et al.* 2000). Co-operative value is not great either, as there are several problems with the user interface and understanding the actions there (Fraser *et al.* 2000; Hindmarsh *et al.* 2000).

CVEs are at their best in virtual reality tailored tasks, but there are also other co-operation-oriented media, where each one is best suited to the accommodated tasks. For example, whiteboard is excellent when the tasks requires drawings to be shared, and memo (or more generally co-authoring tool) when text-sharing abilities are needed. File transfer can be accomplished in four different ways; placing files on a public server, sending them as email attachments, utilising whiteboard or memo, or using peer-to-peer mechanism so that both the sender and the receiver are immediately aware of the success of the transfer (e.g. with awareness widgets). From the viewpoint of real-time group work, the last approach is usually the most suitable as extra acknowledgements are not needed (as described in Article VII).

It is very tempting to rank the media, but that cannot be done as the choice of the medium depends on several factors: situation, task, context, technologies available, and people and their experiences and cultural backgrounds – to mention a few. I thereby concede and acknowledge the benefits and failings of different media.

13.1.3 Question 3: How can multiple media be best integrated?

The third research question is technically sounded, and is touched upon in almost every article. Earlier it has been proposed that multiple media need to be integrated into an aggregate. The easiest solution would be to put different tools together, but as the users only need to be aware of each other and their activities in the workspace, and as the system needs to be scalable in different directions, the situation becomes more complex.

In principle, there are two alternative approaches to combine the media, at the presentation level or at the data level (see Chapter 5 in the Introductory part, or Mandviwalla and Khan 1999). From the technical point of view, scalability in different directions proposes the use of the former approach, since different combinations of media can be selected for different terminals and networks, and for different tasks (Chapter 5). Presentation level integration is even more strongly proposed by the empirical study of Article VII, since, as seen, it allows for more flexible group work. However, the management and control of the media needs to be tightly implemented (in technical level), since its poor development creates new challenges – as illustrated in the airport example of

Article VII and the discussions of Article III of problems with isolated equipment.

Articles IV and V presented the VIVA system design, and Article VII its final user interface. The awareness of other users and their activities is administrated by a dedicated server (the Master server) and displayed to users as a list in the main dialogue. The support for situation awareness is accomplished at two different levels. First, user names, colour codes and letters in the main dialogue represent the user awareness and the status of different media. Second, each medium is in charge of the medium specific activities. The media are integrated at the presentation, i.e. the user interface, level, and they are isolated in the data level. In practice, there is no connection between the media, but everything is controlled and observed through the main dialogue. Hence, the boundaries between the media are solid and nothing can pass them – at the technical level – but vanish at the user level as colour codes and appropriate letters in the main dialogue are visible to users, whom can freely move from one medium to another.

It should be noted that this implementation of presentation level integration of multiple media into an aggregate is just an example – definitely not the only one, and not necessarily the best approach. However, it is argued that the presentation level integration of multiple media provides the best solution for scalable and flexible groupware.

13.1.4 Question 4: How should and could CVEs be extended as a fully co-operative system?

In Article VI, CVEs were strongly criticised for overstating and overemphasising the importance of three-dimensional user interface for group work. Bearing those comments, and discussions from Article I about the unique value of different media in mind, it can be concluded that CVEs may not become fully co-operative systems until the focus moves away from the VR centric way of thinking to multiple media and their integration – issues, which have been profoundly addressed earlier with discussions of other research questions.

13.2 Contributions

The main contributions of this dissertation can be divided into three groups: design suggestions expected by the chosen CSCW research approach, their realisation in the form of technical implementation, and implications because of the CSCW – ISD paradigm.

Design suggestions. Research reported in this dissertation follows and contributes to the CSCW discipline. First, it has been argued that multiple media, when integrated into an aggregate, makes work situations more flexible and support multifaceted nature of group work better than the availability of

just a few media. This is because any assumption that media will be incorporated along the work process cannot be made. This further leads to unanticipated, but successful, uses of groupware in situations for which it was not originally designed. This leads to second contribution, which roughly follows Robinson's notion of common artefacts (Robinson 1993). If a system is designed to be used in unanticipated situations, it must support the characteristics of group work. In this dissertation, one of the contributions is in listing and identifying those characteristics. Third, every medium has its own affordances, that is, benefits and failings. Each medium is at its best in a certain situation and for a certain purpose, and the work environment cannot be technically improved if the chosen medium is inappropriate and the circumstances remain still the same. The solution would be to replace the medium by another, which would suit the case better, or preferably to use some other medium to compensate and overcome the weaknesses of the first one. Technical improvement (made for the medium) does not necessary improve the situation at all, if underlying communicative or co-operative principles, models and assumptions are wrong, or inappropriately supported. Finally, the fourth suggestion is related to the CVEs. It has been argued that, although they are designed for a purpose (Churchill and Snowdon 1998), the number of those purposes is very limited. CVEs are good only for tasks, where the environment and its graphical representation have a special meaning or role. In generic group work sessions, those situations are unfortunately a few. To increase the value of the present CVE applications, they should be expanded in the direction of multiple media – similarly as it was proposed by the first design suggestion. By this, I believe CVEs will be brought closer to real people, real uses and use cases, in practice as an integral part of everyday work situations.

Technical implementation and solutions. The multifaceted characteristics of group work cause the design requirements to be often contradictory when considering generic groupware. For example, an application, which is designed to support office work, must be adaptable to different situations (hence it may easily become extremely complex), while an e-business application must be easy to use in all possible ways (including its installation) as it is used for a single task by several users with dissimilar skills. And, if a system is designed for numerous situations, it may result in it not fulfilling anyone's demands perfectly (Jessup and Van Over 1996; Robinson and Pekkola 1999). Optimising a system for a task or purpose simultaneously reduces its adaptability to and usability in different situations. These settings include, for example, functional vs. professional 'look and feel'; functional, reliable technology vs. powerful, state-of-the-art technology; obtrusive vs. unobtrusive technology; and configurable vs. fixed environment (Jessup and Van Over 1996). If a system is optimised to one feature, its counterpart is neglected, respectively. How does this influence generic groupware design?

Commonly, groupware are designed for a purpose (Briggs *et al.* 1999). However, when considering office work as a purpose, the system is actually designed to be used in extremely complex contexts, situations and environments, as has been argued in this dissertation. In fact, it can be further argued that

there is no explicit purpose for which the system is designed. A technical solution would be to combine multiple media into an aggregate. The challenge of contradictory design requirements can be solved by the presentation level integration of the media, so that the most potential technical conflicts disappear and are not contradictory anymore. At the same time, the system is highly configurable, functional and flexible, but still relatively easy to use – as the VIVA implementation illustrates.

CSCW – ISD paradigm. This dissertation lies between computer science and information systems disciplines. This has caused some difficulties in the research process, since no theoretical model could have been applied. There is neither 'a grand theory of CSCW' nor other theories, which are applicable as their philosophical foundations, methodological assumptions, or approaches are far too different to this one. Roughly, there are ISD methods that address how information systems should be designed, and there are other theories, which address how and what kind of situations different media are utilised. But there are no theories, which address how the two related but isolated approaches should consider each other, at the individual users' level at least.

The most relevant IS related theory to this thesis is heavily criticised media richness theory[41] (Daft and Lengel 1986; Daft *et al.* 1987), for criticism see for example Dennis and Kinney (1998) or Dennis and Valacich (1999). It correctly argues that certain media are better for transmitting different types of information. However, it also argues, with a very narrow view, that the choice of the media depends on the interpretation of the message, i.e. whether the information is used in situations of uncertainty (i.e. the interpretation of the message exists, but information to process it is missing) or equivocality (i.e. there are multiple potentially conflicting interpretations). Briefly, Daft and Lengel (1986) stated that media capable of sending 'rich' information are better suited to equivocal tasks, while those that are less 'rich' are best suited to the tasks of uncertainty. But as discussed in this dissertation, the situation is not that simple. To support (synchronous) group work in its full extent, multiple media need to be at least available, if not simultaneously applicable. The media richness theory, first, tackles mainly asynchronous communication and information processing, and second, greatly generalises and simplifies the group work process, so its applicability for the context and approach of this dissertation is minimal.

There also exist other theoretical models, which attempt to explain the features of the communication media, or the choice or use of the media. These include, for example, the social influence model (Fulk *et al.* 1990), the 'emergent network perspective' (Contractor and Eisenberg 1990), channel expansion theory (Carlson and Zmud 1999), critical social theory (Ngwenyama and Lee 1997), the genre theory of organisational communication (Orlikowski and Yates 1994), and the theory of media synchronicity (Dennis and Valacich 1999). The social influence model and the emergent network perspective, respectively, mention

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41 Originally known as information richness theory.

that the features of media affect its usage and that technology interplays with the social context. Neither of them declares additional concepts for structuring the features of communication media. The channel expansion theory concentrates on the familiarity of the users related to the medium and the task. Critical social theory focuses on analysing the validity of communication and the ways of interpreting and emancipating oneself from distorted communication. Genre theory provides the means to characterise the organisational communication by the communication media. Theory of media synchronicity extends the media richness theory, and proposes, with which I agree, that there are no 'richer' media but the choice depends on the given situation. However, it is common to all these theories that they originate from organisational communication and information processing and distribution. They focus on neither the co-operative side of group work nor individual users' behaviour, hence they are far too limited to be able to elucidate and explain the complexity of group work (session). Consequently none could have been adopted as a theoretical model for the research.

Similarly theories of human communication (c.f. Littlejohn 1996) adapt the communicative approach (obviously) and concentrate solely on the communicative, not co-operative, part of group work. Theories of psychology (e.g. dual-coding theory (Paivio 1986)) analyse only the individual users' perspective and their interpretation of the situation. Often none of the disciplines considers computers in their approaches. CSCW studies do take them into account them, but as said, there is no single theory, which could have been used as a guideline for the research. Thus, one of the contributions of this dissertation is, first to highlight a need for such a theoretical model, and second, to propose that the theoretical model can be developed and evaluated by using the findings of this dissertation as a starting point and basis for work.

13.2.1 VIVA and the realisation of design principles

It was stated back in subsection 2.2 that the VIVA design was based on several principles. They were flexibility, (the support for) common artefact, and 'beyond being there'. Flexibility was discussed in depth in parallel with the original research Question 1 (see subsection 13.1.1). It can be concluded that VIVA is flexible in the way described earlier. The support for common artefacts and double level language is more difficult to evaluate, as the principle is vaguely defined. However, as users were allowed to bring in any information they found appropriate for the context, and information about what is happening in the environment was illustrated at different levels of details, it can be said that the characteristics of common artefacts were supported.

But does VIVA have quality? Did people prefer using it rather than being physically present? The evaluation (Article VII) showed that users mostly use it as an awareness tool and then employ other methods for communication. In that sense, the quality is poor. However, when asking whether they found VIVA to be of any use, and also, when asking for some suggestions for improvements, people considered VIVA to be useful and were eagerly proposing

new features. In other words, people regarded VIVA to have at least some quality. Is the quality principle wrong then? Following Prinz et al. (1998) findings that groupware cannot be evaluated (prospectively) on a theoretical basis and that neither the users or developers can predict all of the users' needs, makes the quality principle wrong. The system might have quality regardless of implying its usage for predefined tasks and situations. Hence, to conclude, it can be said that although VIVA has not met the predefined quality principle, it has some other kind of quality. Most importantly, following the research approach, individual users found it beneficial.

13.3 The Next Step, i.e. limitations and some directions for future research

The work reported in this dissertation is still quite in the early stages, although some results have been gained. But, in fact, there is still quite a lot to do, hence some of the potential future research directions are presented.

First, the incorporation of multiple media has only recently become possible as the technology has been realised, thus observations and wide-scale experiments will respectively form dominant strategies in research in the future. These research methods will reveal the value of each media and prove it empirically (here the issue was approached from a more theoretical angle), and the patterns of situations, if there are any, in which certain media are utilised. This would further lead to the development of a theory model. This work has already been started (e.g. by Tyrväinen and Päivärinta (2002)) but again from an organisational perspective. A more interesting approach, and also more beneficial to the end-users, would be to investigate the issue from their, i.e. individual users', standpoint, as the approach will show whether the system is beneficial for themselves, and not only for the organisation, as the motivation to use the system increases (Grudin 1989).

The research approach of the dissertation has relied on the individual users. However, when new technologies are introduced to individuals, they are also introduced to an organisational context. Orlikowski (1992) studied the acceptance of asynchronous groupware when such tools were new. Now the adaptation of VIVA, and real-time groupware in general, has become possible hence the study by Orlikowski can be repeated. However, as the benefits of real-time groupware are more difficult to recognise as the users must be online at the same time, the acceptability would also be different. But in what way and how much they differ is ambiguous at the moment, but become significant when new systems are developed and adapted into organisations.

The value of CVEs was analysed in Article VI. However, the evaluation of virtual reality interface versus other media available was not accomplished, as the VR interface was not finalised. Instead, it was argued, from the gained experiences and literature review, that the value of VR is often overemphasised.

Empirical analyses of what kind of situations it would be chosen and utilised are missing. In the future, although it may result in a waste of resources, a VR interface needs to be implemented, integrated and evaluated with the other media so that its real value is uncovered.

The focus of this dissertation was solely on synchronous and distributed group work. This was a conscious choice, partly because the focus of the VIVA development was on real-time and distributed group work. Although the VIVA system also supports asynchronous communication and co-operation, the feature was not evaluated in depth. Using such an evaluation, the combination and synchronisation of synchronous and asynchronous media can be studied. As such, it would reveal how these fundamentally different approaches are utilised and how they should be further developed. For example, this includes user interface design, recording, indexing and searching data from real-time conversations, and connectivity to present document management systems.

Finally, technologically this study has concentrated solely on the PC's. Mirroring the central themes into chosen technologies, they have their influence only on scalability. Process and awareness have been discussed context and technology independently, although PC's have a certain role there. From the scalability point of view, upward scalability (large crowds) is slightly irrelevant since co-operating groups are often small in size. Horizontal scalability was already addressed in the form of flexibility, although it was also discussed in the context of PC's. Downward scalability, i.e. to different terminals and networks, provides new challenges and possibilities for group work as technologies set limitations for awareness information and support for processes. In fact, a new follow-up project has already been started to explore the issue.

References

Ahern, T. C. 1993. The Effect of a Graphical Interface on Participation, Interaction and Student Achievement in a Computer-Mediated Small-group Discussion. Journal of Educational Computing Research 9 (4), 535-548.

Becker, B. and Mark, G. 1998. Social Conventions in Collaborative Virtual Environments. In: D. Snowdon and E. Churchill (Eds.) Proceedings of the Conference on Collaborative Virtual Environments (CVE'98). University of Manchester, Manchester, UK, 47-55.

Becker, B. and Mark, G. 1999. Constructing Social Systems through Computer-Mediated Communication. Virtual Reality: Research, Development and Applications 4 (1), 60-73.

Briggs, R. O., Adkins, M., Mittleman, D., Kruse, J., Miller, S., and Nunamaker, J. F. 1999. A Technol-ogy Transition Model Derived from Field Investigation of GSS Use Aboard the U.S.S. CORONADO. Journal of Management Information Systems 15 (3), 151-195.

Carlson, J. R., and Zmud, R. W. 1999. Channel Expansion Theory and the Experiential Nature of Media Richness Perceptions. Academy of Management Journal 42 (2), 153-170.

Churchill, E., and Snowdon, D. 1998. Collaborative Virtual Environments: An Introductory Review of Issues and Systems. Virtual Reality: Research, Development and Applications 3 (1), 3-15.

Contractor, N. S., and Eisenberg, E. M. 1990. Communication Networks and Collective Behaviours. In: J. Fulk and C. Steinfield (Eds.) Organizations and Communication Technology. Newbudy Park: Sage, 143-172.

Daft, R. L. and Lengel, R. H. 1986. Organizational Information Requirements, Media Richness and Structural Design. Management Science 32 (5), 554-571.

Daft, R. L., Lengel, R. H., and Trevino, L. K. 1987. Message Equivocality, Media Selection, and Manager Performance: Implications for Information Systems. MIS Quarterly 11 (3), 355-366.

Dennis, A. R., and Kinney, S. T. 1998. Testing Media Richness Theory in the New Media: The Effect of Cues, Feedback, and Task Equivocality. Information Systems Research 9 (3), 256-274.

Dennis, A. R., and Valacich, J. S. 1999. Rethinking Media Richness: Towards a Theory of Media Synchronicity. In: Hawaii International Conference on Systen Sciences HICSS-32. IEEE Computer Society, CD-ROM.

Fraser, M., Glover, T., Vaghi, I., Benford, S., Greenhalgh, C., Hindmarsh, J., and Heath, C. 2000. Revealing the Realities of Collaborative Virtual Reality. In: Proceedings of the ACM Conference on Collaborative Virtual Environments 2000 (CVE'00). ACM Press, 29-38.

Fulk, J., Schmitz, J., and Steinfield, C. W. 1990. A Social Influence Model of Technology Use. In: J. Fulk and C. Steinfield (Eds.) Organizations and Communication Technology. Newbudy Park: Sage, 117-140.

Grinter, R. E. and Eldridge, M. 2001. y do tngrs luv 2 txt msg? In: W. Prinz, M. Jarke, Y. Rogers, K. Schmidt, and V. Wulf (Eds.) Proceedings of the Seventh European Conference on Computer Supported Cooperative Work (ECSCW'01). Kluwer Academic Publishers, 219-238.

Grudin, J. 1989. Why CSCW Applications Fail: Problems in design and evaluation. Office: Technology and People 4 (3), 245-264.

Hindmarsh, J., Fraser, M., Heath, C., Benford, S., and Greenhalgh, C. 2000. Object-Focused Interaction in Collaborative Virtual Environments. ACM Transactions on Computer-Human Interaction (ToCHI): Special Issue on Collaborative Virtual Environments 7 (4), 477-509.

Hollan, J. and Stornetta, S. 1992. Beyond being there. In: P. Baversfeld, J. Bennett, and G.Lynch (Eds.) Proceedings of the Conference on Human Factors and Computing Systems (CHI '92): Striking a Balance. ACM Press, 119-125.

Jessup, L. M., and Van Over, D. 1996. When a System Must Be All Things to All People: The Functions, Components & Costs of a Multi-purpose Group Support System Facility. Journal of Systems Management 47 (4), 14-23.

Littlejohn, S. W. 1996. Theories of Human Communication. Belmont, CA: Wadsworth Publishing Company.

Mandviwalla, M., and Khan, S. 1999. Collaborative Object Workspace (COWS): exploring the integration of collaboration technology. Decision Support Systems 27, 241-254.

Munro, A. 1996. Multimedia Support for Distributed Research Initiatives: Final Report. Centre for Requirements and Foundations, Oxford University Computing Laboratory, England.

Nardi, B., Schwartz, H., Kuchinsky, A., Leichner, R., Whittaker, S., and Sclabassi, R. 1993. Turning Away from Talking Heads: The Use of Video-as-Data in Neurosurgery. In: Proceedings of the conference on Human factors in computing systems (CHI'93). ACM Press, 327-334.

Ngwenyama, O. K., and Lee, A. S. 1997. Communication Richness in Electronic Mail: Critical Social Theory and the Contextuality of Meaning. MIS Quarterly 21 (2), 145-167.

Olson, J. S., Olson, G. M., and Meader, D. K. 1995. What Mix of Video and Audio is Useful for Small Groups Doing Remote Real-time Design Work. In: Conference proceedings on Human factors in computing systems (CHI '95). New York: ACM Press, 362 – 368.

Orlikowski, W., and Yates, J. 1994. Genre Repertoire: The Structuring of Communicative Practices in Organisations. Administrative Science Quarterly 39 (4), 541-574.

Orlikowski, W. J. 1992. Learning from Notes: Organizational Issues in Groupware Implementation. In: Proceedings of Conference on Computer-Supported Cooperative Work (CSCW'92). ACM Press, 362-369.

Paivio, A. 1986. Mental Representations - A Dual Coding Approach, Oxford University Press.

Prinz, W., Mark, G., and Pankoke-Babatz, U. 1998. Designing Groupware for Congruency in Use. In: Proceedings of the Conference on Computer Supported Cooperative Work (CSCW'98). ACM Press, 373-382.

Robinson, M. 1993. Design for unanticipated use .... In: G. de Michelis, C. Simone, and K. Schmidt (Eds.) Proceedings of the Third European Conference on Computer Supported Cooperative Work (ECSCW'93). Kluwer Academic Publishers, 187-202.

Robinson, M. and Hinrichs, E. 1997. Study on the supporting telecommunications services and applications for networks of local employment initiatives (TeleLEI Project): Final Report. Sankt Augustin, Germany, GMD, Institute for Applied Information Technology (FIT), D 53754.

Robinson, M. and Pekkola, S. 1999. The Studio: Reflections and Issues Arising. In: N. Streitz, J. Siegel, V. Hartkopf, S. Konomi (Eds.) Proceedings of the Second International Workshop on Cooperative Buildings - Integrating Information, Organizations and Architecture (CoBuild'99). LNCS 1670. Springer, 101-113.

Smith, M. A., Farnham, S. D., and Drucker, S. M. 2000. The social life of small graphical chat spaces. In: Proceedings of the CHI 2000 conference on Human factors in computing systems. ACM Press, 462 – 469.

Tyrväinen, P., and Päivärinta, T. 2002. Organizational Communication: Digital or Analogue? Genre-and-Media-Based Metrics and Analysis Method. Submitted for publication.

Valacich, J., Sarker, S., Pratt, J., and Groomer, M. 2002. Computer-Mediated and Face-to-Face Groups: Who Makes Riskier Decisions? In: Hawaii International Conference on Systen Sciences HICSS-35. IEEE Computer Society, CD-ROM.

YHTEENVETO (FINNISH SUMMARY)

Tietokoneavusteinen ryhmätyö (computer-supported co-operative work; CSCW) on monitieteinen tieteenala, joka tutkii ryhmätyöskentelyä ja erilaisia teknisiä järjestelmiä joilla sitä voidaan tukea. CSCW-tutkimuksissa perusajatuksena on selvittää tietyn työkontekstin ja –ympäristön tietojärjestelmälle asettamat vaatimukset ja hyödyntää näitä löydöksiä suunnittelussa. Tällöin järjestelmistä pitäisi tulla käyttäjäystävällisempiä, niiden pitäisi toimia paremmin suunnitellussa kontekstissaan sekä sopia suunniteltuun tarkoitukseensa. Tietojärjestelmistä tulee käyttäjä- ja organisaatioystävällisempiä – useinkin teoriassa, sillä todellisuudessa käyttäjät eivät aina työskentele ennalta suunnitellulla tavalla edes ennalta tutkituissa tilanteissa saati tutkimattomissa tapauksissa.

CSCW-tutkimukset ovat perinteisesti painottuneet organisaatioiden toimintojen tukemiseen. Dokumenttienhallintajärjestelmät ja työn koordinointia tukevat järjestelmät on rakennettu organisaatioiden ehdoilla juurikaan keskittymättä yksittäisten käyttäjien näkökulmaan. Samoin järjestelmät on suunniteltu tukemaan ennen kaikkea tiedon keruuta ja varastointia tai ei-reaaliaikaista työskentelyä, ei niinkään hajautettua ja yhtä aikaa tapahtuvia toimintoja. Viime vuosina, teknisten rajoitteiden poistuessa, videoneuvottelujärjestelmät ja lyhytviesteihin perustuvat henkilökohtaisempaa kommunikointia tukevat järjestelmät ovat myös tulleet mahdollisiksi. Niitä ei kuitenkaan ole juurikaan hyödynnetty organisaatioiden toimintojen tukemisessa, vaan ennemminkin käyttäjien vapaa-aikaan ja sosiaaliseen vuorovaikutukseen liittyvissä epämuodollisissa tilanteissa.

Tässä väitöskirjatyössä tutkitaan miten organisaatioiden hajautettua ja reaaliaikaista ryhmätyöskentelyä voidaan tukea tietojärjestelmien avulla. Yksittäisten työntekijöiden henkilökohtaiset mieltymykset sekä heidän työprosessiensa monimuotoisuus hyväksytään reaalimaailman ilmiöksi ja omaksutaan tutkimuksen lähtökohdaksi. Työ painottuu erityisesti hajautetun toimistoissa tapahtuvan työskentelyn tukemiseen, joten tiettyä työkontekstia ei voida vaihtuvien työtapojen takia kiinnittää. Tutkimuksessa oletetaan ryhmätyöskentelyä parhaiten tuettavan sellaisella ohjelmistolla, joka paketoi useamman erilaisen työkalun, tai median, yhdeksi kokonaisuudeksi. Väitöskirjassa em. hypoteesia tarkastellaan sekä teoreettisesti että konstruktiivisesti pilottijärjestelmän implementoinnin ja käytännön testauksen kautta. Työ on tutkimusmetodologiselta kannalta konstruktiivinen tapaustutkimus.

Teoreettinen tarkastelu pohjautuu CSCW-tutkimusalueen huomioihin ja suunnittelusuosituksiin. Teoreettisen tarkastelun tuloksia on hyödynnetty tutkimuksen osana toteutetun järjestelmän suunnittelussa ja jatkokehityksessä. Ohjelmistoa pilotoitiin kahdessa erillisessä organisaatiossa, jossa käyttäjät käyttivät sitä osana jokapäiväistä työtään. Haastattelut ja loki-tiedostojen analyysit paljastivat käyttäjien olleen tyytyväisiä ohjelmistoon. Tulokset osoittavat hypoteesin olevan oikea ja usean median yhdistävän ohjelmiston tarjoavan joustavam-

man ja miellyttävämmän työskentely-ympäristön yksittäisten käyttäjien kannalta katsottuna.

Väitöskirjatyö kontribuoi CSCW tutkimukseen tarjoamalla useita suunnittelusuosituksia reaaliaikaisten ja hajautettujen ryhmätyöohjelmistojen toteutukseen. Samoin tutkimuksessa selvitetään eri medioiden hyödyntämistilanteita sekä ryhmätyöohjelmistojen implementoinnin erilaisia vaihtoehtoja. Lopuksi osoitetaan tietojärjestelmien perinteisten suunnittelumenetelmien ja CSCW tutkimuksen välinen kuilu sekä tarve käyttäjäkeskeisille suunnittelu-menetelmille ryhmätyöohjelmistojen toteutukseen. Tällöin on mahdollista rakentaa käyttäjä- ja organisaatioystävällisempiä tietojärjestelmiä myös käytännössä.

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