



COMPUTER MEDIATED COLLABORATIVE DESIGN IN  
ARCHITECTURE: THE EFFECTS OF COMMUNICATION  
CHANNELS ON COLLABORATIVE DESIGN COMMUNIATION

By

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To Adibeh and Cesar Gabriel.

# Summary

Up till now, architects collaborating with other colleagues did so mostly face-to-face (FTF). They had to be in the same space (co-located) at the same time. Communication was 'spontaneous' and ideas were represented, whether verbal or non-verbal, by talking and using 'traditional drawing tools'. If they were geographically displaced, the interaction was then space affected as well as the probability of being time affected. In this case communication was usually mediated through the telephone, and graphically represented ideas were sent by Fax or posted documents. Recently, some architectural firms started using modems and Internet connections to exchange information, by transferring CAD drawings as well as design information, through e-mail and file transfer protocol (FTP).

Discussing ideas in architecture, as a more abstract notion, is different from discussing other more concrete arguments using video conferencing. It is more important to 'see' what is being discussed at hand than 'watch' the other person(s) involved in the discussion. In other words the data being conveyed might be of more importance than the mode of communication.

Taking into consideration recent developments in computer and communication technologies this thesis investigates different communication channels utilised in architectural collaboration through Computer Mediated Collaborative Design (CMCD) sessions as opposed to FTF sessions. This thesis investigates the possible effects these different channels have on collaborative design in general and collaborative design communication in particular.

We argue that successful CMCD does not necessarily mean emulating close proximity environments. Excluding certain communication channels in a CMCD environment might affect the flow and quantity of synchronous collaborative communication, but not necessarily the quality and content of mutually communicated and represented design ideas. Therefore different communication channels might affect the type of communication and not necessarily the content of the communication. We

propose that audio and video are not essential communication channels in CMCD environments. We posit that architects will collaborate and communicate design representations effectively although with some differences, since those two channels might cause interruptions and successful collaborative sessions can take place without them.

For this purpose we conducted twenty-four one-hour experiments involving final year architecture students all working to the same design brief. The experiments were divided into three categories, FTF, full computer mediated collaborative design sessions (CMCD-a; audio-video conferencing plus whiteboard as a shared drawing space) and limited computer mediated collaborative design sessions (CMCD-b; with Lambda MOO used as a chat medium plus whiteboard as a shared drawing space). The experiments were video and audio taped, transcribed and coded into a custom developed coding scheme.

The results of the analysed coded data and observations of the videotapes provided evidence that there were noticeable differences between the three categories. There was more design communication and less communication control in the CMCD-b category compared to the FTF and CMCD-a categories. Verbal communication became shorter and straight to the point in CMCD-b as opposed to spontaneous non-stop chat in the other two categories. Moreover in CMCD-b the subjects were observed to be more reflective as well as choosing and re-examining their words to explain ideas to their partners. At times they were seen scrolling back through the text of the conversation in order to re-analyse or interpret the design ideas at hand. This was impossible in FTF and CMCD-a sessions, since the subjects were more spontaneous and audio representations were lost as soon as they were uttered. Also the video channel in the CMCD-a category was ignored and hardly used except for the first few minutes of the experiments, for a brief exchange of light humour on the appearance of each subject.

The results obtained from analysing the experiments helped us conclude that different communication channels produce different collaborative environments. The three categories of communication for architectural collaboration explored in our experiments are indicative of the alternatives available to architects now. What is not clear to architects is why they would choose one category over another. We propose that each category has its own strengths and difficulties for architectural collaboration, and therefore should be selected on the basis of the type of communication considered to be most effective for the stage and tasks of the design project.

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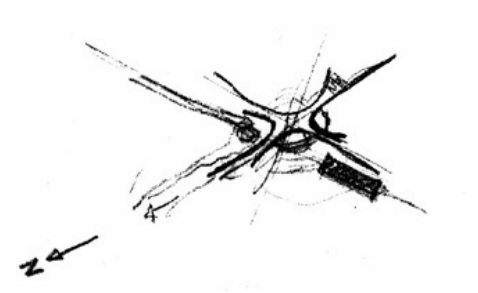
# Glossary

Here are some common abbreviations and terms used in this dissertation:

CAD	Computer-Aided Design
CMC	Computer-Mediated Communication
CMCD	Computer-Mediated Collaborative Design
CMCD-a	Computer-Mediated Collaborative Design with full communication channels
CMCD-b	Computer-Mediated Collaborative Design with full limited communication channels
CSCW	Computer Supported Co-operative Work
DC	Desktop Conferencing
DCP	Design Communication Protocol
FTF	Face-to-face
FTP	File Transfer Protocol
HLD	High Level Design
LLD	Low Level Design
O2	Silicon Graphics O2™ Unix Workstation
SGI	Silicon Graphics Indy™ Unix Workstation
StDev	Standard Deviation
TU	Text Unit
WWW	World Wide Web
VC	Virtual Campus
VDS	Virtual Design Studios
VMC	Video-Mediated Communication

# Chapter *1*

## Introduction



Chapter one begins with a narration on architecture and communication as well as on design representation as a reflection of design ideas. This chapter briefly summarises collaborative design environments used by architects, from face-to-face to computer mediated collaborative design environments to Virtual Design Studios. It discusses the evolution of this thesis, the motivation and the objectives for pursuing the research. It ends with a narration on the organisation of this thesis, the content of the remaining chapters and the appendices.

## 1.1 Architecture and Communication

“Architecture is primarily about communication” (Verzijl, 1997). In general, architects communicate their theories and ideas through their achievements in the built environment. This though, is also achieved through the printed media, in the form of published works by the numerous practising architects as well as architects/ theoreticians in academic circles. First, those theories and ideas need to be communicated to the client(s), their colleague(s) and at times to the public at large (Broadbent, 1988, p.221; Sasada, 1995). According to Van Bruggen (1998, p.27), architects utilise “whatever they thought would communicate their concept for the building”.

Collaborative design in architecture is a common occurrence with architects communicating their ideas to their peers in the form of verbal representations (voiced or typed) as well as graphical representations.

Having said this, there still is a lack of formal research on the effect of computer-mediated communication in the representation of design ideas and documentation. Previous research on the impact of communication channels on collaborative tasks, especially in computer mediated collaborative design (CMCD), has produced mixed findings. Researchers seem to be divided on the issue of what constitutes the ‘essential’ communication channels in order to have successful CMCD sessions.

In this thesis, we do not explore the *‘final design outcome’* of the collaborative design sessions nor the *‘design process’* between collaborating architects as such. Assessing the final design artefact can be a somewhat subjective process which makes it difficult to measure or gauge differences in an objective way and explanations of designs ideas are often open to various interpretations (see O’Connail and Whittaker, 1997, p.108). Rather, we explore how architects communicate when in a collaborative venture through FTF and CMCD sessions. Emphasis is placed on *‘verbal collaborative communication’* and the possible effects communication channels might have on *‘verbal design representation’*, both audio and textual. We explore the idea of whether the exclusion of certain *‘communication channels’* in a CMCD environment might affect the flow and quality of synchronous collaborative communication thus affecting the way mutual design ideas are represented. Therefore we investigate the various communication channels utilised in architectural collaboration and observe how architects communicate design ideas through FTF and CMCD sessions.

This exploration is carried out using experimental methodology as well as questionnaires. Several limitations of using this particular type of methodology are summed up as follows:

All sessions were conducted under laboratory conditions, since after careful consideration of the overall situation, it soon became clear to us that gathering the required number of participants to be involved in real life collaboration (mainly architectural offices) was next to impossible or would take a long time to organise. Added to that was the issue of the design problem, which in real life situations would have been different in each case. This would have rendered the coding schemes more complex and made the correlation and analysis of results more difficult and probably not as fruitful. This is further discussed in chapter four.

In coding and evaluating design protocols the subjectivity of the encoder can at times influence the final result, since individuals can code the same data in various ways. One way to avoid this happening, was to use more than one coder in order to quantify the differences in interpretations through arbitration (see Purcell et al., 1996). This is further discussed in chapter five.

## 1.2 Design representation as a reflection of design ideas

Design theorist Donald Schön (1983) claims there is an implicit relationship between the cognitive aspects of the design process and the design representation. In his pioneering work “The reflective practitioner: How professionals think in action” he depicts the design process as a “reflective conversation” between the designer and the design situation (Schön, 1983, pp. 76-104). Schön describes each design step as a situation in which the designer creates or modifies design representations, and the situation responds back to the designer. The designer interprets the current situation and as a result of this interpretation makes changes to the representation. Representation produces understanding through interpretation.

During this “reflective conversation” the design evolves through repeated cycles of representing and interpreting the design situation. Extrapolating these views, we can say that design representation is an active participant in the collaborative design process. If we extend the metaphor of “reflective conversation” to collaborative design, the conversation is now between the designers and a shared representation. A shared representation is the medium for handling and reflecting individual and shared

understandings. The ability to develop a shared understanding of the problem, depends on the development of mutual understanding between the designers and the ability to compromise in the decision making. The evidence of the shared representation lies in the drawings, notations, and conversation developed during the collaborative design process.

In traditional FTF collaboration, much of the shared understanding is developed through conversation but not recorded. In computer-mediated collaboration, where audio and video are used as communication channels, a similar phenomenon occurs: much of the shared understanding is developed but not recorded with the design representation. However, in computer-mediated collaboration where “talking” is confined to messages typed on the screen, the development of shared understanding is recorded and becomes part of the design representation either as a separate document, or more explicitly part of the representation as designers reflect on their conversation.

### 1.3 Collaborative Design Environments: Face-to-Face Versus Computer Mediated Collaborative Design

In order to compare FTF and CMCD collaborative sessions between architects, we first need to look at how architects collaborate in FTF environments, the media they employ and the communication channels they utilise in order to convey design representations to their partner(s).

Up till now, architects collaborating with colleagues did so mostly FTF. This meant they had to be in the same space (co-located) at the same time. Communication was ‘spontaneous’ and ideas were represented, whether verbal or non-verbal, by talking and using ‘traditional drawing tools’. On the other hand if they were geographically displaced, the interaction was then space affected as well as the probability of being time affected. In this case remote collaboration was conducted either asynchronously through the use of mail, couriers, e-mail, FTP etc ... or synchronously through the use of the telephone and sending verbal and graphical representations of ideas by Facsimile. Recently, some architectural firms have started using modems and Internet connections to exchange information, transferring CAD (Computer-Aided Design) files as well as design information, through e-mail and FTP.

When working FTF, individual architects have been observed to hold certain preferences on the way they set their design and creative environments and what ‘traditional’ tools they choose to use whether designing alone or collaborating with colleagues (Carter, 1993). Some architects might prefer to work with thick pencils scribbling 2D sketches on butter paper (Gross, 1994; Kvan, 1994). Others might sketch as well as start working with 3D volumetry, hastily proceeding to build 3D massing models, made of polystyrene or cardboard (Visser, 1993; Kvan, 1994). This enables them to acquire an enriched ‘experience’ of the space they are working with and makes it easier to communicate their ‘idea’ to other parties involved in the design.

However, the continuous development of computer and telecommunication technologies has seen architects increasingly using these mediums for communication as well as work. Hence architecture as a profession is employing computers not only in ways of documenting designs, but also in the form of representing and communicating design ideas between various parties, from colleagues and various consultants to clients and to the general public.

Therefore in this thesis we investigate three different collaborative design environments, one FTF and two through computer-mediated environments with full and limited communication channels. *Figure 1.1* illustrates the area of research with an emphasis on the synchronous mode since we investigate collaborative communication in the initial conceptual stages of collaborative design sessions between pairs of architects (this is further discussed in detail in section 4.3.1).

### *1.3.1 Virtual Design Studios, a prelude to Computer Mediated Collaborative Design?*

Recent developments in hardware, software as well as telecommunication networks have resulted in an increased number of collaborative design tools accompanying the phenomenal growth of the Internet. This in turn prompted several schools of architecture to setup design studios based on digital collaborative environments (or virtual design studios), which attempted to replicate FTF environments (among others, Chen et al., 1994; Dave, 1995; Tan and Teh, 1995; Wojtowicz, 1995; Maher et al., 1996; Kvan, 1997; Wojtowicz et al., 1998; Maher et al., 1999).

Virtual Design Studios (VDS) consist of a team of designers from various locations whose communication is computer-mediated (Maher et al., 1996). The VDS is dis-

tributed across space and time and data are represented electronically, using the World Wide Web (WWW) as a repository for all information shared amongst the team. Research done in VDS helps in fostering the notion of computer mediated collaborative design with the emerging generation of new architects. This, according to Kvan (1997), is very important since practitioners are no longer reliant on local presence to obtain a commission and some firms are becoming global, and “able to deliver their services in locations wherever they have an architectural value.”

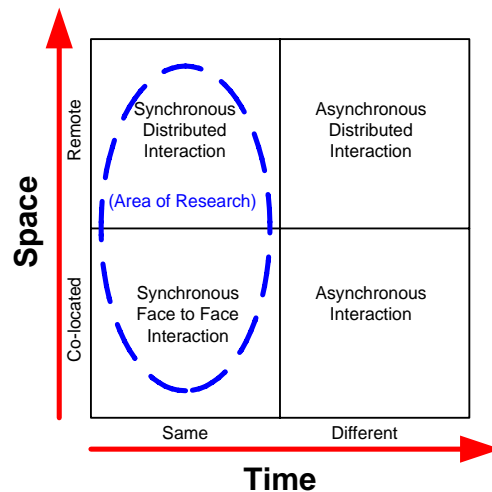


Figure 1.1. FTF and CMCD a relation between time and space (based on GroupWare time/space matrix from Rodden et al., 1992).

According to Dave and Danahy (1998, p.102) some of the motivations that underpin VDS include preparing students to operate in the contemporary technological context which will increasingly require professionals to compete and cooperate both locally and globally.

*“Virtual design studios provide settings in which the activities and needs of collaborating groups can be studied. They can lead to further research and development of computational means to support collaborative activities to benefit not only the pedagogical needs of educational institutions but also the pragmatic needs of professional practice.”*  
(Dave and Danahy, 1998, p.102)

## 1.4 Motivation

While much effort has been placed in search for the proper role in society for computer technology, some considerable attention has been given to the impact of com-

puter use on clerical workers (Otway et al., 1983; Turkle, 1984). On the other hand there is little practical experience with distributed multimedia and CAD systems when it comes to architectural design environments let alone architectural collaborative environments and the possible effects they might have on the way we conduct remote collaborative design work.

CAD systems are currently used as a tool to visualise and document the design idea. However, these systems have had little impact as a tool used in the conceptual design stages. They require much commitment, precision and effort, particularly in choosing from menus and sizing elements, leaving very little room for ‘ambiguity’<sup>1</sup> (Gross, 1994; Kvan, 1994). Requiring highly structured information, these systems make it hard for the architect to explore tentative or incomplete ideas let alone communicate them to others (Carter, 1993).

Computer-mediated communication (CMC) has become an important issue and the problem of developing communication and computer systems that can support collaborative design or problem solving has become an active research area (Peng, 1993; Saad and Maher, 1996; Kvan et al., 1997; O’Connell and Whittaker, 1997; Olsson et al., 1997).

Computer technology in design practices is moving towards distributed resources available to a designer or teams of designers at any one time. Here a matter of great interest to architects, practitioners and researchers alike, is how computer technology might be affecting the way they think and work in a collaborative environment. The concern is not about the notion of ‘support’ alone, but about ensuring that computers do not disrupt the design and collaborative activity that is already going on (Bannon and Schmidt, 1991). Designing new collaborative tools will then have to be guided by a better understanding of how collaborative work is accomplished and by understanding what resources and communication channels the collaborators use and what hindrances they encounter in their work (Tang, 1991).

Research into communication channels used in Computer Supported Cooperative Work (CSCW) and CMCD environments has shown that there is little agreement not only on whether audio and video channels are essential in such ventures but as to what constitutes the appropriate channels for collaboration purposes<sup>2</sup> (Tang and Isacs, 1993; Harrison and Minneman, 1995; Maziloglou et al., 1996; Anderson et al.,

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<sup>1</sup> According to Ballay (1987) vagueness and ambiguity in sketches seems to play an essential part in the creative process, allowing exploration and reinterpretation of tentative ideas.

1997; Olson et al., 1997; Vera et al., 1998). A popular view held by some researchers is that adding audio, video and graphics is somehow expected to make the medium more ‘real’ (see Sudweeks and Rafaeli, 1995).

Another aspect of CMC is the differences observed in the flow of conversations. According to Berdhal et al. (1995), CMC is more likely to provide fewer opportunities for interruption of “speakers” than does FTF communication. This however may vary depending on the particular CMC system in question. For example in asynchronous CMC, one cannot “interrupt” another since messages are sent after they have been written, whereas in synchronous CMC “interruptions” may happen when someone begins a message before another’s message is completed. Berdhal et al. (1995, p.181) further add that:

*“It is, however, possible to complete a message in typed text that can be read independently of the interrupter’s message in a way that is not possible to listen to two people talk at the same time. The difference in ability to interrupt may lead to more equal participation rates in CMC than in FTF communication since people have a better chance in completing a message and having it “heard” in the former rather than in the latter.”*

We believe that in the early stages of collaborative design, the video channel can become a hindrance rather than being of assistance. Discussing ideas in architecture, as a more abstract notion, is different from discussing other more concrete arguments using video conferencing. It is more important to ‘see’ what is being discussed rather than ‘watch’ the other person(s) involved in the discussion. In other words the data being conveyed might be of more importance than the method with which they are communicated (see Kvan, 1994). Similarly, we believe that by using text instead of audio as a medium for verbal communication, verbal representations can then be recorded alongside graphical representations for later retrieval and use, thereby assisting in capturing the “reflective conversation” between collaborating designers and the shared representation.

Therefore this thesis is motivated by our belief that successful CMCD does not necessarily mean emulating close proximity environments. We believe that architects will be able to collaborate and relate design representations effectively, although

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<sup>2</sup> This is further discussed in Chapter 2.

with some differences, in computer mediated environments with full and limited communication channels as opposed to FTF environments. We predict that audio and video are not essential communication channels in CMCD environments and that successful collaborative sessions can take place without them. This can be achieved by replacing the audio and video channels with a less bandwidth-hungry text-based channel while retaining the shared drawing space channel.

## 1.5 Objectives

Although research into CSCW has been very promising, with advances made in all fields, its application into collaborative design is not well developed. Some of the reasons lie in the choice of the appropriate communication channels for the appropriate collaborative needs. A major objective of this thesis is an attempt to gauge collaborative communication within the process of CMCD and how it differs from FTF collaboration between architects and whether this is affected by any limitation of the communication channels. An important question here is ‘what are the requirements of successful remote collaborative communication in a collaborative venture between architects?’ Such an understanding is essential if we are to develop computer and communication tools that can better foster remote collaboration in the future.

In order to better understand and characterise the local as well as the remote collaborative process between two architects in the three environments described earlier, the detailed objectives of this thesis are outlined as follows:

To understand more clearly the nature of collaborative communication taking place between collaborating architects by observing similarities and differences between FTF and CMCD sessions. Mainly this involves investigating how verbal design representations are communicated.

To investigate the requirements of successful remote collaborative communication in a collaborative venture between architects. This is achieved by elaborating on the following:

- By observing whether the limitation of communication channels in a CMCD venture might have any effect on the flow and quality of synchronous collaborative communication in general and verbal ‘design representations’ in particular.

- To characterise differences when designers use different communication channels in CMCD sessions, mainly the audio, video, text and shared drawing space channels.
- To identify adequate communication channels that will enable smoother collaboration through CMCD sessions.
- To better understand the nature of collaborative communication and its role in complementing and enhancing design representation.

To develop a coding scheme specifically suited to synchronous verbal design communication protocols in architecture, which in turn will assist us in gauging and characterising any differences between the three different collaborative mediums.

## 1.6 Organisation of the Thesis

The research in this thesis is organised as follows:

**Chapter one** introduces the relation between architecture and communication in general as well as the various collaborative environments used in this thesis. It further outlines the motivation, objectives and the scope of this thesis.

**Chapter two** gives a general overview on current issues and concepts related to CMCD. The chapter starts with a brief discussion on CSCW and then presents research carried out in the fields relating to communication channels and collaborative design.

**Chapter three** gives a general overview on current issues and concepts related to Protocol Analysis and other issues related to development and usage of Coding Schemes.

**Chapter four** presents the development of the research instruments for both the pilot and final experiments. Furthermore, the variables, brief, questionnaires, media and apparatus as well as the task and procedures are discussed in-depth.

**Chapter five** looks at the coding methodology. It details the development of the pilot and final coding schemes as well as methods used to transcribe, code and analyse the obtained protocols.

**Chapter six** presents all results obtained from the analysis produced by the previous chapter. Measures and characterisations are presented in the form of differences in communication and verbal design representations observed in the

three distinct collaborative environments, through FTF and CMCD. The results as well as reports obtained from the questionnaires are correlated with the results of the analysed data from the protocols.

**Chapter seven** concludes this thesis with a summary, contributions and describes future research directions.

**Appendix A** lists abstracts of published research papers related to this thesis.

**Appendix B** shows the ‘Subjects Consent Form’ which all-participating students were required to fill, date and sign.

**Appendix C** shows the ‘Subject Information Form’, which was handed over to all participating students to be read prior to commencing experiment.

**Appendix D** presents the post experiment final questionnaires as well as the results.

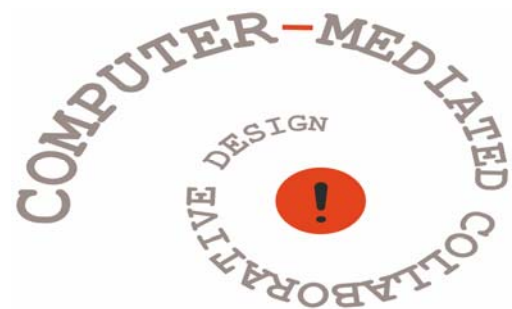
**Appendix E** lists the names of all students who participated in both pilot and final experiments.

**Appendix F** shows a copy of the full design brief in colour in its A4 format as presented to the participants.

**Appendix G** lists all statistical data tables extracted from QSR-NUD\*IST™ with their calculated arithmetic means, medians and standard deviations.

# Chapter 2

## Issues and Concepts in Research on Computer Mediated Collaborative Design



Chapter two reviews the literature in fields that have influenced work reported in this thesis. The chapter looks at issues related to computer mediated collaborative design and computer supported co-operative work. Communication channels in collaborative ventures and related research studies from the past few decades are discussed and examples given. The chapter

ends with a discussion of the presented literature identifying the diversity of results obtained from previous research and indicates where the proposed research fits.

## 2.1 Collaborative Design Work and the Various Spatiotemporal Modes

One of the initial inspirations behind the Internet was not so much the simple on-line access to materials, but rather the possibility of being able to share distributed views at a distance through collaborative work. The idea of collaboration between architects using telecommunication technology is not new and dates back to the fifties. Back then, Weiner (1950; as cited in Kvan and Kvan, 1997) gave us an idea of how architects might use the fax technology to collaborate and serve design communication in the future. On a similar note in 1952, Douglas Englebart (as cited by Veltman, 1997b) the visionary pioneer who invented the mouse, foresaw a) a version of e-mail which would be hyper-linked with b) shared files, c) a journal (library) and d) external (offline) documents.

Kalay (1999) notes that the need for collaboration arises when individuals reach the limit of their capabilities in completing a given task on their own, or when a collaborative arrangement can help them complete a task in a quicker and more efficient way.

Hobbs defines 'Collaboration' in the following way:

*“The agreement among specialists to share their abilities in a particular process, to achieve the larger objectives of the project as a whole, as defined by a client, a community, or society at large.” (Hobbs, 1996, as cited in Kalay, 1999, pIII.1).*

On the other hand design as a social activity (Dwarakanath and Blessing, 1996) is rarely started and completed by an individual these days, since the more common design environment is that of “teams of designers working together towards a final solution” (Saad, 1994).

According to Spurr et al. (1994) the ever-changing external environment has forced companies to look at new ways of delivering fast responses. In a sense this meant that we were embarking on a revolutionary new era in the workplace which was replacing traditional workplace cultures that were no longer appropriate. For large organisations, the idea of increasing the number of co-workers through increased remote collaboration while decreasing the travel costs is becoming very attractive (Johansen, 1984). Therefore it becomes unnecessary for a business to have a physi-

cal presence, pay expensive rent for office sites or even locate its staff physically within the same building (Aldred, 1994).

Today, as Weiner predicted in the fifties, architects no longer have to be present in the same place at the same time in order to develop, discuss and evaluate a particular design idea. Architects with specialist skills will be able to work for larger firms from their home-office, thus collaborating on more than one project with probably more than one firm in parallel.

Therefore a changing world, along with users expectations and requirements as well as rapid advances in technology heralded a new era in collaborative work in general and CSCW in particular. This in turn saw a rapid and prolific development of GroupWare<sup>3</sup> applications. According to O'Hara-Devereaux et al. (1994) those applications, which combine core functionalities such as 'communication, collaboration and coordination', can fit into a GroupWare matrix based on the various possible *spatiotemporal* configurations, as shown in *figure 2.1*. O'Hara-Devereaux et al. (1994, pp80-87) describe those various modes of collaboration as follows:

**Same-Time/Same-Place.** This synchronous collaborative mode is the most common and which most people are used to, face-to-face. In architecture this is still seen by many as the most effective mode of collaborative design, but not necessarily the easiest or the cheapest.

**Different-Time/Different-Place.** This asynchronous collaborative mode is on the opposite extreme of same-time/same-place. It mainly relies on asynchronous links between distributed team members, in which participants communicate through a 'store-and-forward' mode. Applications used in such modes include e-mail, FTP, WWW, voice mail and fax. Architects operating within the sphere of this collaborative mode are usually located remotely and most of the time separated by several time zones.

**Same-Time/Different-Place.** This synchronous collaborative mode relies on technology to link distributed team members. A general trend with researchers and software developers in the last two decades was to develop GroupWare applications that emulate, in one way or another, the same-time/same-place or face-to-face mode. Applications commonly used in this mode of collaboration in-

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<sup>3</sup> Groupware enables a group of people who are geographically distributed to communicate and cooperatively work on shared documents through networked computers (see Greenberg, 1991).

clude the telephone and conference calling; desktop video-conferencing with shared whiteboard.

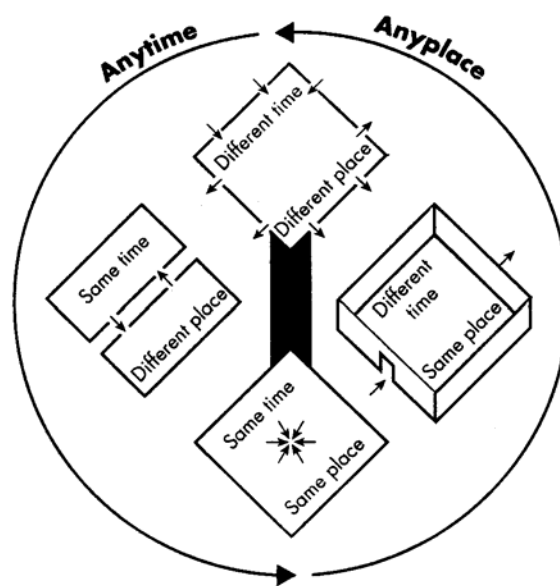


Figure 2.1. The 4-Square Map of GroupWare Options. (Source: Institute for the Future, cited in O'Hara-Devereaux and Johansen, 1994)

**Same-Place/Different-Time.** This asynchronous mode of collaboration is the least familiar of the four exchange modes of the time/place map. However it is not uncommon to see this mode occurring in architectural practices although not as often as the other modes. For example, architects working collaboratively on a physical or computer model in the office but each in his/her own time.

**Anytime/Anyplace.** According to O'Hara-Devereaux et al., this mode does not exist in the time/place map (*figure 2.1*), but ideally it could be the union between same-time/same-place and different-time/different-place. This would form the comprehensive integrated GroupWare, which could provide the familiarity of face-to-face along with flexibility of dispersed asynchronous communications.

The nature of the architectural realm follows a similar pattern to the one shown in *figure 2.1*, since architects rotate between working alone, to collaborating with colleagues FTF, or through mediated environments like the telephone, electronic and hard correspondence, synchronously as well as asynchronously.

The three distinct collaborative design environments we investigate in this thesis in a way reflect two of those collaborative modes, Same-Time/Same-Place and Same-Time/Different-Place (this is further discussed in the 'experiments categories' in sec-

tion 4.3.1). However having said that, it is important to restate here that only the synchronous collaborative mode forms part of the scope of this thesis, since we investigate possible similarities and differences between FTF and CMCD environments. Something not possible in an asynchronous mode of collaboration.

Therefore in going beyond place and time and achieving the anytime/anyplace collaborative environment, possibly through computer-mediation with limited communication channels, architects would then be able to utilise the same system interface while still being able to navigate between those various collaborative modes.

## 2.2 Computer Supported Cooperative Work

According to Schmidt et al. (1992, p8) the term ‘Computer Supported Cooperative Work’ (CSCW) was first coined by two researchers, Irene Greif and Paul Cashman back in 1984. At the time, Greif and Cashman, were trying to describe the topic of an interdisciplinary workshop on supporting people using computers in their work place (also see Greif, 1988). Research in CSCW and CMC focused mainly on developing information systems that can support group work (Bly, 1988; Greif, 1988; Bannon and Schmidt, 1991; Levine and F., 1991). Greenberg (1991) calls it the study and theory of how people work together, and how computer and related technologies affect group behaviour and how it motivates, as a scientific discipline, and validates GroupWare design. This past decade has seen CSCW emerge as a very important research field in numerous domains including collaborative design. This was mainly due to the rapid development of computer and communication technologies.

Although CSCW systems are concerned with the interactions of individuals via computers, Gale (1992, p.523) observed that evaluations should not be restricted to analysing how each individual interacts with the computer. Rather we have to consider the more complex issues of how the individuals interact with each other via the technology.

Therefore CSCW should be conceived as an endeavour to understand the nature and characteristics of cooperative work with the objective of coming up with adequate computer-based technologies. According to Bannon et al. (1991):

*“CSCW is a research area addressing such questions as:*

- *What are the specific characteristics of cooperative work as opposed to work performed by individuals in seclusion?*
- *What are the reasons for the emergence of cooperative work patterns?*
- *How can computer-based technology be applied to enhance cooperative work patterns?*
- *How can computers be applied to alleviate the logistic problems of cooperative work?"*

Some of those questions however, are directly associated with the objectives of this thesis, mainly “*understanding more clearly the nature of communication taking place between collaborating architects by observing similarities and differences between FTF and CMCD sessions.*” Moreover by analysing the use of, as well as identifying adequate communication channels in remote collaborative ventures between architects, we can then apply computer-based technology that has the potential to enhance cooperative work.

### *2.2.1 Communication Channels in Computer Supported Cooperative Work.*

The view held in the past was that new media facilitating remote collaboration needs to emulate FTF interaction in some form or another. By providing certain communication channels, such as video, the all-important visual cues of FTF meetings<sup>4</sup> can then be transmitted across thus recreating the ‘social presence’ effect. This view however is being gradually substituted by one of understanding the collaborators needs and what media becomes essential for individual collaborative environments as well as the differences involved.

Discussing the future of telecommunications, Short et al. (1976, p169) concluded that direct costs favour telecommunications over travel and foresaw the following as the major telecommunication research areas of the future; a) Working at home, b) Education at a Distance, and c) Remote Medical Diagnosis. Today all three fields are active research areas with the first two linked to the architectural realm through studies in CMCD and VDS (as discussed in section 1.3.1). However according to Tang and Issacs (1993) a growing need to support technical and social activity that

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<sup>4</sup> As McGrath (1994) also notes : “*(videosystems, when first envisioned) seemed to offer great promise as convenient and low-cost alternatives to face-to-face meetings for groups whose members were geographically separated. The reality has proven less spectacular than the promise.*”

occurs across geographical distances has not been fully satisfied by the current technologies of phones, faxes, electronic mail, and video conferencing rooms.

Communication remains a very important factor in any collaborative design mode, whether FTF or through CMCD sessions. Therefore before we design systems that enable remote collaborative design we need to understand how technology mediates communication and collaboration as well as the way architects communicate in general when in collaborative ventures. Kalay (1999, pIII.2) maintains that “communication is a prerequisite to (intentional) collaboration” and that “the intents, goals, and actions of each one of the participants are made known to the other participants in the collaborative effort”.

In the past three decades a variety of research projects has been carried out, investigating the importance of audio-visual and text as well as shared graphics channels in remote collaborative settings (e.g., Chapanis et al., 1972; Harrison and Minneman, 1990; Maziloglou et al., 1996; Kvan et al., 1997; Gabriel and Maher, 1999b). However the results of those experiments and subsequent conclusions were of a diverse and mixed nature. The reasons were that most of these experiments addressed different aspects of remote collaboration and reported on different settings as well as communication channels and other mixed variables. Therefore there are as many areas of discontinuity across those studies as there are of overlap, which makes direct comparison a very difficult task (Finn, 1997).

Commenting on the effectiveness of communication during CMCD sessions, Gay and Lentini (1995) examined the communication channels and resources that students utilise during such an activity and then developed a description of what is best for supporting design activities among students. By addressing the communication needs of designers in a CMCD medium, Gay and Lentini (1995) concluded that students need multiple representations of design information to effectively move the design process forward.

*“The ability to use multiple representations allowed the students to supplement a mental and video representation of the design artefact with a drawing that showed details not immediately obvious from looking at the assembled design. Increasing the depth of the interactions allowed students to more effectively communicate their meanings and*

*create much richer representations of the designs.” (Gay and Lentini, 1995).*

Several studies compared video-mediated communication (VMC) with FTF communication (e.g. Chapanis et al., 1972; O’Connail et al., 1993; Olson et al., 1997) whereas others compared VMC with a variety of collaborative settings, omitting the video channel and at times adding a text or a shared graphics channel (e.g., Maziloglou et al., 1996; Olson et al., 1997; Vera et al., 1998; Gabriel and Maher, 1999b).

The situation becomes more complex with certain studies investigating *task outcome* (e.g., Gale, 1989; Olson et al., 1997; Vera et al., 1998) while others, using the same (or similar) collaborative settings, concentrated on *task performance* (e.g., Maziloglou et al., 1996; Anderson et al., 1997; Gabriel and Maher, 1999b) and *user satisfaction* (e.g., Anderson et al., 1997; Olson et al., 1997).

Moreover it is important to note the view of Johansen and Bullen that teleconferencing does not really mean substitution of face-to-face meetings:

*“Many users fail to grasp the full potential of the new technology and try to create teleconferencing systems in the image of face-to-face communication. This sort of horseless-carriage thinking is limited. Though personal meetings are the most familiar, they are not always best for business communications. At times, an electronic meeting is preferable.” (Johansen and Bullen, 1984, p.165).*

A more recent but similar view is echoed by O’Hara-Devereaux and Johansen:

*“Electronic media have already suggested that the face-to-face encounter may not be the ultimate form of human communication for every situation, though most people are not willing to listen to this lesson. Cyberspace will introduce us to a new range of options, at least some of which will be superior to face-to-face, at least for certain tasks.” (O’Hara-Devereaux and Johansen, 1994, p.411).*

This train of thought correlates with our belief that successful CMCD does not necessarily mean emulating close proximity environments and in a way supports our prediction that audio and video are not essential communication channels in CMCD

environments and that successful collaborative sessions can take place without them.<sup>5</sup>

## 2.3 Proponents and Opponents of the Video Channel and its Importance in Computer Mediated Collaborative Design

The problem of developing communication and computer systems that can support collaborative communication and collaborative design or problem solving has become an active research area. Likewise research is being carried out in the field of 'shared workspaces' between designers to facilitate communication and collaboration (Peng, 1993; Maziloglou et al., 1996; Saad and Maher, 1996).

In recent years VMC tools were seen, by some researchers, as indispensable to applications such as remote collaborative settings and distant learning (Short et al., 1976; Harrison and Minneman, 1990). Others however, question the importance of eye contact as well as gesturing in collaborative sessions. Whether or not seeing one's partner has an effect on performance seems to be highly dependent on the type of performed task (Anderson et al., 1997, p.134).

The history of video conferencing and videophone reveals a lack of success (O'Connail et al., 1993, p.390) with video conferencing rooms and other multimedia technology suffering from marketing myths that promoted them as replacements for face-to-face interaction (Egido, 1990; Tang and Issacs, 1993).

On closer examination of the literature we find that numerous studies carried out in this field have resulted in conflicting findings. In this section we present a sample of studies carried out on the importance and usage of VMC as opposed to FTF or other types of mediated communication. However, this is not meant to be a comprehensive list, since we only intend to present a sample of the wide range of, sometimes conflicting, results obtained from research so far.

**Why do users like video?** Tang and Issacs (1993) conducted a study on collaborating remote users working under three conditions: a) using existing tools, that is telephone, e-mail, and videoconferencing rooms; b) using the desktop conferencing prototype (DC); and c) using the DC without the video channel. The DC supported real-time audio-visual conferencing and ShowMe (a drawing tool that facilitates shared mark-up). They found that the DC does not increase overall interactive communication and reduces the number of e-mail messages

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<sup>5</sup> This is discussed in depth in the last paragraph of section '1.4 motivation' of Chapter one.

with users tending to prefer the full-DC mode than DC minus-video mode. The authors also note the importance of video in supporting mediation and increasing gaze awareness.

Apparently, removing the video capability resulted in a significant drop in the use of the desktop conferencing system as opposed to the telephone or FTF meetings. However, with the full-DC mode, users felt that they were utilising the telephone less, and using DC instead of some FTF and videoconferencing room meetings. DC interactions resembled FTF interactions more closely than the videoconferencing room meetings, in terms of interruptions, turn-taking and joking. Most importantly the authors reported that DC was not used at all when the video channel was not available.

As a result of the drop in DC usage when the video channel was omitted, Tang and Issacs (1993, p.192) concluded that a user's desire for video resulted from the impact on the process of their interpersonal interaction, rather than from its perceived effect on any product of their interaction. The authors also concluded that audio is critical, and that high-quality audio is more important than high quality video (Tang and Issacs, 1993, p.193).

**The Media Space.** Harrison and Minneman (1990) presented a new collaborative design environment mediated by a video connection called "the media space".<sup>6</sup> This new medium can connect designers across space and time through the use of video. According to the authors, "*people and places can be brought into the design studio enlarging it to the limits of the electronic network... People who must be in two places at once can be brought into the design studio through recording. Events can be re-experienced.*"

A series of experiments was carried out using the media space and one of these involved a group of three architects collaborating on a design project of an office building. In an attempt to simulate a real design project, the client gave the architects, who were spread across three regionally distributed offices, a detailed program of the building. The architects collaborated, using the video channel, and completed the design without meeting FTF. The design was developed in a two day 'charrette' and the architects were able to design effec-

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<sup>6</sup> The media space is a "system that integrates video, audio, and computer technologies, allowing individuals and groups to create environments that span physically and temporally disjoint spaces, events and realities (see Harrison and Minneman, 1990, p.785)."

tively in this new electronic workplace. They felt that working in a video-based environment constructively influenced the artefact they designed.

The following phenomena were also observed by the authors during the collaborative process: a) the architects were focused on the design task and learned to operate the Media Space very quickly; b) through the video tape, design history became design rationale which later helped describe the design to the client in terms of the process of its creation; c) the architects expressed some preference for the Media Space over FTF relations since it allowed them to work in the privacy of the drafting table while actively collaborating with a group.

The authors maintained that by connecting remote architects through live video, project teams can then be sustained over distances and across organisational lines. This way “the medium retains many of the vital qualities of face-to-face interaction (ambiguity, negotiation, visual communication) that are lacking in computers.” (Harrison and Minneman, 1995, p.790)

**Group Work With and Without Video.** Olson et al. (1997) reported results from two studies that compared the quality of the work, the process, and the perceptions of participants working in four different environments. The four working conditions were: a) FTF with whiteboard, paper, and pencil; b) FTF with a shared editor; c) remotely with the shared editor plus high-quality spatial audio; and d) remotely with the shared editor plus audio and high-quality video. Comparing final outcomes, the authors concluded that design work done by distributed groups using high-quality communication (both audio and video) and shared workspace, was indistinguishable in quality from that done by FTF groups using the same workspace tool. In other words the quality of the work with remote high-quality video is as good as FTF. On the other hand, remote work without video was not as good as FTF. Olson et al. add that FTF work was better when supported by a shared editor than when the group used traditional tools such as a whiteboard, paper and pencil.

However, the process of remote work differs from that of FTF. There is more clarification, regardless of the presence of video. “Taking away the video from remote groups leads to poorer quality designs when compared to face-to-face groups” (Olson et al., 1997, p.169).

By looking at how participants used their time, the authors concluded that distributed work requires more overhead process and that “remote groups spent more time managing their work and clarifying what they meant than the face-to-face groups” (Olson et al., 1997, p.170).

**Disembodied Conduct: Communication through Video in a Multi-media Office Environment.** In their paper with the above title, Heath et al. (1993), report on some of their recent research findings, concerning the organisation of video mediated communication in collaborative work in a dispersed, multi-media office environment. They based their study on a detailed analysis of video-recordings of individuals collaborating on various tasks through audio-visual links. The analysed data were based on more than a hundred hours of video-recordings of individuals interacting and accomplishing various tasks through video.

According to Heath et al. (1993), VMC reveals certain asymmetries which as far as they know, “are neither found within face-to-face interaction or other technologically mediated forms, such as telephone based communication.” Moreover the participants appeared to be aware of each other’s presence and appearance but insensitive to aspects of their partner’s visual behaviour. Through the evidence of their analysis, the authors suggest that video technology (at least the way it was configured) provides the possibility of building an electronic environment which is akin to or simulates, physical co-presence.

The authors conclude “that such communicative asymmetries may facilitate, rather than hinder, certain forms of collaborative work and provide a foundation for the emergence of new forms of sociability in the work place.”

**ROCOCO project.** Researchers in the Rococo project (see Scrivener et al., 1992; Maziloglou et al., 1996) investigated the effects of communication impoverishment between ‘product designers’. The study was divided into two stages, the first studying product designers in six one-hour FTF sessions during which audio and stamped video recordings were made. In the context of the whole project, the study of FTF communication acted as a control for comparison with behaviour observed in remote computer mediated settings. The second phase of the project investigated testing hypotheses concerning the changes in communication activity, such as communication impoverishment when communicating through computer mediated environments. Four conditions were

studied: a) the first having all communication channels on (to emulate FTF), ie. audio, video and a shared drawing surface; b) the second with video removed; c) the third with audio removed; and d) fourth where the designers are left with the shared drawing surface only. Maziloglou et al. (1996, p.392) report that researchers working on the ROCOCO project found it extremely difficult to compare conditions and draw conclusions, since the impoverishment of the communication environment did not seem to perturb the product designers. The product designers were quickly adapting to the new situations thus making it difficult for the observers to see any noticeable change and “hence effects due to impoverishment could not be disentangled from those due to adaptation.” According to Maziloglou et al. (1996, p.392), those results have implications on both the design process and design thinking research. They observed that the designers have a remarkable ability to adapt their behaviour depending on the situation they are in and that there is a need to find “ways of describing design workspace activity, ideas development, and outcomes in different ways and at different levels of detail.”

**Effects of computer mediation on collaboratively solving architectural design problems.** Vera et al. (1998) describe the results of a study carried out at the University of Hong Kong evaluating the effects of computer mediation on collaboratively solving architectural design problems. Pairs of graduate design students collaborated on a landscape architecture design problem using computer terminals as a medium. The experiments were divided into two categories: a) the participants communicated through a video-conferencing application as well as an electronic whiteboard; b) the video-conferencing channel was substituted by a chat line.

The transcribed protocols were coded in terms of patterns of collaboration, distinguishing between “meta-planning, negotiation, evaluation, and individual work” as well as problem solving content, distinguishing between “task-related exchanges, interface-related exchanges, low-level design exchanges (LLD), and high-level design exchanges (HLD).” Performance was measured in terms of the quality of the final output.

According to Vera et al. (1998) they found negligible influence of the communication channels on the collaborative execution of expert tasks. The participants in the study “carried out their collaborative tasks using the same collabo-

rative process (Meta-Planning, Negotiation and Evaluation) regardless of the communication channel.” However changing the communication channels had an effect on the ratio of HLD to LLD. In the chat line based experiments, the level of LLD dropped compared to the video-conferencing category. However the change in communication channels did not influence the design outcome, since the final designs were evaluated by professional architects who found no differences between the two categories. This indicated “that chat-line participants implicitly compensate for the narrower bandwidth interface.” Vera et al. (1998) thus concluded:

*“that designers adapt the nature of their communication to the bandwidth of the channel available without compromising their collaborative strategy or expert contributions”.*

## 2.4 Being There and Beyond

Research into CSCW and CMCD has been mainly motivated by the idea that successful remote collaboration needs to emulate FTF interaction. In other words to preserve the idea of *tele-presence*<sup>7</sup> and the feeling of *being there* (Johansen and Bullen, 1984; Egido, 1988; Greenberg et al., 1992; Veltman, 1997a). According to Hollan et al. (1993), researchers have followed in a way the path set by an article published in ‘The Strand Magazine’ over a hundred years ago. In the article titled ‘The Pleasure Telephone’, the author gives the impression that the telephone will solve the telecommunication problem between two distant locations by creating a sense of being there (Mee, 1898, p. 345).

Levine (1991) made the observation that telephone-based communication is usually very fast, but could also lead to serious communication breakdowns, since two and three-dimensional visual representations would have to be translated into words or verbal representations. It is very hard in a telephone conversation to point to part of a drawing in context unless both parties hold separate copies. Even then it is very difficult to establish long distance frames of reference (Bly, 1988).

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<sup>7</sup> Telepresence is a mental state in which a user feels physically present within the computer-mediated environment (Akin et al., 1983; as cited in Draper et al., 1998). For example, Sheridan (1992, p.120; as cited in Draper et al., 1998) described telepresence as a “sense of being physically present with virtual objects at the remote teleoperator site”. Sheridan described it elsewhere as an “illusion” occurring when the user “feels physically present at the remote site”.

Veltman (1997a) goes further in saying: “while it is true that local telephones offer us synchronous connectivity, most of us are so busy with work and meetings that if we always answered every call we might never get to our real work”. Hence answering machines, voice mail, and secretaries come into the picture, in other words asynchronicity.

However the permanent presence of electronic media in our lives today, along with the ubiquity of computers and CAD systems, has become inevitably embedded in our culture. As Smulevich (1993) puts it “It might then come as no surprise to us that bits and pieces of this ‘high-technology’ have become transparent to our senses”.

Hence, as in many other professions, architects are increasingly using this new medium for work as well as communication (refer to chapter one). Faster processors, better storage devices and other hardware and network advances have enabled software companies to create more powerful, feature-rich software that make collaborative work at a distance a lot easier. This particular type of software, often referred to as GroupWare, embodies collaborative work and provides a way of doing things jointly with others that might be situated at a distance. Therefore software designers need to have a good understanding of what that joint work or activity is, in order to create a product that will actually enhance that activity and not make it harder to perform. This means that in order to successfully integrate traditional multimedia and computation in ways that enhance creativity and communicate it, we need to understand designers’ existing work practices (Hewson, 1990). In other words we need to study existing modes of communication between collaborating architects working FTF in order to propose new models of computer mediated communication in remote collaborative design sessions.

Having said this, there is still a lack of formal research in the application of computer-mediated communication in design processes. Research into communication channels used in CMCD environments has shown that there is little agreement on whether audio and video channels are essential in such ventures as well as on what constitutes the appropriate channels (Maziloglou et al., 1996; Olson et al., 1997; Vera et al., 1998). This may be due to the fact that most of the novel representational and communicative uses of the electronic medium today almost by definition fall outside what people are currently used to (Hollan et al., 1993). A popular view held by some researchers is that adding audio, video and graphics is somehow expected to

make the medium more “real” (Sudweeks and Rafaeli, 1995). Hollan et al. (1993, p 848) take this a bit further:

*“Any system which attempts to bring those that are physically distant into a physically proximate community by imitating physical proximity will always keep the former at a disadvantage. This is not because of the quality of the system, but because of what they attempt to achieve”.*

The question remains here whether it is more important for architects, collaborating at a distance, to feel the presence of their partners, i.e. *tele-presence*, or to find new methods of defining the quality of the information that is being conveyed between them, i.e. *tele-data* (see Greenberg (1992, p 609) for a more detailed account on tele-data). To do this we need to look at collaborative activity between remote architects in a different way. In other words we need to go *beyond being there* and frame the problem in terms of needs, media and mechanism (Hollan et al., 1993). According to Hollan et al. (1993) the goal then becomes “identifying needs, which are not ideally met in the medium of physical proximity, and evolving mechanisms which leverage the strengths of the new medium to meet those needs”.

## 2.5 Conclusion

In this chapter, literature related to CMCD and CSCW was discussed and examples given. In particular we have concentrated on communication channels, such as audio, video, and text as well as shared graphics channels, in both FTF and computer-mediated collaborative ventures. We highlighted the various views, taken by researchers and their position regarding the importance and usefulness of the video channel as one that can help or hinder replication of FTF interaction and collaboration in computer-mediated environments.

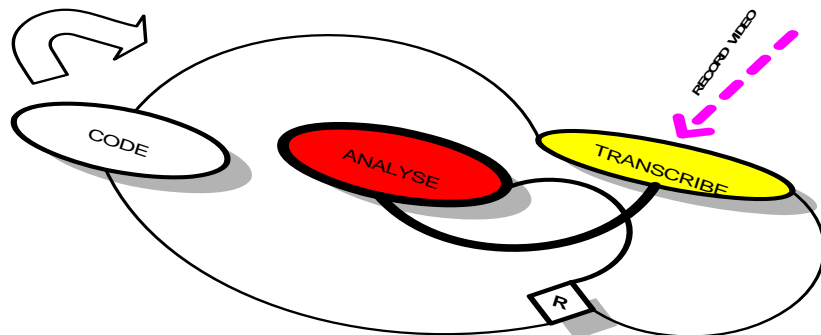
The various examples of studies carried out on communication channels, indicate that there is a wide divergence in the results obtained and methods used and therefore reveal some difficulties in trying to compare results across studies. Two views were presented on the usefulness of the video channel along with examples; a) proponents of the video channel, b) opponents of the video channel. A third and more neutral view was that of the researchers who did not find any major differences between experiments carried out with and without the video channel.

The above studies provide some background on the position of present research in relation to the importance and use of the various communication channels in collaborative ventures. More so, they bring out the need for developing a richer understanding of how communication channels are used in FTF and CMCD sessions and whether or not they might affect the flow and content of design communication.

Although computer-mediated collaborative environments with no audio or video channel lack verbal, visual and gestural actions compared to FTF environments, an electronic medium can be designed to compensate for this loss and capitalise on certain social features of discourse. This however can reduce social inhibitions and potentially increase the quality of the design communication process by reducing interruptions and increasing reflection. Therefore the exploration of CMCD using different communication channels remains a central issue to this thesis.

# Chapter 3

## Protocol Analysis as a Research Method



Chapter three reviews literature related to Protocol Analysis as a research method in design studies. It starts with a brief look at the history of Protocol Analysis and then outlines the various investigation and data collection methods, from verbal and retrospective protocols to discussion protocols. Verbal and graphical design representations are discussed in brief as well as qualitative and quantitative analysis used in protocol studies. Finally, this chapter investigates previous research done in the area of the development of coding schemes.

### 3.1 Protocol Analysis

Protocol analysis as a method of psychological research first emerged in the 1920s, where early studies into problem solving depended on the researcher's ability to take notes (Cross et al., 1996b). However it was not until later in the 1960s (after the introduction of the tape recorder) that the major protocol studies were carried out. Back then they were used by de Groot (1965) in his studies of chess playing as well as by Newell and Simon (1972) in their studies of cryptarithmic and logical problem solving.<sup>8</sup> According to Newell and Simon (1972), “protocols are recordings of subject’s problem-solving behaviour which can be subsequently analysed to identify the invariance in the subject’s patterns of behaviour”. Akin (1986) affirms that “a protocol is the recorded behaviour of the problem-solver which is usually represented in the form of sketches, notes, video or audio recordings”. Cross et al. present an explanation of protocol analysis in the introduction to their book entitled ‘Analysing Design Activity’ in the following way:

*“Of all the empirical, observational research methods for the analysis of design activity, protocol analysis received the most use and attention in recent years. It has become regarded as the most likely method (perhaps the only method) to bring out into the open the somewhat mysterious cognitive abilities of designers. In essence, protocol analysis relies on the verbal accounts given by subjects of their own cognitive activities.” (Cross et al., 1996b, p.1).*

The number and variety of protocol studies investigating architectural design activity using single designers, has grown significantly in recent years (e.g. Foz, 1973; Akin, 1979; Hamel, 1990; Goldschmidt, 1991; Cross et al., 1996a; Suwa et al., 1998), with one of the first protocol studies on design activity attributed to Charles Eastman (1970) in the late 1960s. Eastman studied six architects performing a simple task of improving a bathroom layout through drawing while documenting each of their design operations, the objects they manipulated and the “control mechanisms” they employed.

In addition to the verbal protocol technique used extensively in early design protocol studies, researchers have used a variety of methods when investigating design activ-

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<sup>8</sup> Both de Groot (1965) and Newell et al. (1972) were cited in Cross et al. (1996a, p.3)

ity and design discussion. Those research methods include the following: *interviews with professional designers* (e.g. Darke, 1979; Lawson, 1994), *concurrent or verbal protocol studies* (e.g. Akin, 1979; Goldschmidt, 1991; Cross et al., 1996a), *retrospective protocol studies* (e.g. Guindon, 1990; Suwa et al., 1998; Gero and Tang, 1999).

In general studies investigating single designers during a design session applied verbal and retrospective protocols most of the time. On the other hand studies investigating discussion as well as interaction between a number of designers in a collaborative design venture used discussion protocols (e.g. Scrivener et al., 1992; Kvan et al., 1997; Gabriel and Maher, 1999a). Waldron and Waldron (1996) have presented a survey of various empirical research methods, in use today in design studies. Definitions of these methods as well as advantages and disadvantages are summarised in *table 3.1*.

Empirical method	Appropriate Scenario	Advantages	Disadvantages
<b>Deposition:</b> timely interviews during the process (can also be used with verbal protocol)	Single designer	Targeted data capture. Easier analysis. Can study long tasks. Data is chronological.	Interferes with design process. Incomplete data capture.
<b>Verbal Protocol:</b> designer talks out loud during design to externalise thinking process	Single designer	Access to designers thoughts. Comprehensive data capture. Data are chronological.	Difficult and time consuming analysis procedure. Can only study short tasks. Verbalising may interfere with design process.
<b>Discussion protocol:</b> natural communication among team members	Small team	No interference with design process. Can study communication, negotiation and such.	Difficult and time consuming analysis. Incomplete data capture. Can only study short tasks.
<b>Retrospection:</b> interviews or questionnaire after the design process	Single or small team	No interference with design process. Targeted data capture. Easier analysis.	Data collected are not chronological or real-time partial data capture
<b>Participant observer:</b> observer is also a member of the design team	Small or large team	Can study very long tasks. No interference with design process. Data are chronological.	Difficult and time consuming analysis. Incomplete data capture.

*Table 3.1 Empirical design research methods by Waldron and Waldron (1996).*

### *3.1.1 Concurrent Protocols versus Retrospective Protocols in Design Studies*

According to Dorst and Dijkhuis (1995), protocol analysis methods are divided into two categories; concurrent protocols focusing on the process-oriented aspect and retrospective protocols, which focus on the content-oriented or cognitive aspect. In the concurrent protocols, the experimental subjects are requested to verbalise their thoughts (think aloud method, see Ericsson and Simon, 1993; van Someren et al., 1994) as they work on the task given to them. The verbalisations are recorded on an audio and a video medium thus providing the raw data for analysis.

However the appropriateness of the concurrent protocol method has been debated extensively since it is not understood in what manner as well as how much the verbalising act affects the natural thought processes and the behaviour of the experimental subjects (Baya and Leifer, 1996).

Despite these limitations, the concurrent protocol method is a popular one for single subject studies because of its relative simplicity and tacit assurance that the verbalisations are at least the subjects' own words. Procedures and guidelines have been developed for collecting and analysing such data so that the results obtained are valid and free from bias (Ericsson and Simon, 1993). From a cognitive viewpoint Ericsson and Simon have argued that:

*“Subjects can generate verbalisations, subordinate to task-driven cognitive processes (think aloud), without changing the sequence of their thoughts, and slowing down only moderately due to the additional verbalisation.” (Ericsson and Simon, 1993, p.xxxii).*

On the other hand Galle and Kóvacs (1992) claim that concurrent protocols have the “undeniable advantage of facilitating comparison of and generalisation from different designers' behaviour,” though Galle and Kóvacs' main concern remains in the fact that a person other than the designer undertakes the analysis and interpretation. According to Passerault and Rouet (1995), verbal protocols are often difficult to analyse, and thinking aloud is sometimes considered a costly secondary task that may interfere with the main activity, that is the high-level cognitive processes. Lloyd et

al. (1996) ask the questions whether the words ‘thought aloud’ accurately reflect the design thinking and does a concurrent verbal methodology actually affect the designing it seeks to reveal? They go on to say:

*“A misconception that remains implicit in using protocol analysis (concurrent protocols) in design is what we term ‘the unitary notion of design’. That is the idea that designing is one ‘thing’. The premise of protocol analysis is that by putting a designer into a laboratory and asking them to design while thinking aloud we are able to capture much information about this ‘thing’.” (Lloyd et al., 1996, p.258).*

The other ‘option’ to the concurrent protocol method is offered by retrospective accounting. As a direct observation method, it aims to reveal the thinking behind choices made by the designer in the production of the design. Such protocols are clearly removed from the immediacy of the ‘designing’ event, and therefore potentially open to criticisms of non-reliability (Galle and Kovács, 1992). Therefore unless the interviewer is prepared to spend much time and effort, reflection will then be limited to a short period of time, during the interview. Galle and Kóvacs (1992) add that “the interview method is therefore either expensive, or it may miss information that may otherwise have surfaced.” For this reason, some researchers choose to take the ‘combination approach’ by using both protocol methods in the one study (e.g. Gero and Tang, 1999) in an attempt to overcome the limitations of one single method of data collection.

Hence retrospective protocols form an important data collection tool when single designers recount the design stages they went through as well as what they were thinking of at any particular moment during the design session. However we have already established in chapter one of this thesis that we will not be investigating the design process as such but instead studying design communication in collaborative ventures, a more naturally occurring spontaneous activity. Therefore the use of retrospective protocols, as a measure of collecting data, becomes redundant in our case since participating designers will not be able to recall exactly the utterances they made during the one hour collaborative venture.

### *3.1.2 Protocol Analysis in Design Groups; from Design Protocols to Design Communication Protocols*

A significant change occurred in the late 1980s by extending the conventional single-subject method of design protocol analysis into one of investigating teams of designers during collaborative activity (e.g. Tang, 1991; Scrivener et al., 1992; Visser, 1993; Gay and Lentini, 1995; Cross and Cross, 1996; Kvan et al., 1997; Gabriel and Maher, 1999b).

According to Cross and Cross (1996), “working as a member of a team introduces different problems and possibilities for the designer, in comparison with working alone.” Cross and Cross (1996, p.291), selected the following aspects to observe teams of designers at work:

- *Roles and relationships*
- *Planning and acting*
- *Information gathering and sharing*
- *Problem analysing and understanding*
- *Concept developing and adopting*
- *Conflict avoiding and resolving*

The Delft Protocol Analysis Workshop (Cross et al., 1996a) presented a group of researchers with the opportunity to examine a two hour long videotape of a team of practising industrial designers developing a preliminary solution for a mountain bike luggage rack. Through repeated observation, analysis and discussion they were able to develop a better understanding of how professional designers do such things as: collaborate, develop design solutions, reconcile differences and manage their work. Cross et al. present team discussion as a form of discussion or communication protocol, that resembles the ‘think aloud’ method, in the following way:

*“The classical protocol study relies on an individual subject ‘thinking aloud’; this is not possible in teamwork, of course, but the verbal exchanges of members of a team engaged in a joint task seem to provide data indicative of the cognitive activities that are being undertaken by the team members.” (Cross et al., 1996b, p. 3).*

Therefore investigating design communication between two architects is not too different from one architect verbalising his/her design thoughts. In a way, a single ar-

chitect is requested to verbalise design-related ideas in order to communicate the train of thought and provide insights for the researcher on the cognitive activities during a design session. On the other hand two architects involved in a collaborative design session, verbalise their thoughts, in the form of audio or textual utterances accompanied by graphical sketches, as part of the natural collaborative process in order to communicate their ideas.

Therefore in this thesis we base our analysis of the interaction between collaborating architects on what we term *design communication protocols* (DCP), a method that combines both verbal and discussion protocols. Compared to verbal protocols DCP, as a natural process of communicating design ideas, does not interfere with the main activity, that is the high-level cognitive processes since the subjects are externalising what they think is adequate to communicate their ideas to their partners.

### 3.2 Verbal and Graphical Design Representations

A representation can be defined as “something that stands for something else... some sort of model of the thing (or things) it represents” (Palmer, 1978, p. 262). According to Scott Johnson, architects use physical and digital representations of proposed designs for the real world. Johnson then clarifies representations in the following way:

*“Representations also exist internal to a person’s mind. In order to properly understand the role of representations in design and other mental activities, we need to consider both internal (mental) and external (physical or digital) representations, how they are used, and how they relate to each other.” (Johnson, 1997, p. 5).*

External representations however, can come in the form of verbal and graphical representations. In his seminal study on architects performing a simple task, Charles Eastman (1970) demonstrated that the ‘verbal and graphical’ representations designers use correlate with the problems they find and solve. Later in an example on “reflective designing,” Schön (1983, p. 79) echoes in a way Eastman’s findings by illustrating what he terms the “language of designing.” Schön explains how “drawing and talking are parallel ways of designing”:

*“But as Quist<sup>9</sup> says these things he also draws, placing the kindergarten “here” in the drawing, making the line that “carries the gallery level through.” His words do not describe what is already there on the paper but parallel the process by which he makes what is there. Drawing and talking are parallel ways of designing, and together make up what I call the language of designing.” (Schön, 1983, p.80).*

Schön further explains how design representations in the form of verbal and non verbal dimensions are closely connected. He maintains that communication between the two subjects in his experiments is not complete and remains unclear if the verbal communication is not closely linked with non-verbal communication:

*“The verbal and non-verbal dimensions are closely connected. Quist’s lines are unclear in their reference except insofar as he says what they mean. His words are obscure insofar as Petra can connect them with the lines of the drawing ... Whether Quist and Petra speak in words or drawings, their utterances refer to spatial images which they try to make congruent to one another. As they become more confident that they have achieved congruence of meaning, their dialogue tends to become elliptical and inscrutable to outsiders.” (Schön, 1983, p.81).*

Although we have identified that design representation embodies both verbal and graphical representations, in our analysis we focus mainly on coding the verbal aspect of design representations. Having said that, it is important to clarify that we have also observed some differences in graphical representations between the three categories of experiments and we briefly report on them in chapter seven.

### 3.3 Qualitative and Quantitative Analysis in Protocol Studies

Michael Eckersley (1988, p.86) observed a group of five interior designers<sup>10</sup> working on a small design problem for a period averaging approximately forty minutes. The recorded protocols were then coded, “analysed, quantified and statistically manipulated to reveal a unique and scientifically rigorous facsimile of problem-solving processes.”

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<sup>9</sup> In an experiment within a design studio of an architecture school, Quist as the studio master reviews the work of his student Petra (Schön, 1983).

<sup>10</sup> Eckersley’s (1988, p.88) experiments involved five interior designers, two of which were practising interior designers and three were junior-level interior design students at the Department of Design at the University of Maryland.

However Brereton et al. (1996) observed that protocol analysis is more associated with quantitative analysis rather than qualitative analysis. Generally speaking researchers would hold experiments, with either concurrent or retrospective protocols (sometimes both) used to gather data, and then develop coding schemes to categorise the design activity. They then “spend the bulk of the research effort coding, quantifying and analysing the data looking for interesting patterns in graphs or informative statistics” (Brereton et al., 1996, p. 320). Rather than taking a quantitative approach “focusing on counting design acts or design content”, Brereton et al. (1996, p. 320), took a qualitative approach focusing on describing designer interaction. In an attempt to illustrate their interpretation of collaboration in the design team, Brereton et al. made a deliberate attempt to try and consider several facets of design activity in the video tapes of the experiment they were involved with.<sup>11</sup> “Sometimes looking at long segments of tape to get a broader perspective, other times looking at short segments over and over again” (Brereton et al., 1996, p.320).

Passerault et al. (1995) studied the reliability of evaluation methods that test the development of computerised information systems. In addition to traditional techniques (e.g., post-tests or self-reports), Passerault et al. claim that the analysis of learner-courseware interaction protocols (e.g., videotaping, reading time records, selections logbooks, etc.) can be a valuable source of information to the researcher or the system designer. The collection of verbal protocols during the subject’s activity is a means of coming closer to a qualitative look at the cognitive processes, and therefore by analysing the verbal protocols, indicators of the various processes involved in the activity can then be identified (Passerault and Rouet, 1995). However according to Passerault et al., the analysis of interaction protocols poses two major types of problems:

*“First is the problem of mixing a qualitative analysis with quantitative indicators. Qualitative analysis consists in describing thoroughly the navigation patterns of a few subjects. It may provide rich and meaningful observations of subjects’ navigation strategies. However, due to its cost it is hardly generalisable beyond a few cases. Quantitative indicators (e.g., percentage of “loops”, or multiple visits of the same node) allow a faster processing of many cases but they may distort the infor-*

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<sup>11</sup> Brereton et al. (1996), worked on a 2 hour videotape presented to them as part of the “Delft Protocol Analysis

*mation contained in the interaction protocols. Combining these two approaches is a major problem in most empirical studies of interaction protocols. Second is the problem of interpreting the navigation patterns.” (Passerault and Rouet, 1995).*

Since we are using design communication protocols to investigate the possible effects of communication channels on design representation, a large portion of the analysis of experiments carried out in this thesis is accomplished through utilising quantitative methods. This however does not limit our study to one of quantitative measures as such, since our investigation has a qualitative aspect to it as well. Our qualitative inquiry deals mainly with observations on the differences between the three collaborative environments. These observations, which are further discussed in chapter six, are categorised into two parts, communication differences and verbal representation differences.

### 3.4 Issues Related to the Development of Coding Schemes

In order to investigate collaborative communication within a design session between two architects, we need to record and analyse verbal utterances in the form of communication protocols occurring naturally as part of the collaborative act. According to Purcell et al. (1996), an audio-visual recording of a design session and the resulting protocol “represent a particular type of qualitative data.” However those protocols and the resulting transcripts are not the actual data on which analysis is performed, rather they are segmented or categorised, with the frequency of occurrence of those categories forming the data, which are later analysed (Purcell et al., 1996, p. 225). Analysing these communication protocols involves the development of a detailed and well-suited coding scheme.

Robillard et al. (1998) present how a multidisciplinary team, made up of software engineers and cognitive psychologists, developed an approach to studying cognitive activities in collaborative software development. The basis of this approach was to improve understanding of software development by observing professionals at work, and deriving lines of conduct or good practices. Therefore Robillard et al. developed a coding scheme, which enabled the coding of episodes (of the design process) using syntactically structured labels, also called categories. According to Robillard et al.,

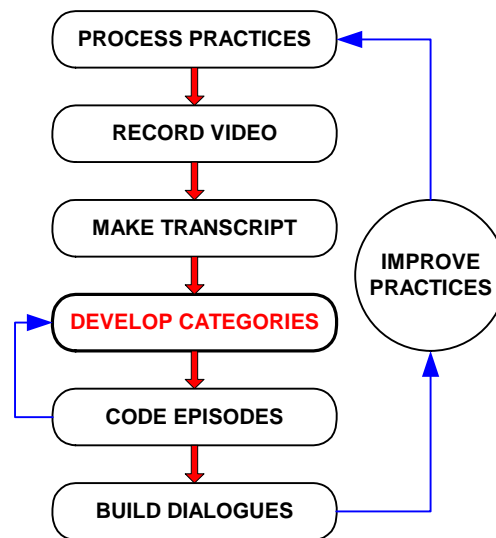
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Workshop” (see Cross et al., 1996a).

categories must be exhaustive and exclusive and the code must be able to model the meeting activities, between software designers, adequately and yet be formal enough to support quantitative analysis. *Figure 3.1* presents the generic steps in the measurement approach as well as the development and testing of the coding scheme, which Robillard et al. followed.

According to Ericsson and Simon (1993, p. 276), the sequence for deriving data from recordings of verbal behaviour and its subsequent encoding and analysis can be roughly described as follows:

**Input** (Protocols & Questionnaires) ==> **Encoding** (Coding schemes)  
 ==> **Output** (Descriptive and/or Statistical results).



*Figure 3.1. The Measurement approach in developing a coding scheme suited for coding cognitive activities in collaborative software development (source, Robillard et al., 1998, p. 294).*

### 3.4.1 Deriving the Structure of Coding Schemes

The design protocol literature indicates that there are three ways of deriving the structure of coding schemes in protocol studies; a) data generated structure, b) externally derived structure and c) theory derived structure (for a full review of this subject see Purcell et al., 1996, pp 225-227). Data generated structure in a coding scheme, which is the traditional approach, is generated after the transcribed protocols have been parsed, segmented and reviewed. Therefore issues emerging from the data dictate in a way the structure of the coding scheme. However recently, there has

been a tendency towards imposing externally derived structures onto a coding scheme. Those external structures occur when parts of an already established coding scheme are used to develop another one.

Purcell et al. (1996) highlight two consequences of this shift in developing coding schemes. The first one is the number of categories used in the analysis, which is relatively limited and the second lies in the difficulty of comparing the results “of the later experiments to the earlier work and to each other.” Purcell et al. give an example of a study using this method in Lloyd and Scott (1994, p. 127) who observed five designers working on a motor control box. Lloyd and Scott used three categories; generative utterances, which bring something new to the design situation, deductive utterances which understand the specific needs of the problem thus making it clearer, and evaluative utterances which are general comments about the discipline, designing or the situation. Purcell et al. are concerned that a coding scheme of this size might represent a “severe loss of detail from the original protocol” (Purcell et al., 1996, p. 226).

On the other hand, theory derived structure occurs when part of a coding scheme is generated through a particular theory and subsequently tested.

In their study of an individual designer working on the design of a backpack rack for a mountain bike<sup>12</sup> Purcell et al. (1996) developed a coding scheme that brought together the various approaches previously identified.<sup>13</sup>

On further examination of the literature dealing with coding schemes, we find a variety of coding schemes developed for protocol studies analysing design processes and lately, design communication. However most of the studies concerned with design communication or communication in general, were again limited in their scope. They covered categories such as: ‘introducing new ideas and clarifying those ideas’ (e.g. Olson et al., 1997), development of ideas (Peng, 1994), investigating ‘Interruptions, (e.g. Levinson, 1983; Tang and Issacs, 1993) overlaps, handovers and dominance’ (e.g. O’Connail and Whittaker, 1997, p.112), and floor holding (e.g. Jefferson, 1984).

Other coding schemes investigated communication in collaborative ventures such as Sudweeks and Albritton (1996) categorising communication types as follows: infor-

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<sup>12</sup> This was the design brief for the Delft protocols workshop (for more details on the brief, see Cross et al., 1996b, p.9)

<sup>13</sup> The coding scheme used was previously developed by Gero and McNeill (1998) and consists of twenty-seven categories (see also Purcell et al., 1996, p.229-233).

mal control of communication, formal control of communication, socio-emotional communication, conceptual communication, task communication.

On the other hand, Vera et al. (1998), investigated architecture and landscape architecture students collaborating through computer mediated environments. The coding scheme they developed distinguished between “meta-planning, negotiation, evaluation, and individual work” as well as “task-related exchanges, interface-related exchanges, LLD exchanges and HLD exchanges.”

### *3.4.2 Single Versus Multiple Segment Coding*

A more traditional way of coding transcribed protocols was by first segmenting them into information fragments. Subsequently categories were developed after carefully reviewing the segmented protocols and coding each segment or fragment under a single category only (Purcell et al., 1996). This was performed by developing a set of rules to identify the transition points from one fragment to another. Typical points of transition were for example: noticeable change in designers thought and designers’ attention shifting from one concept to another, pauses in the flow of words as well as semantic/syntactic criteria for recognising discrete utterances (Baya and Leifer, 1995; Purcell et al., 1996, p.226).

A more recent method, as cited by Purcell et al. (1996, p 225), is the potentially richer approach of using the ‘grounded theory’ by Glaser et al. (1973), which allows for multiple coding of the single segments. According to Radcliffe (1996, p.345), those segments, in the form of text units, “were chosen to be individual utterances by the designers no matter how long or convoluted.” The text units were then revisited, with the possibility of each text unit being coded under multiple categories.

Having established earlier that we will be investigating design communication protocols rather than design protocols as such, this emphasises the unsuitability of the segmentation method for the purpose of our research in the following ways. Firstly, researchers investigating single subjects using the think aloud method applied the segmentation procedure in order to break down utterances into “meaningful” segments, or design episodes, that can then be coded under a specific category relating to the design process. Secondly, segmentation results in the fragmentation of an utterance whereby the flow as well as the content of the communication within the utterance, in our case, is potentially disrupted.

Since our interest lies in observing the possible effects communication channels might have on design representation, using various mediums, therefore it becomes essential to retain utterances as a whole rather than segmenting them. This way the potentially richer “grounded theory” approach can be applied by multiple coding each utterance (Suwa et al., 1998). In turn this would facilitate the observation of possible differences between the three categories of experiments.

### 3.5 Summary

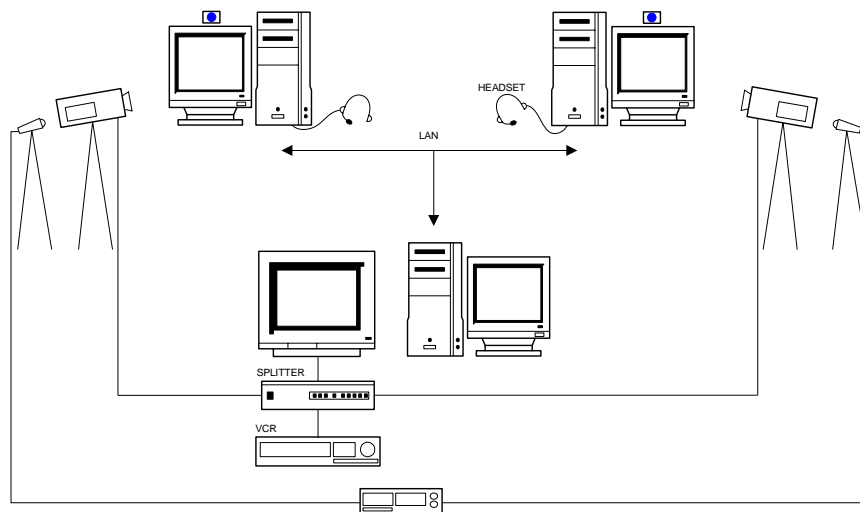
In this chapter we presented literature related to the various methods of data collection as well as the development and testing of coding schemes in protocol analysis. Having already established in the introductory chapter of this thesis that we are not investigating the design process as such, but the design communication resulting from collaborative ventures between pairs of architects, a new approach towards design protocols is pursued. This meant that methods used in traditional design protocols, like the think aloud method, were not adequate for our line of investigation. Therefore we proposed and presented an alternative method, the design communication protocol technique (section 3.1.2), as a more suitable procedure to study collaborative design communication.

Also discussed was the issue of verbal and graphical design representations and their importance in collaborative ventures, not only as a “language of designing” but as a means of communicating design in a clear and direct way.

And finally we briefly presented the various methods by which coding schemes were traditionally developed and the methods, by which transcribed data are coded, that is, single versus multiple segment coding.

# Chapter 4

## Development of Research Instruments



Chapter four describes the experimental procedure carried out in this thesis. It begins with a methodology overview outlining the variables and the development of research instruments used for gathering data as well as preparation and procedure of both pilot and final experiments. The development and implementation of the pilot study is discussed and the shortcomings highlighted. This is followed by the final experiments and implemented changes from the pilot study.

## 4.1 Methodology Overview

In order to investigate and compare the effects of communication channels on design representation between FTF and CMCD sessions involving architects, a collaborative design setting was created at the Faculty of Architecture simulating both collaborative environments. A special design brief, post experiment questionnaires and a coding scheme were developed for the one-hour pilot study experiments with all sessions video taped. It was kept in mind that it was important to create an appropriate design problem and procedure in order to keep the participant interested and motivated during the collaborative sessions.

Transcribing part of the ensuing communication protocols along with our initial observations of those pilot experiments guided us towards further refining the brief, questionnaires, coding scheme, and improving on the general procedure of the experiments. The development of the post experiment questionnaire helped in collecting direct information from the participants. The information gathered from the final questionnaires was correlated with the results of the coded transcripts from the final experiments.

In this chapter we will discuss the development of the research instruments which included variables, participating subjects, brief, questionnaires, media and apparatus as well as procedure from the pilot studies to the final experiments.

## 4.2 Variables

The pilot study was directly influenced by variables in the environment. Controlling some of those variables meant that we had a more meaningful data set to work with. While the predominant variable was the three distinct categories of experiments, most of the other variables had to be standardised, notably the length of experiment, participating subjects and the design brief.

In order to reduce the number of those variables as much as possible, only architecture students were called upon to participate as opposed to practising architects. The brief was the same in all three categories of experiments, and each pair of participants engaged in only one collaborative session. *Table 4.1* shows a list of variables in all three categories of experiments.

	FTF	CMCD-	CMCD-b
		<b>CMCD-</b>	
		<b>a</b>	
<b>Time</b>	1 Hour/synchronous.	1 Hour/synchronous.	1 Hour/synchronous.
<b>Space/Location</b>	Same Space. Participating subjects are located in same room.	Different Space. Participating subjects are located in different rooms.	Different Space. Participating subjects are located in different rooms.
<b>Communication</b>	Full verbal (audio and text) and non-verbal.	Full verbal (audio and text) and non-verbal (through video-conferencing and whiteboard).	Limited verbal (text) and non-verbal (through Virtual Campus and whiteboard).
<b>Data Collection</b>	Time stamped video plus audio-tapes.	Time stamped video plus audio-tapes.	Time stamped video plus text transcripts from Virtual Campus (VC) sessions.
<b>Data</b>	Audio verbal utterances communicated by the subjects as well as graphical communication in the form of the produced drawings.	Audio verbal utterances communicated by the subjects as well as graphical communication in the form of the produced drawings.	Textual verbal utterances communicated by the subjects through the VC as well as graphical communication in the form of the produced drawings.
<b>Participants</b>	5th and 6th year architecture students.	5th and 6th year architecture students.	5th and 6th year architecture students.
<b>Brief</b>	Same brief printed on A4 paper in colour.	Same brief in html format available through a Netscape window.	Same brief in html format available through a Netscape window.
<b>Questionnaire</b>	Custom developed multiple choice questions to suit environment.	Custom developed multiple choice questions to suit environment.	Custom developed multiple choice questions to suit environment.
<b>Media</b>	Paper and pencil.	Computer hardware and software.	Computer hardware and software.

*Table 4.1 The table of variables.*

### 4.2.1 Time and Space

The time variable was the same in all three categories of experiments where paired participants collaborated synchronously for one hour. However the space variable differed between FTF and CMCD categories. Participants in the FTF experiments worked collaboratively on the design brief while co-located in the same room thus simulating face-to-face collaborative sessions. On the other hand, participants in the CMCD categories were located in separate rooms and collaborated through networked workstations simulating in turn remote collaboration between architects.

### 4.2.2 Participants

Initially we approached practising architects to participate in the experiments. This proved to be harder than first anticipated, since in a period of six months we only managed to recruit six practising architects from different architectural firms around Sydney. Soon afterwards we decided to involve architecture students in the experiments for three main reasons. The first reason was the modest number of practising architects that volunteered for the task, when we wanted at least fifty to sixty participants in order to carry out seven to ten collaborative experimental sessions in each of the three collaborative design modes (when most design protocol studies investigated, used one to six experiments per category). The second reason was the varying degree of experience between the six volunteering architects, with some recent graduates and others having over ten years' experience. The third reason was the flexibility and availability of the students compared to the practising architects. Since on most days, the students were present on campus it was easier to pair them up, organise schedules and times for the experiments.

A total of sixty-eight 5th and 6th year architecture students from the Faculty of Architecture at the University of Sydney volunteered for the pilot and final experiments (for a full list of their names see *appendix e*).

Prior to engaging in the experiment all participants had to complete and sign a 'subjects consent form' (see *appendix b*) in accordance with policies of the University's Human Ethics Committee. The form allows us to use the recorded data and reproduce the results in the form of reports, papers and the final thesis of this candidature. At no time will any information be attributed to individuals thus preserving their total anonymity. In addition to that, and by request of the University's Human Ethics Committee, the participating students were handed a 'subject information form' which detailed information about the experiment (see *appendix c*).

### 4.2.3 Communication and Data Collection

The communication variable between the three categories of experiments deals with the communication channels available to and used by participants during the experiments. In the FTF category the participants had access to all communication channels, verbal and non-verbal. Audio-visual formed the verbal channels while shared graphics, eye contact, and gesturing formed the non-verbal communication channels.

In the CMCD-a sessions, participants had access to similar communication channels as the FTF category through a video conferencing and shared white board software, which simulated FTF collaborative sessions to a certain extent. However in the CMCD-b sessions, participants were restricted to the use of certain communication channels namely a text-based channel as verbal communication and a whiteboard for non-verbal graphical communication with no audio-visual contact as the audio and video channels were taken out.

Data collection also depended in a way on the communication channels used. In the FTF category, audio verbal utterances as well as non-verbal communication were captured on video. Graphical communication was captured in the form of sketches done on A1 detail paper provided at the start of the experiment.

In the CMCD-a category, video was also used to capture verbal (audio) utterances as well as non-verbal communication. Graphical communication in the form of electronic sketches was captured through the video conferencing software provided for the experiment. On the other hand in the CMCD-b category, video was used to capture individual activity on the part of each participant. Verbal communication taking place between collaborating participants was captured through the text-based channel, while graphical communication was captured electronically through the shared whiteboard.

### 4.3 Pilot Study, Development and Implementation

We conducted one-hour experiments divided into three categories, FTF, CMCD-a and CMCD-b (as described section 4.3.1). The sessions were video taped, and excerpts of the transcribed protocols were coded into a custom developed coding scheme. Preliminary observations of the videotapes as well as the transcribed protocols and the coded data provided evidence that there were noticeable differences, in communication and the collaborative activity in general, between all three categories of experiments. This section of chapter three details the three categories, the development of the brief and questionnaire as well as the general preparation and running of the pilot study in September of 1997.

### 4.3.1 *Experiment Categories*

To better understand the nature of collaborative communication and its role in complementing and enhancing design representation, we recreated on the premises of the Faculty of Architecture, three different collaborative environments simulating contemporary collaborative settings. Those three settings were meant to help us observe and analyse in detail the flow and content of collaborative communication between pairs of collaborating architecture students. The collaborative environments are:

- Simulating a face-to-face (FTF) collaborative environment; participants in the first category of experiments dealt with a specific design brief for one hour while co-located in the same room at the same table using traditional media like pencil and tracing paper.
- Computer-Mediated Collaborative Design sessions with full duplex audio, video and a shared whiteboard as shared drawing space (CMCD-a) formed the second category of experiments. Participants in this category collaborated for one hour, on the same design brief as the FTF category, through networked workstations situated in separate rooms. This environment simulated remote collaborations with participants having access to high bandwidth connections.
- Computer-Mediated Collaborative Design sessions with limited communication channels (CMCD-b) formed the third category of experiments. In contrast to the two previous categories, participants in these sessions had no audio or video channels and their only means of verbal communication was through the Virtual Campus<sup>14</sup> (VC) in text form. However they still had access to the shared whiteboard as shared drawing space. Participants in this category collaborated synchronously for one hour using the same design brief as the two previous categories. This medium was simulating remote collaboration between two architects with access to low bandwidth connections, thus using skeletal communication channels.

### 4.3.2 *Brief*

Leading up to the ‘Delft Protocols Workshop’ an appropriate design problem for the experiment had to be devised (Cross et al., 1996a). Researchers spent some consid-

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<sup>14</sup> The Virtual Campus (VC) is a text-based virtual world based on the lambdaMOO core, the location of the campus is <http://www.arch.usyd.edu.au:7778>.

erable time going through the problem, getting an overview of issues and tradeoffs that could possibly occur during the design processes. According to Dorst (1996):

*“The requirements of the design tasks were meant to be: (i) challenging, (ii) realistic, (iii) appropriate for the subjects, (iv) not too large, (v) feasible in the time available and (vi) within the sphere of knowledge of the researchers”.*

However, Akin (1986) believes that in order to have a manageable size protocol, or recording, a suitable design problem has to be selected. Akin (1986) goes on to say that designing problems for protocol analysis experiments, has to be ranked for realism, length of required design time and completeness. (For some examples of briefs used in design protocol experiments see Eastman, 1970; Akin, 1986; Goldschmidt, 1991; Martinez and Katz, 1992; Katz et al., 1993; Maher et al., 1996; Kvan et al., 1997)

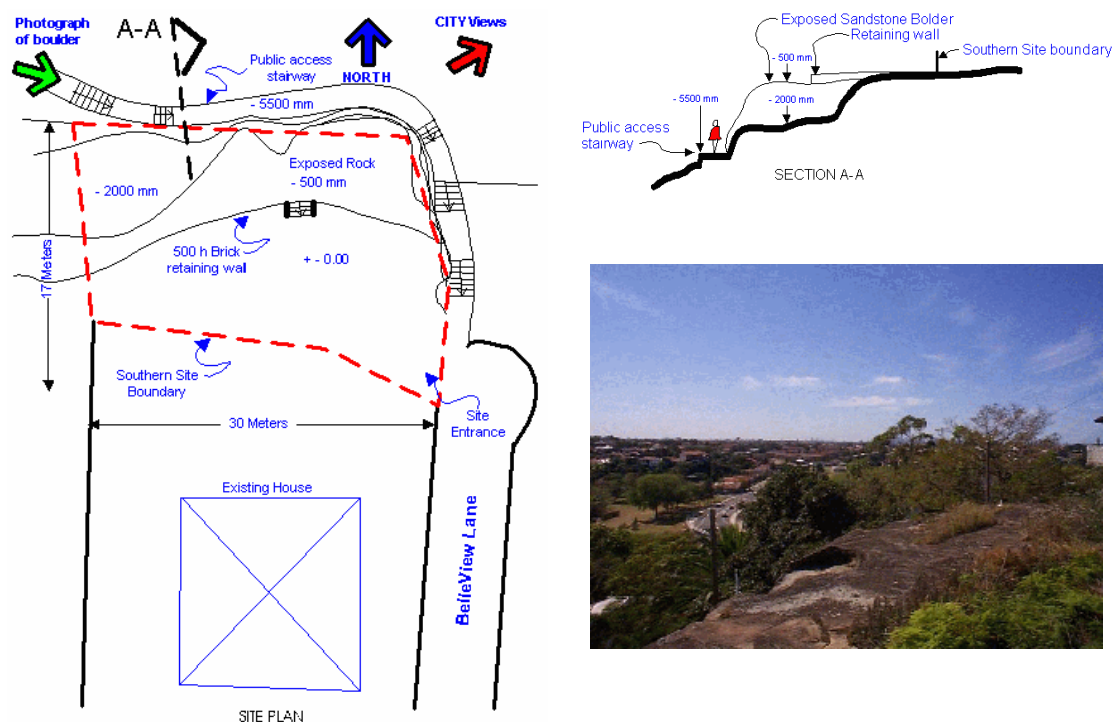


Figure 4.1 The site plan, section (NTS) and photograph (taken from site), as presented in the brief, showing aspect and views towards city.

Therefore the brief for this study had to be concise, realistic and manageable in a one-hour collaborative session. This meant it had to be interesting enough to stimulate the participants' imaginations and get them to collaborate and communicate together enthusiastically. The brief details the needs of an artist's young family and his

need for an ‘atelier’. A spectacular site in Sydney’s inner west suburb of Earlwood was chosen. The site is perched on an exposed sandstone boulder over a cliff with uninterrupted vistas from the city all the way to the Blue Mountains in the west, *figure 4.1*. A location plan, a site plan and a section through the site as well as four coloured photographs of the site were provided to the participants within the brief (see *appendix f* for the final brief). The preliminary brief worked well in the pilot study, and this was reflected in the post experiment questionnaires.

### 4.3.3 Questionnaires

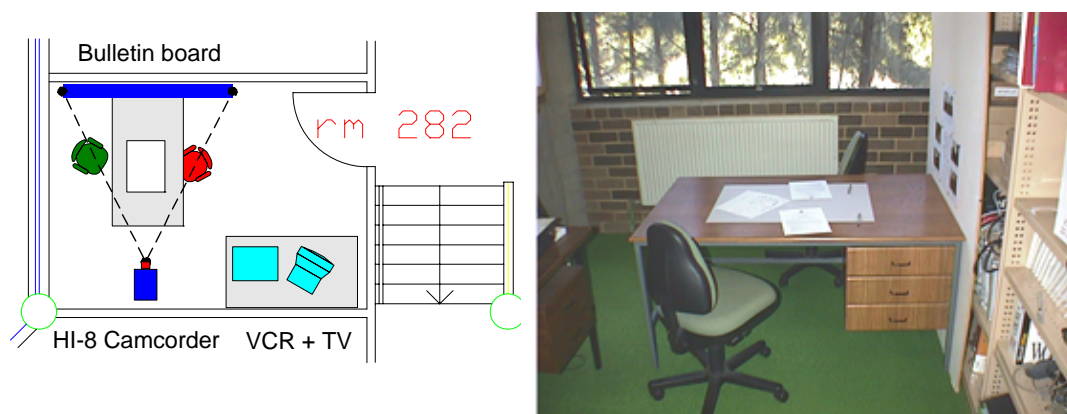
Another important instrument of research is the ‘questionnaire’. It can contain checklists, attitude scales, projective techniques as well as rating scales and is often used as a tool for data collection (Oppenheim, 1992). Issues like anonymity, number and length of questions, duration of questionnaire, problems of item wording or phrasing, structured interviews, multiple choice or open ended questions had to be addressed before the questionnaires were written (Oppenheim, 1992).

After careful consideration, a post experiment multiple-choice questionnaire was formed to survey the participants’ opinions on the ‘collaborative experience’ while it was still fresh in their minds. The use of multiple-choice questions was the preferred option since it gave us more direct control of the outcome when compared to a simple ‘Yes/No’ answer or even open-ended questions. Having said that, each question had one of the answers as an open-ended answer labelled ‘other’, in case none of the answers suited the participants or they needed to add valuable information relating to their experience.

The questionnaires were not intended to be comprehensive on communication, but they were meant to complement the experiments already undertaken. The questions focused on issues such as the procedure of the experiments as well as the importance of eye contact and various needs in a collaborative environment. Those preliminary questionnaires were meant to help us evaluate the ‘running’ of the experiments and assist us in applying any required modifications to final experiments that were completed a year later. The questionnaires were addressed to all three categories and differed slightly to suit the collaborative environment and category of experiment.

#### 4.3.4 Media and Apparatus

The type of collaborative media available to the designers in order to communicate their design ideas through graphical and verbal representations differed in all three categories of experiments. Two different settings were used for the three categories of the pilot experiments. *Figure 4.2* shows the layout of the room for the FTF experiments. The room had a deep desk placed in a position accessible from both sides with a chair for each participant on either side. A bulletin board with a copy of the site plan and coloured photographs of the site pinned on it was placed adjacent to the desk. A Sony™ Hi-8 camcorder attached to a VCR was positioned perpendicularly to the desk in order to capture verbal and non-verbal activity between the participants. Each pair was given six A2 sheets of tracing paper as well as felt pens. Separate A4 sheets with site plan and section were handed out to participants in order to facilitate tracing the site boundaries directly onto the A2 tracing paper.



*Figure 4.2* The setting for the three FTF pilot experiments with bulletin board holding coloured pictures of site as well brief. Picture of FTF setting.

For the CMCD sessions, two adjoining rooms were used as illustrated in *figure 4.4c*. Each room was equipped with a Silicon Graphics Indy™ (SGI) Unix workstation with a 21" monitor. The choice of the SGI workstations as opposed to a PC or Mac platform was directly linked to the choice of collaborative software chosen for the experiments. At the time the pilot study was done (September 1997), Inperson™<sup>15</sup> 2.0 had the technical edge over its competitors, which included Microsoft's Net-Meeting™ 2.0 and Netscape's Communicator™ amongst others.

What made Inperson™ a more robust videoconferencing software in comparison to its competitors are the following characteristics:

- full duplex audio, uncompressed video at 25 fps as well as shared whiteboard.
- An intuitive interface with simple easy to use drawing tools, like line, (with line weight and line colour), basic geometric shapes like circles, ellipses, squares and rectangles as well as free form drawing with a pencil tool. Forms could also be easily edited by selecting and dragging to move or delete certain objects or could simply ‘copy and paste’ objects even between pages as illustrated in *figure 4.4f*.
- The option of having multiple pages on the whiteboard with the ability of one participant to call the attention of the other participant onto his/her page for consultation, by simply double-clicking on the page’s tab.
- Inperson had in-built a variety of cursor shapes which when assigned were unique to each participant. This way participants could distinguish their cursor and where they were at any time from the other user. At any given moment during the experiment, participants saw each other’s cursors in action, thus they were able to constantly monitor the activity and whereabouts of their partner.
- Inperson™ had the ability to make a direct connection between the two SGI workstations without having to go through a server, such as in this case Net-Meeting’s™ remote group servers. This meant that we avoided the difficulty of logging onto those servers at peak times as well as lessening the possibility of the connection dropping off while in the middle of an experiment.

The two SGIs were networked along with the observer’s terminal onto a high speed Local Area Network (LAN). For the CMCD-a sessions, each workstation was equipped with a video camera mounted on top of the monitor as well as a ‘lapel’ microphone attached to each participant for them to use the videoconferencing capabilities. A diagram of equipment used in all CMCD experiments is illustrated in *figure 4.3*. The video camera and the microphone were removed during the CMCD-b sessions and the audio channel was replaced with the text based Virtual Campus (VC) medium. The VC used a web based interface to a LambdaMOO<sup>16</sup> database (for more

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<sup>15</sup> For more information go to the ‘Silicon Graphics’ Inperson™ web site on <http://www.sgi.com/software/inperson/features.html>

<sup>16</sup> The LambdaMOO (MUDs Object-Oriented) was created by Curtis (1992) and is based on the MUDs (Multi-User Domains) environment. According to Curtis (1992) “A MUD is a network-accessible, multi-participant, user-extensible virtual reality whose user interface is entirely textual.”

information on MUDs and MOOs, see Cicognani, 1998). The reason for using the VC was its robustness as well as its functions of time stamping<sup>17</sup> and saving the content of the collaborative exchange at the end of each session.<sup>18</sup> Those were two important functions that were not present in other chat based software available at the time of the Pilot experiments. Another function of the VC was that participants logged in using two non-gender specific names, “Alex and Toni”. This way either one of the two names identified each utterance at the start by “Alex says” or “Toni says”.

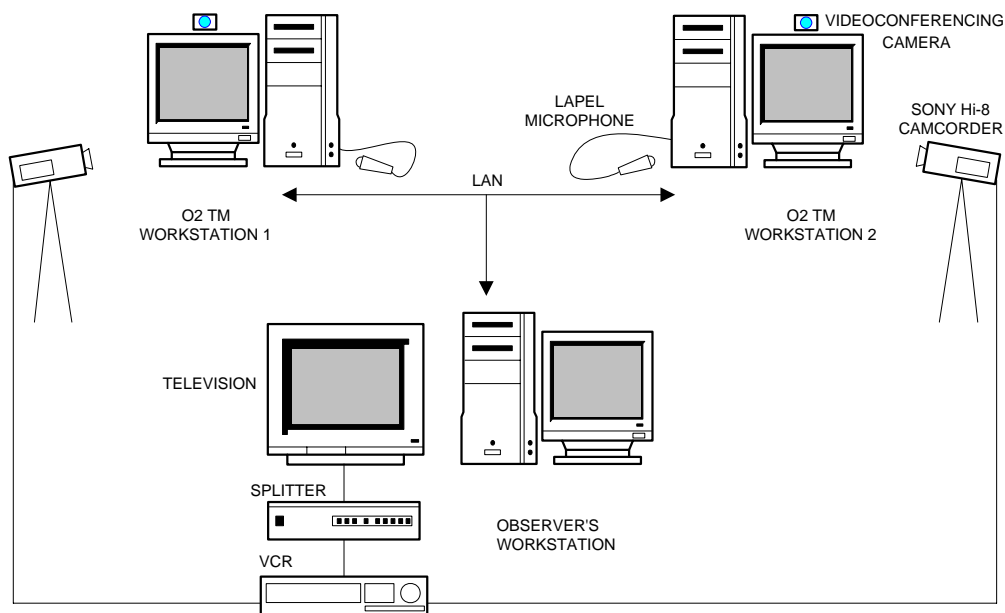


Figure 4.3 Diagram of all equipment used in the six 6 CMCD categories of the pilot experiments.

Two Sony™ Hi-8 camcorders were positioned behind the workstations at a slight angle, in order to capture the screen activity, *figures 4.4a, b and c*.

The camcorders were connected to a video splitter with four audio and video channels. In turn the video splitter out-puts to a VCR and a 34inch TV monitor for the observer, *figures 4.4d and e*. Initially we had intended to use tape deck recorders to capture audio in the FTF and CMCD-a categories for transcription use. This idea was dropped after we ran one test session using only a camcorder to capture audio

<sup>17</sup> On our request Cicognani added time stamping thereby producing the time in hours minutes and seconds after each utterance or verbal exchange between the two participants, in case time became an important factor in the analysis.

<sup>18</sup> This was important since it was the only way to capture the verbal (textual) communication between the two participants in the form of communication protocols to be coded later on.

and video. At the time, the resulting audio quality from the test video was good enough.

#### *4.3.5 Task and Procedure*

On arrival at the experiment location, participants were welcomed and thanked in advance for their participation. Before the briefing began each participant completed and signed the 'subjects consent form' separately and participants were reassured of their anonymity when it came to publishing the findings. Participants were then briefed on the procedure of the experiments and the tools used for twenty minutes before the start of experiments. They were also informed of what was expected from them at the end of the hour, with each pair participating in one experiment only.

They were instructed that a notice would be issued at the fifty-minute mark, so they can start wrapping up their ideas. Participants were also notified that a final design is not expected at the end of one hour, but that they were required to produce some planning sketches in 2D and 3D if possible. Since every design idea, whether in sketch or text form was important for the analysis, participants were asked not to delete or destroy any information in all three categories of experiments.

Although the duration of the collaborative experiment was one hour each, two hours were allocated for the running of each session. After briefing, each pair proceeded into a one-hour collaborative session.

In the FTF experiments, the pairs were provided with A2 tracing paper plus pens for each session. They were also issued with a printout of the brief in black and white on A4 paper with a detached site plan and section through the site on A4 as well. Four coloured photos of the site, as well as a copy of the site plan and section, were fixed on a pin-board adjacent to their desk as shown in *figure 4.2*. Before starting the video recorder, the participants were asked if they had any questions on the procedure and their task. Soon afterwards recording started and they were allowed to start reading the brief with the observer leaving the room. Fifty minutes later the observer made a brief appearance and instructed them that there was ten minutes left. At the end of the hour, the observer returned with a questionnaire sheet for each participant, and they were given ample time to read and complete it. After that recording was stopped, and participants were thanked again for their co-operation and participation in this study.

In the CMCD experiments, the brief was presented to participants in the same format as in the FTF sessions but in 'html' form and was accessible through Netscape™<sup>19</sup> along with the four coloured photos of the site. Both CMCD categories were provided with a skeleton representation of the site plan and section on the first five pages of Inperson's™ whiteboard. This way they did not waste any time drawing them and proceeded straight into designing. Interference by the observer was minimal and limited to answering technical questions if and when they arose.



Figure 4.4a Workstation of participant 1 with video-conferencing camera on top of the monitor



Figure 4.4b Workstation of participant 2 with camcorder positioned behind participant.

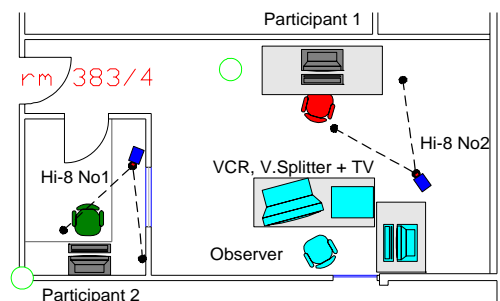


Figure 4.4c CMCD setting for the six experiments.



Figure 4.4d Observers post.

<sup>19</sup> Netscape™ Communicator™ was used to display the brief in both CMCD sessions and as the VC interface in the CMCD-b session.



Figure 4.4e Observers TV monitor showing split screen with Hi-8 No 1 and 2.

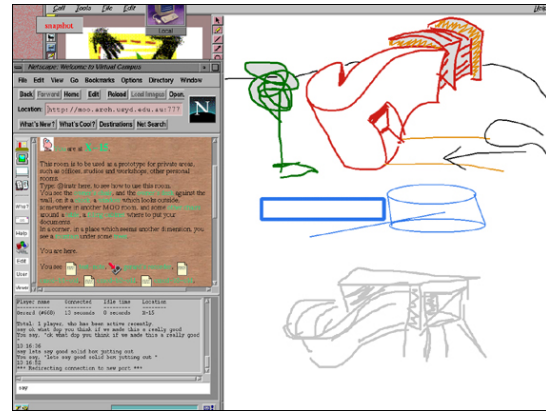


Figure 4.4f Screen grab of Inperson showing shared whiteboard and the VC interface in a Netscape window.

Figure 4.4 The setting for the six CMCD pilot experiments also showing the observers post and participants workstations.

Although the drawing tools of the Inperson™ whiteboard were intuitive and very easy to use, participants in each CMCD category were given ten to fifteen minutes after the briefing to try out the equipment and familiarise themselves with the collaborative environment.<sup>20</sup>

In the CMCD-a sessions, all communication channels were available to the participants (see section 4.3.4) with the SGI video camera placed on top of the monitors. A Netscape™ window with the brief and an Inperson™ window with the shared whiteboard and video display were open and available for users at the start of the experiment. After briefing and the period of training, recording started and participants were allowed to start reading the brief and were notified after fifty minutes to start wrapping up their ideas. During the experiment, the observer was sitting in the larger room along with participant one. He followed the experiment through the two video cameras on his TV monitor making sure the connection was working well and the participants had no technical problems (see figures 4.4c and d).

In the CMCD-b experiments the use of Inperson™ changed slightly. The communication channels were limited to the use of the VC interface as their verbal channel, through a Netscape™ window, and the whiteboard of Inperson™ as their shared drawing space. The video and audio channels were turned off. Participants had three windows running simultaneously on their monitors. As in CMCD-a, the brief was displayed through a Netscape™ window, Inperson™ had the shared whiteboard

only, and the third window was that of the VC through a Netscape™ window as illustrated in *figure 4.4f*. The observer in the CMCD-b sessions had access to the VC sessions in order to observe and help with any potential technical problems. The observer also instructed the participants of time left through the VC at the fifty-minute mark.

After the experiments, participants in the CMCD sessions completed the questionnaires that were slightly different from the FTF one. This difference also occurred between the two CMCD categories since the questionnaire had medium specific questions.

All participants were asked not to discuss the brief and procedure of the experiment with subjects who were yet to participate so as not to compromise the experiments.

Data sets collected in all categories include video, along with notes made by the observer as well as all the graphical sketches produced by participants in hard copy and electronic formats.

#### *4.3.6 Pilot Experiments*

In September 1997, eighteen final year architecture students from the Faculty of Architecture at the University of Sydney volunteered and participated in the pilot experiments. This meant we had enough volunteers to carry out nine pilot experiments, three in each category (FTF, CMCD-a and CMCD-b, see section 4.3.1).

The subjects were paired and each pair participated in only one experiment of either category. In the end eight experiments were conducted in the space of ten days, since one of the subjects of the first FTF experiment did not show up on the day. As a result, we were able to conduct three experiments in each of the CMCD categories and two in the FTF category. All the experiments were carried out as described in section 4.3.5 with all sixteen subjects completing and signing the ‘subjects consent form’ as well as the post experiment questionnaire.

#### *4.3.7 Discussion*

In hindsight the omission of audio recorders from the FTF and CMCD-a categories, proved costly since only two of the videos (one FTF and one CMCD-a) were clear

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<sup>20</sup> Although no prior knowledge of CAD was needed for the experiments, basic mouse and keyboard skills were required. Most participants, in all the pilot CMCD sessions, had no problems at all using Inperson™.

enough to be fully transcribed. The audio on the other three videotapes was of such poor quality, because of excessive background noise, that large parts of the one-hour experiments were incomprehensible. Therefore only one experiment of each category (along with the three transcripts from the CMCD-b category) was transcribed and partially coded into the custom developed coding scheme.

The preliminary observations from the pilot study helped to clarify and further develop the procedure of the experiments. The shortcomings in the procedure of the pilot study, especially the excess noise generated around the room where the FTF experiments were held, helped in rethinking how verbal audio data are gathered. Added to that were observations that the SGIs workstations at times lacked the power to respond to users' needs especially when using the videoconferencing facility in tandem with manipulating graphics through the whiteboard.

## 4.4 Final Experiments and Implemented Changes from Pilot Study

Following the pilot study and the initial observations gathered, a range of issues regarding the running of the experiments and collection of data had to be refined. Corrective measures in the procedure of the experiments as well as upgrade of hardware were undertaken prior to proceeding with the final experiments.

Section 4.4.1 presents the development of the questionnaires, which now include ratings of the various communication channels. Background noise and other inadequacies prompted changes to the rooms and room layout for all three categories of experiments, which is further discussed in section 4.4.2.

This section of chapter four details the preparation and running of the final experiments in September of 1998.

### *4.4.1 Questionnaires*

As expected the preliminary questionnaires developed for the pilot study proved to be a bit weak. They were only meant to help us evaluate the 'running' of the pilot experiments and assist in applying any required modifications to the final experiments. The main purpose of the final questionnaires was to complement the coding scheme by providing direct input from the participants. Questions related to the importance and use of communication channels were added. Overall the questions fo-

cused on procedure of experiments, rating the value of audio, video and the graphics communication channels, as well as the importance of eye contact and various needs in a collaborative environment. Again the questionnaires were addressed to all three categories and differed slightly to suit the collaborative environment (see *appendix d* for questionnaires used in final experiments).

The compiled data, from the questionnaires, were correlated with the results of the coded and analysed communication protocols (presented in detail in section 6.5, pages 118 – 122). This in turn assisted us in checking the consistency of the coding scheme as well as providing valuable insight towards the collaborative environment directly from the participants.

#### *4.4.2 Media and Apparatus*

The experience gained from the pilot study helped us better plan the final experiments in terms of upgrading the media and apparatus used. Excessive background noise as well as a number of other factors necessitated that we modify both settings used for the pilot study. The room used for the FTF experiments in the pilot study was situated next to a computer lab used by a large number of faculty students who accessed it regularly. The high volume of student traffic outside the room generated too much background noise. This in turn reflected badly on the quality of audio recording on the videotape as well as at times in distracting the participants. A tranquil environment was essential and this factor played an important role when it came down to deciding on a location for the final experiments.

*Figure 4.5* shows the layout of the room for the final FTF experiments. The room had a deep desk placed in a position accessible from both sides with a chair for each participant on either side. The use of the bulletin board was deemed redundant since a full brief in colour was provided to each participant.

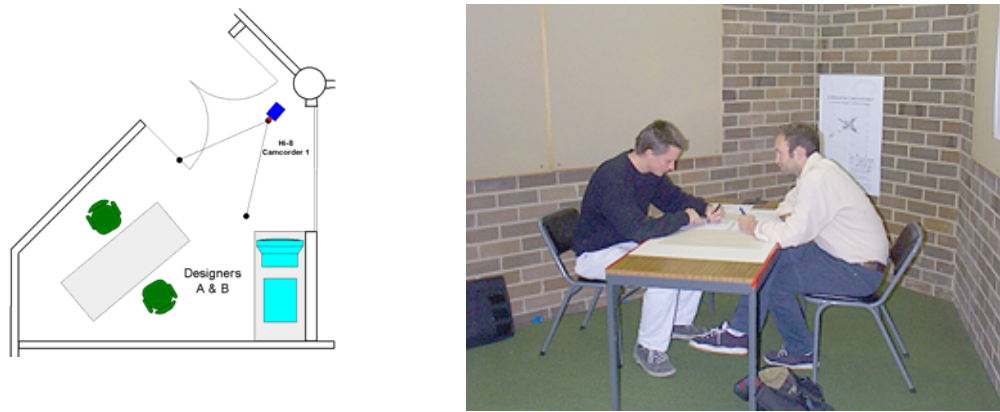


Figure 4.5 The setting for the seven FTF final experiments as well as picture of a couple of participants engaged in the collaborative process.

A Panasonic™ camcorder attached to a VCR was positioned perpendicularly to the desk in order to capture verbal and non-verbal activity between the participants. As a result of the poor audio quality in the pilot study a Sony™ tape deck along with a plate microphone, placed on the edge of the table, were used to record the collaborative communication taking place between the two participants. As in the pilot study, each pair was given six A2 sheets of tracing paper as well as felt pens. Separate A4 sheets with site plan and section were handed out to participants in order to help trace site boundaries directly onto the A2 tracing paper, if needed.

Noise was a problem also in the CMCD settings used in the pilot study. To avoid noise being transferred between the two participants through the door, between the two rooms, a third adjacent room was added to the new setting as illustrated in *figure 4.6c*. This move also helped in alleviating two minor problems. The problem of who wanted to work inside the small room as well as the problem of the participant in the large room feeling slightly intimidated by the presence of the observer in the same room (refer to layout of CMCD settings in pilot study, *figure 4.4c*).

Each room was equipped with a Silicon Graphics O2™ (O2) Unix workstation.<sup>21</sup> The two O2 were connected along with the observer's terminal (in the central room, *figures 4.6c and d*) by a high speed LAN. Two Sony™ Hi-8 camcorders were positioned behind the O2 at a slight angle, in order to capture the screen activity taking place as illustrated in *figures 4.6a and b*. The camcorders were connected to a video splitter, which produced output to a VCR and a 34inch TV monitor used by the observer as shown in *figure 4.6d*.

As in the pilot study, the CMCD-a sessions used Inperson™ for audio-visual conferencing as well as shared electronic whiteboard, *figure 4.6f*. Two Sony™ microphones on stands were placed in an unobtrusive position close to the O2 workstations. In turn the two microphones were connected to a Sony™ tape deck recorder placed on the observer's station. This move ensured that we obtained good quality audio recording which in turn helped us in transcribing the resulting communication protocols. The O2 came with video cameras that had an in built microphone to help the participants communicate. *Figure 4.7* represents a diagram of all equipment used in both CMCD categories. Following its success in the pilot study, the VC interface (see section 4.3.4) was used again in the CMCD-b sessions as a means for verbal textual communication. Once more Inperson™ without the audio and video channels was used only as a shared electronic whiteboard.

#### 4.4.3 Task and Procedure

The brief was the same as the one used for the pilot study with minor modifications in the diagrams and coloured photographs as well as in the way it was made available to participants. In the FTF category it was presented to participants in the form of a three-page A4 colour print out which included a location map, a revised site plan, a revised section through the site as well as four coloured photographs.



Figure 4.6a Workstation of participant 1



Figure 4.6b Workstation of participant 2

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<sup>21</sup> The Silicon Graphics O2 were on loan for a period of four weeks from Silicon Graphics Australia.

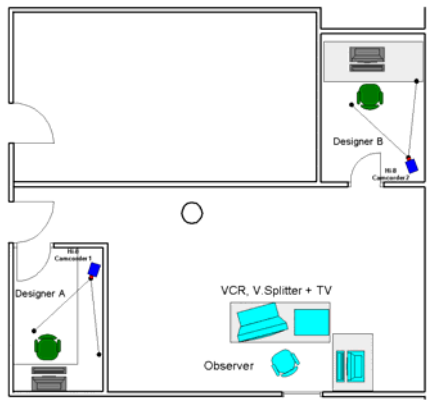


Figure 4.6c CMCD setting used for the eighteen experiments.



Figure 4.6d Observers post.

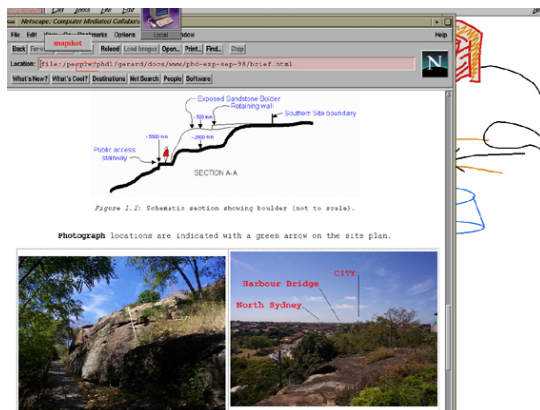


Figure 4.6e Screen grab of the brief through a Netscape™ window in front of Inperson™.

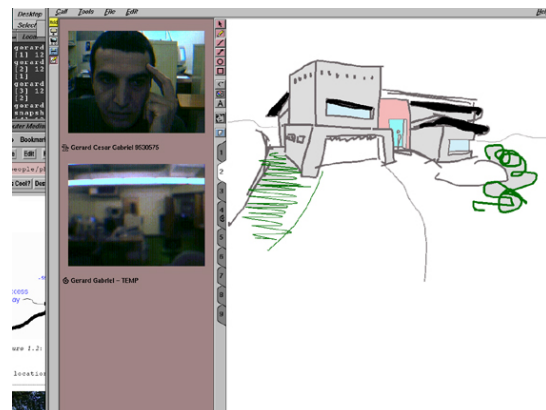


Figure 4.6f Screen grab of Inperson™, showing video windows as well as shared whiteboard.

Figure 4.6 The setting for the six CMCD final experiments also showing the observers post and participants workstations.

The html version of the brief, used in all CMCD sessions, was updated to reflect the changes done to the hard copy version (handed over to the participants of the FTF sessions) and was accessible through a Netscape™ window as illustrated in figure 4.6e.

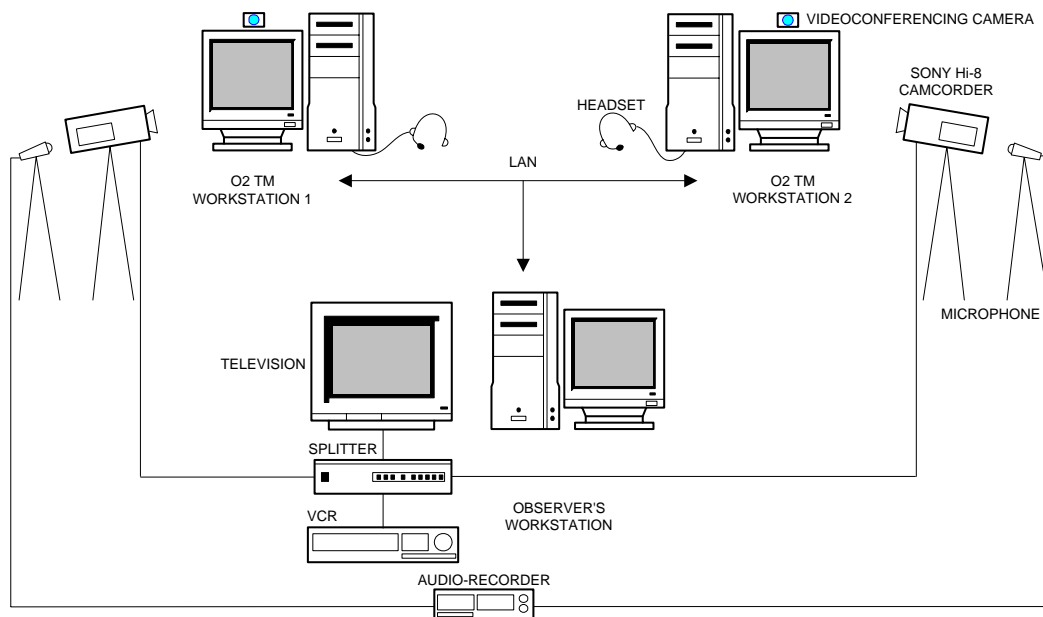


Figure 4.7 Diagram of all equipment used in both CMCD categories of the final experiments.

Participants were welcomed on arrival to the experiment location and thanked in advance for their participation. A 'subjects consent form' was completed by each participant prior to the briefing and participants were reassured of their anonymity when it came to publishing the findings.

Briefings for the FTF experiments took place around ten minutes before the start of the experiments allowing time for questions and clarification about the task at hand. For the CMCD sessions briefing occurred twenty minutes before the start of the one-hour experiments. This gave participants ample time to ask questions as well as time to practice using the drawing tools of Inperson™ and the VC interface in the CMCD-b sessions.

All participants were instructed that they would be notified at the fifty-minute mark, in order to start wrapping up their ideas. They were also notified that a final design is not expected at the end of one hour, instead basic planning sketches in 2D and 3D would be enough. As in the pilot study, participants were asked not to delete or destroy any information in all three categories of experiments.

#### 4.4.4 Final Experiments

Timing was critical in organising and running the final experiments. Final year architecture students have a hectic schedule hence the experiments had to be done in the first half of the semester.

In September of 1998, we conducted the final twenty-five one hour experiments using fifty 5th and 6th year architecture students from the Faculty of Architecture at the University of Sydney (for a full list of participants see *appendix e*). The participants were paired and each pair participated in only one experiment from any of the three categories using the same brief. We conducted seven experiments in the FTF category, eight in the CMCD-a and ten in the CMCD-b categories.

The main reason for not doing an equal number of experiments in all three categories was our concern of potential technical, logistical and human related problems. Since most of the equipment was on loan and had to be returned in a very short period of time, we decided to carry out the largest amount of experiments that required the most preparation, up front. It was decided that seven experiments in each category would be needed (in order to get an adequate data set) thus the buffer of the extra CMCD sessions. The FTF category only needed the participants, which was a lot easier to organise if a problem occurred with one of the FTF protocols.

The one-hour sessions were audio and video taped, and the ensuing communication protocols later transcribed, coded and analysed.

As a way of acknowledging the students' involvement in the final experiments, each participant was given a copy of the latest issue of the architectural magazine '*Monument*' as well as two cinema tickets.

#### *4.4.5 Discussion*

The final experiments had their fair share of problems and delays. Initially they were planned for March of 1998, but an insufficient number of 6th year students meant that we had to delay the experiments until September of that year. For this reason we decided to use a combination of 5th and 6th architecture students.

Organising fifty students into twenty-five experiments to be held in the space of three weeks was a challenge. The first week saw many changes to the schedule when some participants realised that they could not make it on the day of the experiment. Pairs were reshuffled and experiments postponed but in the end they were all completed in three and a half weeks.

Problems encountered with the audio recording apparatus in the pilot study were not totally avoided in the final experiments for two reasons. The first came in the form of the highly sensitive microphones we used for the tape deck recorders. The micro-

phones worked very well except they were picking up the noise of the return air ‘hiss’ from the air conditioning (A/C) grills. That problem was rectified by ‘taping’ the A/C grills but not until after having run three FTF experiments.

The second problem was human related with some participants in the FTF experiment going into a ‘muttering’ rhythm every now and then. At times this was due to having both hands free and propping their chin while talking<sup>22</sup> and at other times when they spoke away from the microphone.

Although participants were instructed at the start to try and speak clearly at all times, an observer in the room reminding them of that would have been disruptive and detrimental to the flow of collaborative communication.

The surprises did not stop there. On one occasion we had problems with one of the microphones at the start of a CMCD-a experiment. The participants had to wait for close to an hour while the Faculty’s technician<sup>23</sup> installed two new matching Sony™ microphones along with new cabling and tested the whole set-up. Fortunately, the participants spent the time browsing their new magazines.

## 4.5 Summary

In this chapter we discussed the development of research instruments used for gathering data as well as the preparation and procedure of both the pilot and final experiments.

We started by outlining some of the variables affecting the experiments, like time, space and media as well as the participants. We also presented the brief, the preliminary and final questionnaires, the media and apparatus used as well as the general procedure of the experiments.

The three categories simulating FTF collaborative sessions and CMCD sessions between architects were presented.

Some problems, encountered during the pilot study, were presented as well as the ensuing solution for the final experiment.

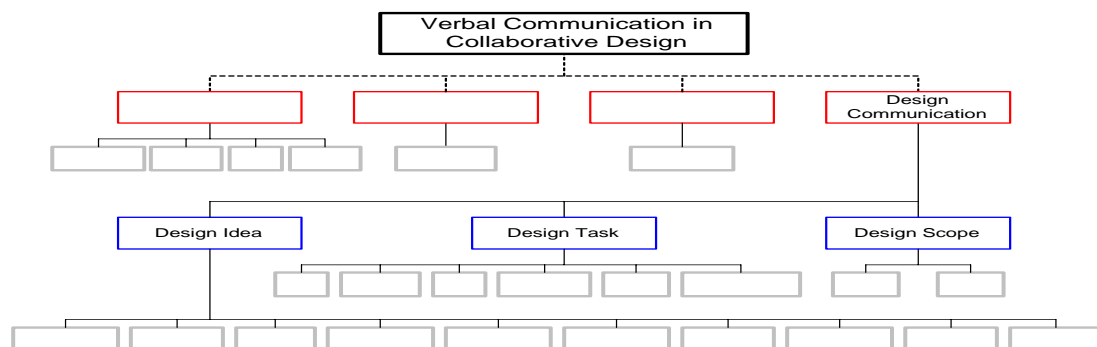
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<sup>22</sup> As a comparison participants in the CMCD-a sessions had their hands occupied with the mouse and keyboard nearly all the time.

<sup>23</sup> Ken was always available to help at very short notice and many thanks go his way for helping in setting out and testing the audio equipment.

# Chapter 5

## Development and Use of a Design Communication Coding Scheme



Chapter five reports on the coding scheme used in this thesis. It begins by outlining the way the preliminary coding scheme was developed for the pilot experiments. The coding scheme developed for the final experiments is then presented and examples given. The chapter also presents the coding methodology used in this thesis; the transcription and preparation process of recorded data prior to coding, the methods used to minimise coding errors as well as the arbitration process.

## 5.1 Development of Pilot Coding Scheme

In chapter one of this thesis, it was established that we would not be analysing the design process as such. Instead we will be investigating the collaborative communication that transpires within a collaborative session. Therefore we need to record and analyse the verbal utterances, in the form of design communication protocols (DCP), that occur naturally as part of the collaborative act between two architects. Analysing these DCP involves the development of a custom coding scheme. This meant investigating existing coding schemes related in a way to our research, possibly ‘borrowing’ from them as well as further building and customising them for our own purposes.

The initial coding schemes were allowed to evolve during the preliminary analysis, since re-examination of the transcripts brought to light new data, which did not fit within the predefined categories (this was also the experience of Purcell et al., 1996, p226).

To begin with, we investigated three different coding schemes from separate research projects. The first, (see Sudweeks and Albritton, 1996) categorises communication types as follows: informal control of communication, formal control of communication, socio-emotional communication, conceptual communication, task communication. The second coding scheme investigates the amount of time spent in computer mediated collaborative sessions ‘introducing new ideas and clarifying those ideas’ (see Olson et al., 1997). The third coding scheme on the other hand classifies interaction between FTF and Video-conferencing technologies by investigating ‘Interruptions, overlaps, hand-overs and floor holding (see O’Connell and Whittaker, 1997).

As a result of this initial investigation into the characteristics of communication in collaborative architectural design, we considered the following two coding schemes:

- The first coding scheme, ‘*communication control*’, distinguished between the externally derived types of communication and the data derived sub-categories of task communication (planning the collaboration) as well as control of tools/environment. Adding to it the following externally derived sub-categories, ‘interruptions, hand-overs and floor holding’ expanded it further, *table 5.1*.
- The second coding scheme, ‘*communication content*’, distinguished between the externally derived sub-categories of ‘*socio-emotional*’ and ‘*conceptual*’ forms

of communication. *Conceptual* communication was initially formed of two externally derived sub-categories, *introduction of idea* and *clarification of idea*. After an initial run through the transcripts two more data derived sub-categories were added to conceptual communication and they are shown in *table 5.2*. Both coding schemes were applied to verbal representations recorded during the one-hour pilot design session.

<b>Communication Control</b>	<b>Code</b>	<b>Description</b>
Interruptions	<i>INT</i>	Interruptions are associated with simultaneous speech (Levinson, 1983; O'Connell and Whittaker, 1997).
Floor Holdings	<i>FLO</i>	Occurs when one speaker tries to take the conversational floor while the other attempts to hold the floor while producing utterances that do not contain any information as well as self-repetition (Jefferson, 1984; O'Connell and Whittaker, 1997).
Hand-overs	<i>HAN</i>	Three indications of relinquishing floor: a) Use of questions; b) using stereotyped questions such as "isn't it?" "Aren't they?" or statements as "you know"; (O'Connell et al., 1993) c) naming the next speaker (Sacks et al., 1974; Levinson, 1983).
<b>Task Communication</b>		
Brief	<i>TBR</i>	When participants referred back to brief.
Schedule	<i>TSC</i>	When participants worked or referred back to a schedule or program.
<b>Control of Tools/Environment</b>	<i>CTE</i>	Communication in regards to use of tools and collaborating environment.

*Table 5.1 First pilot coding scheme: Communication Control.*

<b>Communication Content</b>	<b>Code</b>	<b>Description</b>
<b>Socio-emotional Communication</b>	<i>SOC</i>	"Communication content dealing with interpersonal relationships" (Sudweeks and Albritton, 1996)
<b>Conceptual Communication</b>		
Introduction of Idea	<i>DIN</i>	When participants directly introduce a new idea (Olson et al., 1997).
Clarification of Idea	<i>CLA</i>	When a participant clarifies his/her idea to the other participant (Olson et al., 1997).
Evaluation of Idea	<i>EVA</i>	When participants spend the time evaluating and further developing the idea.
Acceptance of Idea	<i>ACC</i>	When a participant makes it clear to the other participant that he does accept an idea.

*Table 5.2 Second pilot coding scheme: Communication Content.*

After developing the pilot coding scheme, a period of testing followed where selected random segments from the pilot experiment transcripts<sup>24</sup> were coded. We soon realised that both coding schemes as they stood, were relatively limited and not detailed enough in order to code the rich communication resulting from the conversation that was taking place between the collaborating subjects. That is large segments

<sup>24</sup> Those random segments were obtained from the transcripts of the three categories of pilot experiments.

of the transcribed protocols did not fit any of the proposed categories in both coding schemes.

## 5.2 Development of Final Coding Scheme and Implementing Changes from the Pilot Coding Scheme

The initial coding schemes developed for the DCP of the pilot experiments were allowed to evolve further during the preliminary parsing of transcripts resulting from the final experiments. The richness of the final collaborative transcripts compared to the limited capacity of the pilot coding schemes to define and code the data, prompted the addition of several external, data and theory derived sub-categories. Therefore after further reviewing literature on both design (Akin, 1986; Goldschmidt, 1991) and communication protocols (Kvan, 1994; Sudweeks and Albritton, 1996; Olson et al., 1997; Vera et al., 1998) it was apparent that ‘parts’ of these coding structures could be added to our final coding scheme. In addition our theoretical views were adopted as sub-categories in the coding scheme thereby further enriching it and the ensuing analysis.

Therefore the two pilot coding schemes were merged into one becoming part of the final coding scheme, ‘*verbal communication in collaborative design*’. The final coding scheme classifies verbal communication in collaborative design into four primary categories: *communication control*, *communication technology*, *social communication and design communication*. In turn these are further broken down into sub-categories as illustrated in *figure 5.1*.

In the following sections, those primary categories as well as their secondary and tertiary sub-categories are presented in more detail. We further decompose them into more precise categories of communication, thus capturing and coding the richness of the resulting collaborative communication as well as indicating how they were derived.

### 5.2.1 Communication Control in Verbal Communication

In the first primary category *table 5.3*, we investigated existing coding schemes with relevance to *communication control* and found the ones we used in the pilot coding scheme still valid. Therefore we ‘re-used’ parts of O’Connell et al. (1997) coding scheme which included ‘*Interruptions, hand-overs and floor holding*’. In addition to

that we added a fourth ‘data derived’ sub-category naming it ‘*online acknowledgment*’. This latest inclusion covered utterances such as “mmm”, “yeah” and “aha” among others, produced by participants as an indication that they are following up the conversation or as means of indicating that they are still “online”.

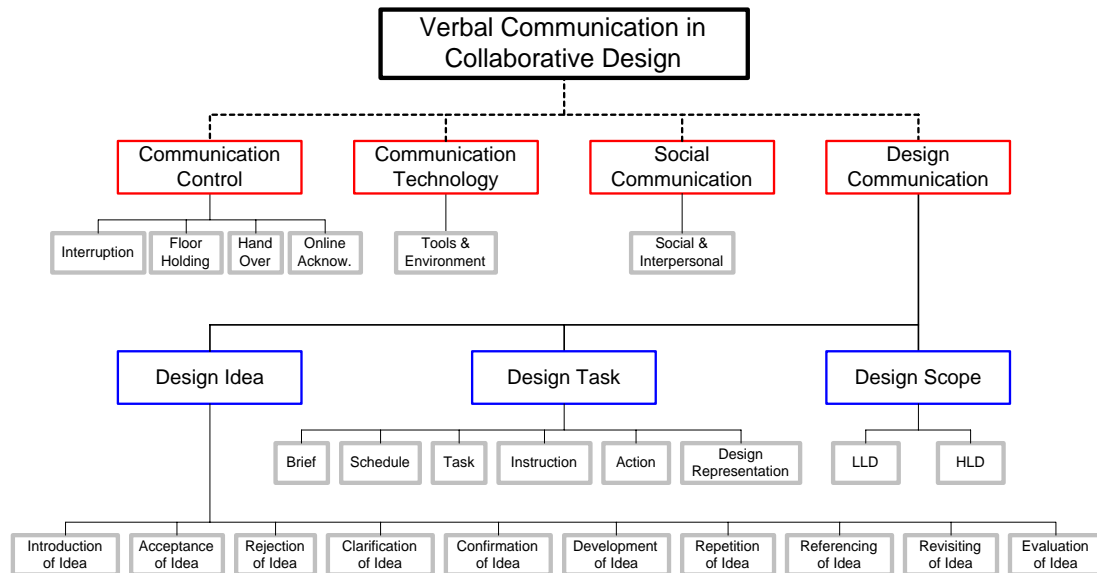


Figure 5.1 The final Verbal Communication in Collaborative Design coding scheme.

## Verbal Communication in Collaborative Design

Communication Control	Code	Description
Interruption	<i>INT</i>	Interruptions are associated with simultaneous speech (Levinson, 1983; O’Connell and Whittaker, 1997).
Floor Holding	<i>FLO</i>	Occurs when one speaker tries to take the conversational floor while the other attempts to hold the floor while producing utterances that do not contain any information as well as self-repetition (Jefferson, 1984; O’Connell and Whittaker, 1997).
Hand-over	<i>HAN</i>	Three indications of relinquishing floor: a) Use of questions; b) using stereotyped questions such as “isn’t it?” “Aren’t they?” or statements as “you know”; (O’Connell et al., 1993) c) naming the next speaker (Sacks et al., 1974; Levinson, 1983).
Online Acknowledgment	<i>ONL</i>	When a participant produces such utterances as “mmm” and “yeah” as an indication that participant is following up the conversation or as means of indicating that participant is still “Online”.

Table 5.3 The communication control primary category and its four secondary sub-categories of the final coding scheme.

These externally and data derived sub-categories will help in identifying possible differences between the three distinct collaborative mediums (FTF, CMCD-a and CMCD-b), by showing either an increase or a decrease in levels of interruptions, floor holding, explicit hand-overs as well as online acknowledgement. This in turn

could further clarify the process through which communication flows between collaborating subjects as well as the continuity of proposed and discussed ideas.

### 5.2.2 *Communication Technology & Social Communication in Verbal Communication*

The second and third primary categories, which look at *communication technology* and *social communication*, were re-used from the pilot coding scheme, *table 5.4*. Under the data derived *communication technology* we had the *tools and environment* secondary sub-category that coded utterances relating to the use of drawing tools, user interface and the general collaborating environment in all three categories. We were particularly interested to see whether this classification increases or decreases by altering the communication channels in the different collaborative mediums.

On the other hand the externally derived *social and interpersonal* secondary sub-category under *social communication*, coded utterances dealing with interpersonal relationships as well as joking and laughing among other things. Of interest to us was whether the changes in communication channels affected the amount of time spent ‘socialising’ in the three collaborative mediums.

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#### **Verbal Communication in Collaborative Design**

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<b>Communication Technology</b>	Code	Description
Tools & Environment	<i>CTE</i>	Communication in regards to use of tools and collaborating environment.
<b>Social Communication</b>		
Social & Interpersonal	<i>SOC</i>	“Communication content dealing with interpersonal relationships” (Sudweeks and Albritton, 1996).

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*Table 5.4 The communication technology and social communication primary categories and their two sub-categories of the final coding scheme.*

### 5.2.3 *Design Communication in Verbal Communication*

After reading through all the transcribed DCP and reviewing the videotapes, we soon discovered that the ‘*conceptual communication*’ sub-category of the pilot coding scheme (see *table 5.2*) inadequately represented the rich design data being communicated between the collaborating subjects. In order to adjust that deficiency we set about reviewing random sections from all the DCP observing and highlighting repeated patterns of communication. This resulted in the development of a preliminary set of sub-categories to code specific design communication characteristics. Those

were later finalised and firmed into three secondary sub-categories forming the fourth and final primary category, *design communication*, which mainly dealt with the way participants appeared to communicate their design ideas and design tasks.

Our intention was to detect qualitative and quantitative variations (if any) in design communication between the three different mediums and whether discussing and communicating design ideas suffered from the loss of certain communication channels in the CMCD environments.

The three secondary sub-categories of *design communication* are *design idea*, *design scope* and *design task*. *Table 5.5* further summarises in detail the tertiary level of coding under design communication.

***Design idea*** deals with direct and indirect verbally communicated design ideas and design intentions. The majority of the tertiary level codes in this sub-category were ‘theory and data generated’, only three being ‘externally derived’ (as shown in *table 5.5*). Therefore in addition to introduction, clarification, evaluation and acceptance of idea a host of sub-categories that emerged from the data were used to code the transcripts thus further enriching the coding scheme and reinforcing the results.

***Design scope*** on the other hand contains two tertiary level ‘externally derived’ sub-categories; low level design (LLD) and high level design (HLD) borrowed from Vera et al. (1998). The purpose behind using these two subcategories was to determine whether we would obtain similar results to the ones mentioned by Vera et al. (1998) when using similar types of collaborative environments between collaborating designers. Applied to our DCP, we were able to distinguish between LLD and HLD in the following way:

- LLD materialised at detail level. Therefore amongst the utterances coded with LLD are activities such as placing individual elements; rooms, circulation, functions, materials and colours into the framework set previously by the HLD actions.
- HLD embodied notions such as the discussion of referenced ideas, general site planning and the development of broad ideas. It also includes identifying important issues such as entry to site, relationship of building to site and vice versa, vistas and relation to northern aspect as well as theoretical, abstract and conceptual overall ideas.

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## Verbal Communication in Collaborative Design

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Design Communication	Code	Description
<b>Design Idea</b>		
Introduction of idea	<i>IDE</i>	When participants directly or indirectly (in the form of a question) introduce a new idea (Olson et al., 1997).
Acceptance of Idea	<i>ACC</i>	When a participant makes it clear to the other participant that he/she accepts a particular idea.
Rejection of idea	<i>REJ</i>	When a participant makes it clear to the other participant that he/she does not accept a particular idea.
Clarification of idea	<i>CLA</i>	When a participant 'seeks' clarification of an idea or 'presents' a clarification of an idea, sometimes in the form of a statement (Olson et al., 1997).
Confirmation of idea	<i>CON</i>	When a participant confirms an idea, for example in response to a requested clarification by the other participant.
Development of idea	<i>DEV</i>	When participants spend time refining and further developing (explaining and discussing) an idea. (Peng, 1994).
Repetition of idea	<i>REP</i>	When participants repeated or reintroduced ideas already clarified or rejected.
Referencing an idea	<i>REF</i>	When participants make references to external ideas and draw on architectural or design ideas in general.
Revisiting an idea	<i>REV</i>	When participants specifically revisited or inquired about (the whereabouts of) a graphically or textually represented idea, or mentioned an idea/ detail they have already discussed.
Evaluation of idea	<i>EVA</i>	When participants spend time evaluating an idea.
<b>Design Scope</b>		
Low-Level Design	<i>LLD</i>	When designers place individual elements, discussing colours etc ... (Vera et al., 1998).
High Level Design	<i>HLD</i>	When designers make broad decisions which affect significant aspects of their later decisions (Vera et al., 1998). Abstract ideas as well as conceptual over all ideas.
<b>Design Task</b>		
Brief	<i>BRI</i>	When participants read, analyse and refer back to brief.
Schedule	<i>SCH</i>	When participants worked on a schedule or referred back to a program.
Task	<i>TAS</i>	"A specific piece of work required to be done" (Collins Dictionary).
Action	<i>ACT</i>	A verbal or non-verbal action taken by a participant relating to a drawing task in the form of text, sketch or reference, or in pointing to a particular representation.
Instruction	<i>INS</i>	When a participant hands over instructions to the other participant on how, what or where to draw, what to do or where to go.
Design Representation	<i>DES</i>	When participants inquire about or discuss how to 'draw or represent' specific design ideas or design details. Communication about design representation in general

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*Table 5.5 The design communication primary category and its three secondary sub-categories as well as their eighteen tertiary sub-categories of the final coding scheme.*

**Design task** the third and final tertiary sub-category, deals with utterances that cover discussions on the brief, schedule, action taken as well as instructions given and various tasks to be done. It consists of six tertiary level 'theory and data generated' sub-categories which are further clarified in *table 5.5*.

## 5.3 Coding Design Communication Protocols of Final Experiments

The methodology adopted for coding the design communication protocols of the final experiments consisted of three stages: transcription, coding and arbitration. In the following sections we discuss the importance of a properly transcribed and prepared document for coding as well as the reasons and advantages of multiple coders and the coding process followed by the arbitration between coders.

### *5.3.1 Transcription and Preparation of Recorded Data Prior to Coding*

As discussed in section 4.4.5, problems encountered with the audio recording apparatus in the pilot study were not totally avoided in the final experiments. This time the problems were twofold, equipment related problems and human related problems (mainly muttering from participants). At times, this unfortunately made the task of transcribing the resulting protocols in an accurate way very difficult to say the least. New technologies were tried out to speed up the transcription process with very little success. The latest in speech recognition software was used to try and input directly from the audiotapes into the word processor via a mediator (myself).<sup>25</sup> The results were at best mediocre and at times hilarious, but basically a waste of time. Therefore we resorted to the traditional way of transcribing documents by using a Sanyo™ TRC 8800 transcribing machine with a foot pedal to start/stop and rewind the audiotape.

All FTF and CMCD-a videotapes were reviewed at least once immediately prior to transcribing and revisited during the process if the need arose. On average, the FTF and CMCD-a one-hour experiments took around six to eight hours of transcription with an average length of sixteen A4 pages. Some of the audiotapes with excessive noise took a bit longer to transcribe. In total fifteen documents were transcribed entirely and one abandoned half way through because of the bad audio quality on the tape. We ended up with eight CMCD-a and seven FTF out of the fifteen transcripts. One CMCD-a transcript was later left out (since it contained the largest amount of incomprehensible utterances) in order to bring the number of transcripts available for coding, in all three categories to seven.

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<sup>25</sup> The author 'trained' the Dragon™ Naturally Speaking speech recognition software for over a week with very little success which resulted in the abandonment of the idea altogether.

During the transcription process, the following ‘codes’ were added to the text in order to facilitate the coding process later on:

- “(TOP)” when two participants spoke over each other, interrupting each other or starting to speak simultaneously.
- “(laughs)” when one or both participants laughed.
- “(...)” incomprehensible utterances or part of an utterance.
- “...” denotes a slight pause.

On the other hand, the CMCD-b experiments produced their own transcripts through the VC (see section 4.3.4). This meant that at the end of each CMCD-b session the transcript was saved in text format and later on was ‘cleaned’ but only by replacing ‘says’ with a semicolon and removing all quotes. The reason the transcripts were cleaned was to facilitate handling them inside QSR - NUD\*IST™, the software used for the analysis. The CMCD-b transcripts average around three and a half A4 pages per experiment, since participants were observed to dramatically reduce communication control in favour of clearer and more direct design communication. Participants in the CMCD-b sessions were also observed at times, writing notes to each other on the shared whiteboard.

The following is an example of an extract from CMCD-b02 in ‘raw’ format and the subsequent ‘cleaned’ format:

Raw format:

**Toni says**, "the relationship between the critical spaces suggest some form of a heirachy eg. The parents bedroom, children's, living, workshop....."

**Alex says**, "looking at the section, with the sandstone boulders I think the fold should be an extension of the ground."

Cleaned format:

**Toni:** the relationship between the critical spaces suggest some form of a heirachy eg. The parents bedroom, children's, living, workshop.....

**Alex:** looking at the section, with the sandstone boulders I think the fold should be an extension of the ground.

To maintain a consistent trend, we followed the same non-gender specific naming policy as for the CMCD-b category. Therefore participants in the FTF and CMCD-a categories were coded as “Alex and Toni”.

### 5.3.2 Coding Process and Minimising Errors Through the use of Multiple Coders

Qualitative research uses a range of ways to discover and explore the meaning of unstructured data. On the other hand, qualitative data present a number of challenges which researchers need to deal with. These challenges are related to the nature of qualitative data, their lack of explicit organised structure, sheer volume and specificity (Gahan and Hannibal, 1998, pp 50-54). Purcell et al. (1996, p.233), maintain that qualitative research is mostly based on the subjective opinion of the researcher(s) coding the available data, thus resulting at times in possible variations between individuals coding the same data. Therefore the use of more than one individual to code the same data is a common procedure in order to ensure the accuracy of the results. This is done by quantifying the variations in their interpretation of the data (Purcell et al., 1996,p.234).

The coding process we applied in this thesis matches, in certain ways, the coding strategy adopted and used by Purcell et al. (1996, pp. 233-234) who also used 2 independent coders. They maintain a strategy that:

*“Acknowledges differences in interpretation between coders and views these differences as a legitimate opportunity to explore the data in greater detail and to develop a coherent, consensus coding which reflects the structure of the data.”*

This process follows a strategy based on the Delphi method which may be characterised as a method for structuring a group communication process in order to achieve agreement (Linstone and Turoff, 1975; Purcell et al., 1996). In our case, this meant that 2 independent coders, both architects, individually coded all twenty-one DCP transcripts. This was then followed by an arbitration process where the coders proceeded to resolve any differences in the coding thus converging towards a unified final coded DCP transcript for analysis.

At the start of the coding process, there was a period of initial familiarisation with the material and preliminary appraisal by the coders. Before starting to code, each coder viewed the videotape and read the corresponding DCP transcript in its entirety. This helped them familiarise themselves with the sequence of events and the flow of the design discussion taking place in the one-hour experiments.

After reading and analysing an individual 'text unit' (TU), each coder then proceeded to write an abbreviation of the coding sub-category, from one of the four primary categories, which he/she thought best described it. There was no limit as to how many codes a single TU can have and that number varied from one code to several codes. The method employed here was the one proposed by Radcliffe (1996, p.345) (see section 3.4.2) which meant that each TU could be coded under several sub-categories of the coding scheme.

The coding was done by categories of experiments, and each completed category was put aside for several days before initiating the arbitration process. On average, the CMCD-a and FTF DCP transcripts took around five hours each to code, while the CMCD-b ones took around one and a half hours each.

We further illustrate the coding process, followed by the individual coders, through examples from the coded DCP transcripts of each category of experiments. *Tables 5.6, 5.7 and 5.8* display excerpts of coded examples from the FTF and the CMCD transcripts respectively.

### *5.3.3 Arbitration Process Between Coders*

In the arbitration process, the coders sat down together several days after having completed coding a category individually. To refresh their memories about that particular design episode, the coders reviewed together the videotape of the particular experiment they were about to arbitrate one more time. In order to facilitate the arbitration process, a procedure was put in place, whereby the coders marked all the arbitration on the DCP transcripts of Coder A. By following this method, all arbitration was then concentrated on one transcript, which in turn made it easier to enter the coded data (agreed and arbitrated) into QSR - NUD\*IST™ for analysis.

As mentioned previously, the number of codes per TU varied between coders and therefore it was expected that some differences in interpretation between coders would occur. However having said that, a few types of differences in the final coding were observed and they are outlined with examples in *table 5.9*. The code coloured in red and struck-through was omitted after arbitration, while the code coloured in blue was added after arbitration. Once one of the above-presented differences was identified, the arbitration process began. In these particular cases, each coder presented a justification of his/her idea backed up by an argument while refer-

encing the source material, usually reaching agreement. This agreement however varied according to the degree of difference in a TU needing arbitration.

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### Verbal Communication in Collaborative Design: coded excerpt

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Type	Code	Utterance
Design Communication	<i>BRI</i>	<b>Toni:</b> It's quite a small house.
Social Communication	<i>SOC</i>	<b>Alex:</b> So maybe ... (laughter)
Design Communication	<i>EVA</i>	<b>Toni:</b> It could be more like that.
Design Communication & Communication Cont.	<i>CLA</i> + <i>FLO</i> + <i>ACT</i>	<b>Alex:</b> Yeah maybe, ... well we could go by the contours and it could be like ... (...), the house could be like ... sitting maybe ... like in that direction.
Design Communication & Communication Cont.	<i>EVA</i> + <i>IDE</i> + <i>FLO</i> + <i>ACT</i> + <i>DEV</i> + <i>LLD</i>	<b>Toni:</b> Mmmm ... (...) Another way you could do it is if you think about it, there's like these two things sort of ... sit on the boundary ... like quite thin things, and then (...) this ... sort of pool and also this sort of beautiful garden it's sort of (...) and (...). And maybe the car parks sort of parks in here, and it's like a small entry to the garden and you have to walk back in, and this is all like the living things ... so that there's a view out, which can also sort of get these views across this sort of thing, and this is like, kind of, star structure. You actually sort of view through your living room here, which is quite nice.
Design Communication	<i>CLA</i> +	<b>Toni:</b> Mmmm.... So what would we have on the west?

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Table 5.6 Coded transcript excerpt from one of the FTF experiments.

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### Verbal Communication in Collaborative Design: coded excerpt

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Type	Code	Utterance
Design Communication	<i>CLA</i> +	<b>Alex:</b> sure, and, how would you fit the sleeping emm ... the sleeping wing into this?
Design Communication & Communication Cont.	<i>CLA</i> + <i>INT</i>	<b>Toni:</b> well I mean it, ok, if this is the lower part of the site and this is the higher part of the site (TOP)
Design Communication & Communication Cont.	<i>ACC</i> + <i>INT</i>	<b>Alex:</b> yeah, yeah I like it (TOP)
Design Communication & Communication Cont.	<i>CLA</i> + <i>FLO</i>	<b>Toni:</b> well maybe if we, maybe it could be ... that the studio space, still trying to talk about what we talked about before ... went emm ... on this pavilion here ... and the ... garage was still at the back part here with the ... emm
Design Communication	<i>REF</i> + <i>LLD</i>	<b>Toni:</b> and the bedrooms all along here ... and then there was the living glass pavilion which joins the two, which was the entertaining area as well
Design Communication	<i>CLA</i> +	<b>Toni:</b> maybe? What do you think?
Design Communication & Communication Cont.	<i>CLA</i> + <i>FLO</i> + <i>LLD</i>	<b>Alex:</b> I mean it's emm ... it's a bit ...diagrammatic, ...emm, I mean that's emm ... it's kind of ... strength in that, you know, ... you can see immediately what ... what the spaces are and you could read through what they are made of ... through their materials, you know ...

---

Table 5.7 Coded transcript excerpt from one of the CMCD-a experiments.

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**Verbal Communication in Collaborative Design: coded excerpt**


---

Category	Code	Utterance
Design Communication	IDE	<b>Alex:</b> It would make a great hearth - fire
Design Communication Communication Cont.	IDE + HLD + REF + HAN	<b>Toni:</b> do you know of the Ancher house in Killara that is actually built on top of a similar sized exposed rock? It kind of perches on it, and it makes a great footing
Communication Tech.	CTE	<b>Alex:</b> sorry started using yellow
Communication Tech.	CTE	<b>Toni:</b> I'll go green then
Design Communication	ACC + EVA + REF	<b>Alex:</b> don't know the house but good idea for solidity, physically & metaphorically
Design Communication.	BRI + EVA + HLD + REF	<b>Toni:</b> yeah, and if you look at the four photos, the boulder kind of lurches out over the public pathway: there could be some scope for long FLW balconies along it
Design Communication	IDE + HLD	<b>Toni:</b> well what about putting a rooftop pool in then?
Design Communication	CLA + HLD	<b>Alex:</b> are you thinking flat useable roofs
Design Communication	CLA + HAN	<b>Toni:</b> did you get that bit about the terrace?

---

Table 5.8 Coded transcript excerpt from one of the CMCD-b experiments.

---

**Differences in coding**


---

**1 One more One less**

The first and most common difference was when coders applied similar codes to the respective TU in their transcripts, but with one more or one less code than the other.

Example:

Coder A	Coder B	Utterance
ACT + CTE + CLA	ACT + CTE + CLA + <b>TAS</b>	<b>Alex:</b> East. OK it needs to be ... I think, OK, I'll get a pencil and ... I'll go green since it's contrasting to what's there. I think that the house should be, sort of, in this sort of, oh God ... sort of there.

---

**2 Coded and Uncoded**

This less occurring difference happened when one TU was coded by a coder and not coded by the other.

Example:

Coder A	Coder B	Utterance
UNCODED <b>CLA</b>	CLA	<b>Toni:</b> If they're crawling around to the bedroom.

---

**3 All different**

This happened when coders applied totally different codes to the same TU. Most of the time this was due to the lack in clarity of the TU. This was either because of the problems in transcription highlighted earlier or due to the ambiguity of the TU, which meant that interpreting and coding it was fairly hard.

Example:

Coder A	Coder B	Utterance
<b>ACT</b> + DEV + LLD	<b>CLA</b>	<b>Toni:</b> you fold up in between

---

Table 5.9 The major 'types' of differences observed in coding between coders A and B.

Arbitration fluctuated from adopting the code of one coder against the other and vice versa, going for a totally new code which both coders agreed upon or decided to

leave the TU uncoded. A method of colour coding the different types of arbitrations was devised and is summed up in *table 5.10*. The main reason behind the arbitration coding scheme was to get a feel for the difference in interpretation between coders and the level of arbitration. This was made possible by entering the colour-coded arbitrations in QSR - NUD\*IST™ at the same time as the agreed and arbitrated coding.

Arbitration Coding Scheme		
Category	Code	Description
Uncoded	<i>X (Blue)</i>	When a coder could not resolve what code would apply to a particular TU or when the TU was not clear enough because of either the ambiguity of the utterance or because of missing words as a result of difficulties in transcription. This was usually marked with the letter 'X' in blue.
Late Decision	<i>(Blue)</i>	Occurred when after arbitration on a particular utterance the coders decided not to go with either of their original codes, but with a new one. The new code was then written in blue.
Coder A Arbitration	<i>(Red)</i>	Occurred when after arbitration on a particular utterance the coder decided to go with the original choice of coder A. The code was then highlighted in red.
Coder B Arbitration	<i>(Green)</i>	Occurred when after arbitration on a particular utterance the coder decided to go with the original choice of coder B. The original code of coder was then struck and replaced with the original code of coder B in green.

*Table 5.10 The arbitration coding scheme.*

*Figure 5.2* demonstrates the percentage of arbitrated and uncoded TU in the three categories of experiments compared to the total number of agreed upon TU. In general, utterances in the CMCD-b category were much more dense which probably explains the reason for the higher level of arbitration and lower level of uncoded 'text units'.

However we need to clarify here that this is not the overall percentage of variation, between arbitrated and agreed 'codes', since it covers a degree of variance within a TU where only one out of six possible codes could be different. This means that the total variance in number of codes per experiment per category could be markedly lower than the variance per TU. In other words, the ratio of the total number of arbitrated and agreed upon codes to that of the total number of codes per experiment will be lower than the ratio of total number of arbitrated and agreed upon codes to that of the total number of TU per experiment. In turn, this potentially translates into a higher level of agreement than what is presented in *figure 5.2*. Having said that and

because of the limitations in QSR - NUD\*IST™ we only show the percentage of variance in TU where there was an average of around 78% of agreement.

## 5.4 Summary

We started this chapter by outlining the method by which both coding schemes were developed. We also presented the transcription, and coding as well as the arbitration processes carried out on the twenty-one transcripts from the three categories of experiments. Initial testing of the pilot coding scheme exposed its limited potential in properly coding design communication protocols. Therefore the main reason for developing a detailed custom coding scheme can be summed up as follows:

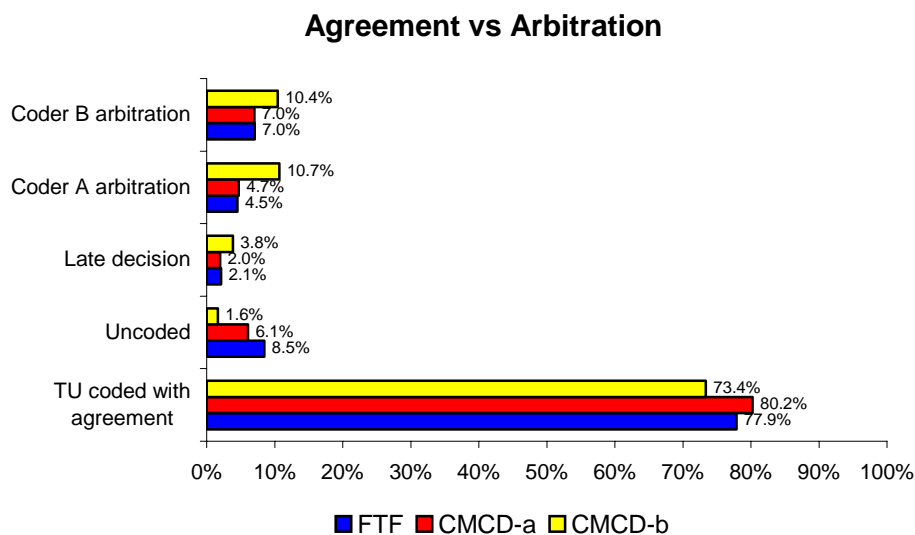


Figure 5.2 The average percentage of agreement vs arbitration between coders per 'text unit' in all three categories of experiments.

- In order to assess the potential differences in verbal design representation between pairs of collaborating architects in the different collaborative environments outlined earlier.
- To investigate whether the exclusion of certain 'communication channels' in a CMCD environment might affect the flow and quality of synchronous collaborative communication.

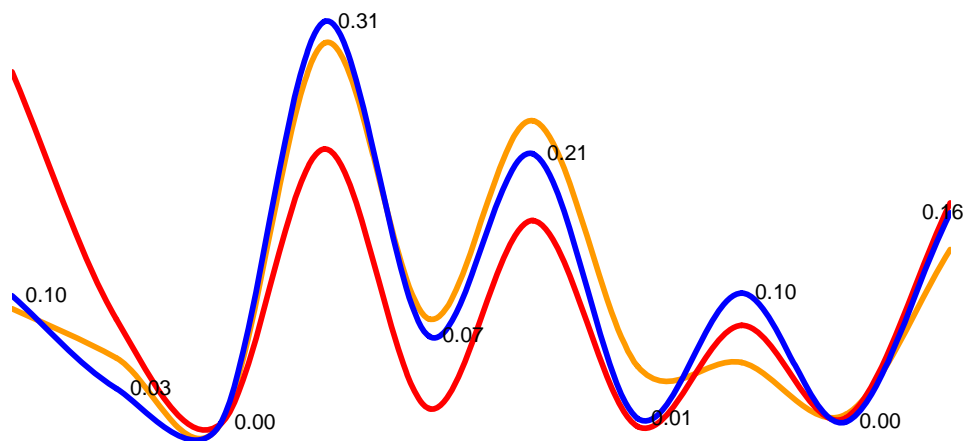
Therefore the primary categories of our final coding scheme presented above, are not intended to be exhaustive, but to indicate, through analysis, the relative amounts of communication in each category when comparing FTF and CMCD sessions between collaborating architects.

However having said that, it is essential here to clarify that the complexity of the custom developed coding scheme (through the detailed coding levels present within the primary categories) facilitated the coding of the rich DCP. This explains the high level of agreement, between both coders, on the total number of coded TU compared to arbitrated TU. Such consensus reached between both coders indicates the good quality of the final results.

This in turn makes the custom developed coding scheme presented earlier a significant contribution in itself.

# Chapter 6

## Computer-Mediation and Collaborative Design Communication



Chapter six reports on the quantitative and qualitative results and analysis of the experiments held and discussed in previous chapters. Measures and characterisations are presented in the form of differences in communication, and verbal design representations observed in the three distinct collaborative environments discussed in chapter four. The results of the analysed data from the design communication protocols are correlated with the results obtained from the questionnaires followed by the conclusion.

## 6.1 Quantitative and Qualitative Interpretation of Results

Earlier in chapters four and five we recounted the process of setting up the experiments and organising the participants as well as the post experiment processes: transcription, coding and arbitration. In this chapter we report on the results obtained from the analysis of the DCP.

The twenty-one experiments used in this study are a sample of collaborative design activity. They involve pairs of architecture students collaborating and communicating their design ideas on a conceptual design, through three different collaborative environments. Although the results may not generalise statistically, they do however raise our level of understanding about the effects of communication channels on collaborative design communication in general and verbal design representations in particular.

The analysis of the coded DCP, in this thesis, is accomplished through utilising quantitative and qualitative methods. In this chapter we describe through quantitative measures as well as the qualitative observations and characterisations the differences between the three collaborative environments.

### *6.1.1 Central Tendency of Results Using the Arithmetic Mean*

It is important here to clarify how the results in this chapter were obtained. As stated in section 5.3.1 there was a significant difference in transcript lengths between the three categories of experiments as well as within each category itself. In other words the one-hour experiments in the FTF and CMCD-a categories averaged a much higher total of TU per transcript (739 and 653 TU respectively) than the CMCD-b category (91 TU). This, we believe, is primarily due to the variations in the communication channels between categories of experiments which in turn led to the dramatic reduction of communication control by the CMCD-b participants in favour of clearer shorter and more direct design communication. Another reason could be that participants in the CMCD-b sessions were at times observed annotating their sketches on the shared whiteboard therefore bypassing the use of the VC. That information could not be inserted in the transcripts for two main reasons; time sequence and anonymity of utterance's owner.

Given that the time variable was the same for all experiments, the variance in the total number of TU per experiment per category as well as across categories resulted in

both negatively and positively skewed distributions. This in turn resulted in slightly skewed distributions of coded TU per sub-category of the coding scheme.

Having said that, we investigated using the median as a measure of the central tendency of the data, since the mean can be greatly influenced by extreme scores or skewed distributions. Only we found that the differences between the results using both the mean and the median were very small (appendix g, pages 162 – 170).

For that reason using the mean<sup>26</sup> as a measure of the central tendency was more appropriate in our case, since we also needed to use the Standard Deviation<sup>27</sup> (StDev) of the mean as well. Therefore all results conveyed in this chapter are reported in the form of the mean unless indicated otherwise.

All results obtained from QSR - NUD\*IST™, of each sub-category in each experiment, with their normalised values as well as calculated means, medians and StDev are illustrated in appendix G.

## 6.2 Observed and Analysed Differences between the Three Collaborative Environments: Measures and Characterisation

After the initial direct observations,<sup>28</sup> and the reviewing of the videotapes as well as analysis of the DCP, some expected and unexpected results emerged, which are presented in subsequent sections of this chapter. A glimpse at the distribution of overall coded text units, across the four primary coding categories in all three categories of experiments, reveals some important variations, figure 6.1. These differences are clearly demonstrated, for example, in the lower level of communication control and the higher level of design communication in CMCD-b compared to the other two categories.

However, to further measure these differences and assess the impact of the distinct collaborative mediums in the three categories of experiments, we characterise our observations and analysis of the coded DCP into two principal classifications. These are differences in *communication* (related to the first 3 secondary sub-categories of the final coding scheme) and differences in *verbal design representation* (related to the fourth secondary sub-category of the final coding scheme). In the following sections we report on findings, observations and differences within these two principal

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<sup>26</sup> Data representing the mean is highlighted in bold throughout chapter six.

<sup>27</sup> The standard deviation is a measure of how widely values are dispersed from the average value (the mean).

<sup>28</sup> Preliminary observations held by the author during the implementation of the final experiments.

classifications, by further expanding and investigating the results of the experiments through the sub-categories of the final coding scheme, as outlined in table 5.5.

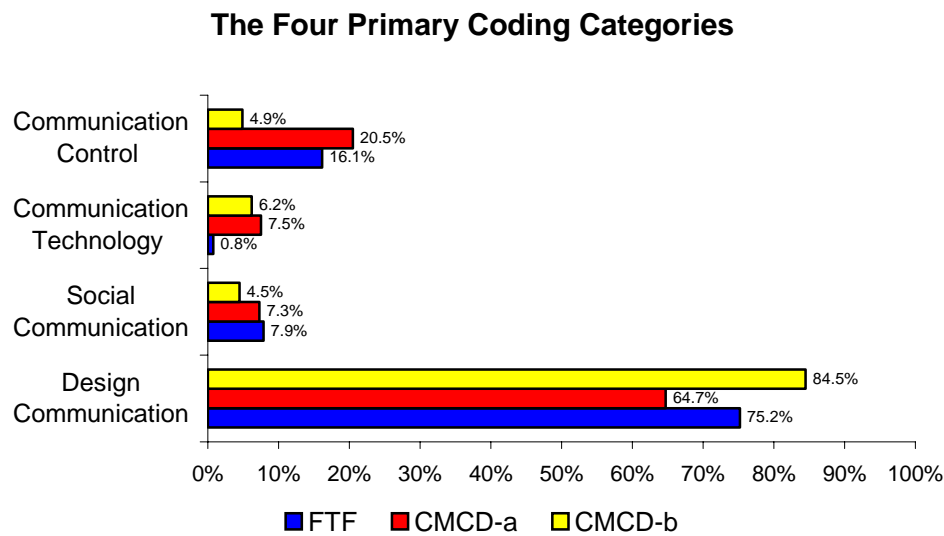


Figure 6.1 Distribution of the four primary coding categories across the three categories of experiments.

## 6.3 Differences in Communication between the 3 categories of Experiments

We start by comparing communication differences across the three categories of experiments and whether this was affected, in any way, by the use of different communication channels in the CMCD-b category. Here we report on general observed differences in communication as well as variations related to the first three primary categories of our final coding scheme:<sup>29</sup> *communication control*, *communication technology* and *social communication*.

### 6.3.1 Variations in Communication Control

Communication Control varied markedly between the three categories of experiments. As predicted, we were expecting differences at the level of communication control mainly between FTF and CMCD-a categories on one side and the CMCD-b category on the other. We believed that the participants in CMCD-a will produce higher levels of interruptions in an attempt to overcome the novel collaborative envi-

<sup>29</sup> 'verbal communication in collaborative design', for the full coding scheme, see chapter five section 5.2.

ronment and the remoteness created by the communication medium. However the unexpected result came in the form of higher *interruptions* in FTF, although minimal, and not in CMCD-a as illustrated in *figure 6.2*.

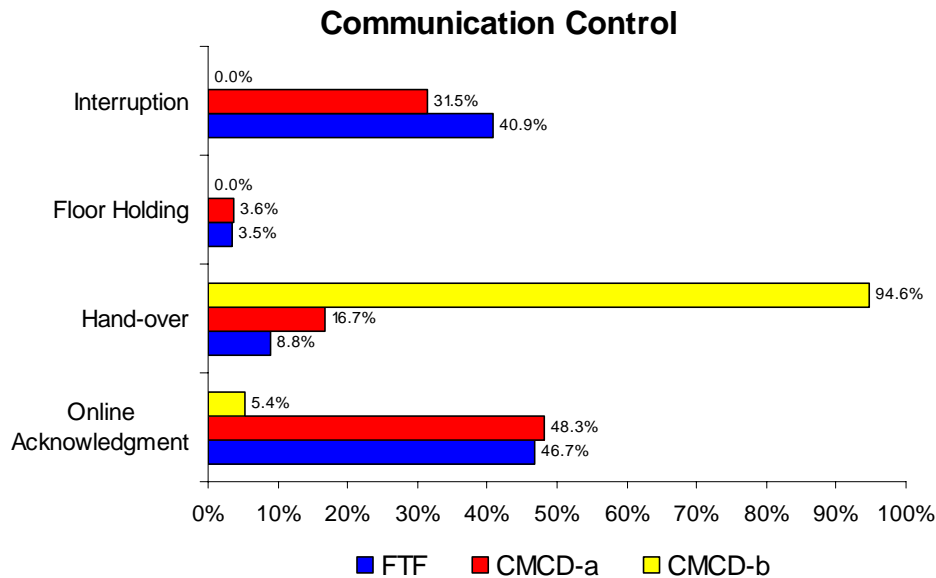


Figure 6.2 Distribution of communication control across the three categories of experiments.

**FTF.** In general verbal (audio) communication in the FTF category was ‘spontaneous’ and the participating subjects were observed speaking throughout the experiment, often repeating verbal utterances. From the word go, there were brief periods when they did not chat, even when each participant was working on a separate sketch. At times participants were observed competing for the ‘conversational floor’ which resulted in higher levels of interruptions thereby obstructing the flow of communication (**40.9%** interruptions out of total TU coded under communication control with a StDev of 8.9%). On several occasions participants who were interrupted while attempting to discuss an idea, never bothered to continue after regaining the floor, e.g.:

**Alex:** and then that can be sort of emm ... and also if we are talking about maybe going in deeper so that we excavate a bit further so that the bedroom can be off the cave like a quiet ... nestled area ... emm maybe (TOP)

**Toni:** how, how would you put the swimming pool?

**Alex:** I do not know

**Toni:** probably we put the swimming pool in a place where it is sunny (...) in the western part"

In addition to *interruption* being the highest, in FTF out of the three categories of experiments, the other highly omnipresent characteristic observed was *online acknowledgement*, figure 6.2 (49.3% of total TU coded under communication control, StDev 6%). Participants constantly used the utterances “mmm”, “yeah” and “aha” among others, to indicate their attentiveness to their partners as well as their “online” presence. Both *hand-over* and *floor holding* returned fairly low levels (8.8% & 3.5% with a StDev of 5% & 4.5% respectively). The higher standard deviation in both *hand-over* & *floor holding* indicates that there was no clear trend emerging. However if we consider the four sub-categories of communication control in the FTF category, *floor holding* consistently scored the lowest values.

Even though participants were seated across from each other on the same table they still managed, at times, to get distracted from following what their partner was saying and therefore lost the thread of the conversation. In this case and since communication was spontaneous, repeated utterances were never the same and thus at times chunks of information were lost forever. In the following example, the participant ‘Toni’ was gazing at a sketch while ‘Alex’ was developing and evaluating an idea verbally. Toni asked for a clarification, and Alex struggled to reword the previous explanatory utterance only to be interrupted by Toni, and this time losing the information for good:

**Alex:** we can go all the way across to here ... see this is the parent's bedroom above ah because I quite like the idea of opening ... into the under ... space ... about 10 meters by 10 or something, which is huge ... then you can have a bathroom here and then another bathroom ... ensuite

**Toni:** sorry, what do you do?

**Alex:** sorry, I was just saying that maybe this is the emm, ... this is the line of this (TOP)"

FTF participants were also observed to hold non-simultaneous occasional eye contact. For example participant A would speak at length about an idea or simply ask a question and look at participant B for a reaction and an answer, while participant B was either drawing, reading the brief or just ‘staring’ in a totally

different direction. When both participants ‘locked’ eye contact, it was mainly due to either a repeated question (that grabbed their attention) or a joke, which got both of them laughing. Even in the case of excitement about a new idea, eye contact was very brief and was soon diverted back to a sketch and on some limited occasions to hand gesturing.

**CMCD-a.** Similar to the FTF category in many ways, verbal (audio) communication in the CMCD-a category was ‘spontaneous’, and subjects talked all the time repeating verbal utterances. However, as mentioned earlier, contrary to our expectations, the level of *interruptions* in the CMCD-a category was lower, compared to the FTF one as shown in *figure 6.2* (**40.9%** FTF and **31.5%** CMCD-a StDev 10.5%). Nevertheless the same counter effects produced by *interruptions* in FTF were present in the CMCD-a category, mainly failure to continue discussing ideas after regaining the conversational floor e.g.:

**Toni:** falling water (TOP)

**Alex:** and the pool ... say again?

**Toni:** mmm, yeah go on"

Having said that, the difference in the level of *online acknowledgement* between the FTF and CMCD-a categories was negligible (**46.7%** FTF and **48.3%** CMCD-a StDev 9.6%). We believe the high level of online acknowledgement in CMCD-a can be in a way attributed to the necessity, felt by the participants, of establishing and maintaining an ‘online presence’. We feel that this is due to the need of overcoming the silence as well as bridging the distance created by the collaborative medium.

The level of *Floor holding* was virtually the same as in the FTF category (**3.5%** FTF and **3.6%** CMCD-a StDev 1.5%) which did not seem to have any effect on the over all management of communication between participants. Having said that, the utterances coded under the *hand-over* sub-category nearly doubled that of the FTF category (**8.8%** FTF and **16.7%**CMCD-a StDev 6.2%). This combined with the lower level of *interruptions* could be interpreted as a sign of courteousness that the collaborative medium creates.

Participants in the CMCD-a category hardly used the video channel as was expected. It was mostly used at the onset of the experiments and most of the time

participants proceeded to cover it with the brief for the remainder of the session. In a sense the video channel was used initially to ‘check out’ the way their partners looked on video, briefly exchanged some light humour, had a laugh and that was the end of it, e.g.:

**Alex:** Just reading ... I can only see from your nose up, like I can see your eyes and your nose. If you just sit back a bit, you're getting a bit too close to the camera. The camera just needs to be on a different angle. Oh that's better I can see your chin and everything now (both laugh)".

**CMCD-b.** On the other hand, participants in the CMCD-b sessions were less ‘spontaneous’ in their verbal (typed text) communication than both the FTF and CMCD-a categories. It seemed that they were not perturbed by the ‘online silence’ (see *figure 6.2*) and were observed to take their time thinking and reflecting while ‘typing’ their thoughts before communicating them over to their partners. A few times they were even observed deleting a few words or rewording their ‘written verbal representations’ before sending them over. In other words, there was no self-repetition and they were getting straight to the point rather than spending time on chit-chat.

Another significant observation is that a number of subjects in the CMCD-b sessions occasionally scrolled up through the recorded text of their conversation in the VC. One explanation could be that they were searching for clues and verbal representations that they or their partner had previously stated. This is harder to achieve in the FTF or CMCD-a sessions, since the subjects were more spontaneous and audio representations were lost forever<sup>30</sup> soon after they were uttered.

The nature of the collaborative medium<sup>31</sup> did not allow *interruptions* since the subjects had to complete their verbal text utterances before sending them over. This explains the zero levels of both *floor holding* and *interruption*.

However having said that, there was a substantial increase in the level of hand-over in the CMCD-b category compared with the other two categories (**8.8%**

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<sup>30</sup> Unless the conversation was taped, but this will make the process of rewinding and listening to past utterances a bit of a nuisance and not very practical.

<sup>31</sup> Participants used the Virtual Campus interface as their text based verbal communication medium, which in turn is based on the LambdaMOO. See section 4.3.4 for more information.

FTF, **16.7%** CMCD-a and **94.6%** CMCD-b StDev 9.8%).<sup>32</sup> This could be attributed to the loss of the audio-visual channels thereby removing the possibility of indirect alternation of the discussion, between participants, and invitation of comment or advice. Therefore higher levels of hand-over can be interpreted as a 'turn taking'; signalling mechanism, whereby participants needing feedback or confirmation on whether an idea was understood or appreciated would do so directly and explicitly.

Following are examples of hand-over extracted from the CMCD-b category:

**Toni:** do you agree with the room arrangement I proposed or do you want something on one level?"

Another example:

**Alex:** I think we need to try and represent this as a 3D object with a rough perspective or something.what do you think?"

### 6.3.2 Variations in Communication Technology

Communication Technology as expected, was nearly non-existent in FTF compared with the other two categories as shown in *figure 6.3* (**1%** FTF StDev 0.6, **9.7%** CMCD-a StDev 3.7 and **7.7%** CMCD-b StDev 2%). Although participants in the CMCD categories were given time to familiarise themselves with the tools and the environment prior to the commencement of the experiments, they still had some minor difficulties. Having said that, we had anticipated participants in the CMCD categories to produce a higher level of utterances coded under communication technology, since the majority were new to the technology and to this kind of collaborative environment.

**FTF.** Even with a very low level of utterances coded under communication technology some of the participants still communicated and discussed issues related to the technology at hand. For example one participant was not very keen on using the issued pens and expressed a clear preference on using a different tool instead:

**Toni:** where is my charcoal?

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<sup>32</sup> Those percentages are from the mean distribution of the total number of text units coded under communication control in each of the three categories of experiments.

**Alex:** (laughs) ...okay the other thing is that if we have this living

**Toni:** I need my charcoal

**Alex:** I think it is a little bit messy ... I prefer using pastels

**Toni:** nah, I much better prefer to work with charcoal

**Alex:** really?"

### Communication Technology

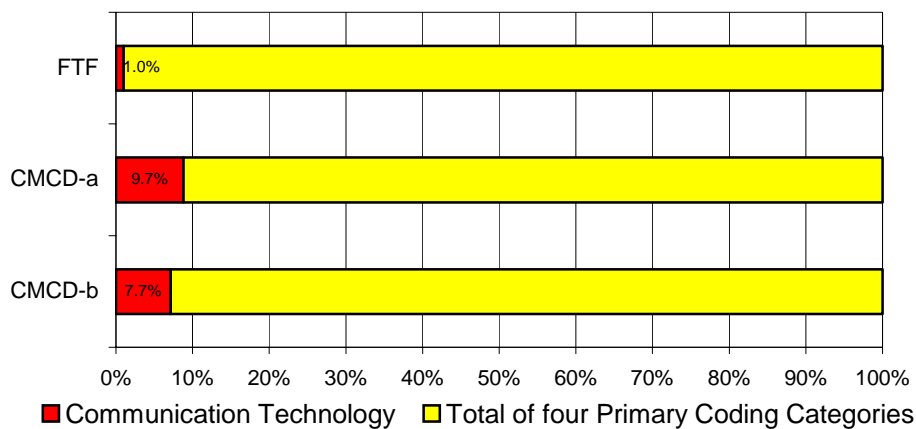


Figure 6.3 Distribution of communication technology across the three categories of experiments.

**CMCD-a.** The subjects in this category initially had some difficulty adjusting to the new collaborative medium, but most of them settled in within a few minutes without major problems. At times participants were observed ‘thinking aloud’ and communicating to their partners what they were trying to do and what tool or colour they were about to use or had problems using, or even that they were moving to a new page, e.g.:

**“Alex:** And, I'm just trying to select a colour, and it's not working. I guess I'll go to a new page. OK. Pencil. What colour am I. OK, let's do it. Um, OK ... this section ... um ... (laughs). Oh my God.”

Although Inperson’s™ interface was very simple with straightforward easy to use drawing and editing tools, participants still found the mouse, as a substitute to the pencil, awkward and frustrating to draw with. Therefore a large chunk

of communication technology revolved around the use of the drawing and editing tools including mouse, e.g.:

**Alex:** I mean (TOP) have you ever tried to draw a small person with a mouse? It's really hard!

**Toni:** (laughs) I'm afraid my computer skills are limited in that way yeah"

At times participants also communicated their frustration at the limitations of the medium. In the example below, 'Alex' was frustrated about not being able to point with the cursor on the brief page<sup>33</sup> and make that display synchronously on 'Toni's' brief page:

**Alex:** Yeah, like ... If I ... Can you ... make ... I can't actually point to anything. We can't communicate on anything.

**Toni:** No, I can't see it here, yeah.

**Alex:** We need to be able to communicate on this drawing by, by clicking"

At other times they were just happy to share their discoveries on how to use certain tools with their partners, e.g.:

**Alex:** (TOP) Yeah that's what I was just thinking, I've got to ... Straight line, OK. We're going in a straight line now. Oh God I've just moved something did I? Just dragged, I just dragged that thing away ... Drag this ... Hey, this is wild!"

**CMCD-b.** Similar to CMCD-a, the participants in this category had some difficulties initially, mainly not knowing when the other person was writing or reading, thus creating a lapse in communication. This is not necessarily a disadvantage, since participants were able to do multiple activities in parallel without disturbing each other's activities or concentration, instead of constantly making an effort to stay 'on-line'. Another technical difficulty, imposed by the collaborative environment, materialised in the physical impossibility of drawing and verbally explaining representations simultaneously.<sup>34</sup> However they soon overcame this by quickly annotating their sketches with short notes, thus

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<sup>33</sup> The brief was displayed through a Netscape™ window, which was not 'synchronised' between the two workstations.

linking their verbal representation to the graphical representation. On the other hand, they still reminded each other every now and then not to write on the whiteboard, but in the VC, e.g.:

**Alex:** best not to write on the white board"

The largest chunk of utterances coded under communication technology was by far about navigating through the 'drawing pages' of Inperson™. Although Inperson™ allowed participants to automatically 'summon' their partners onto the page they were working on,<sup>35</sup> they still preferred to ask before relocating their partners, e.g.:

**Alex:** can I shift u to page 3"

Another example:

**Alex:** come to page 13 for better space"

Or even just to check what page they were drawing on,<sup>36</sup> what page to draw on or whether it is better to go to a new blank page, e.g.:

**Alex:** I am working on page 11 of upper story plan"

Another example:

**Alex:** should we draw up one on page 8? a 'clean' page?"

At times participants in the CMCD-b category showed clear frustration of the collaborative tools they were using, e.g.:

**Toni:** I am getting really frustrated with the limitations of the drawing capabilities of this computer.

**Alex:** I think if that is the case we should think about materials and assembly, as lightweight is very regular and organic is most usually haphazard. Yes the computer is limiting."

In a similar but less frequent way to the CMCD-a category, the subjects expressed their thoughts about the medium out loud in writing, e.g.:

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<sup>34</sup> For reasons of obtaining a sequential transcript of the sessions (described in chapter four), participants were asked to communicate verbally (textually) through the VC and graphically through Inperson™.

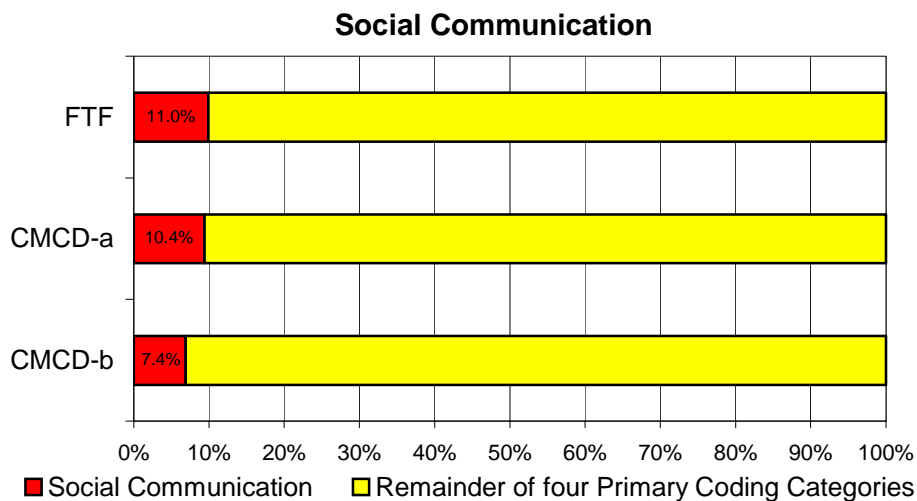
<sup>35</sup> By double clicking the tab of the page, participants could force their partners to come to that particular page.

<sup>36</sup> They still notified their partners of page they are on despite the fact Inperson™ always indicated where the users were, that is on what page by displaying the unique cursor identifying each user on the tab of that page.

**Alex:** I am not typing as fast as I am thinking.  
Sorry for being a bit slow."

### 6.3.3 Variations in Social Communication

Social Communication on the other hand, presented us with unexpected results. Initially we thought that by removing the audio-video channels from the CMCD-b category, thus removing the element of proximity, social interaction would drop dramatically and maybe disappear altogether. This however did not occur, since the utterances coded under social communication, out of the total coded text units (TU), in all three categories were comparatively close as shown in *figure 6.4* (**11%** FTF StDev 5.2%, **10.4%** CMCD-a StDev 3.9% and **7.4%** CMCD-b StDev 3.6%). Therefore we conclude that the participants in CMCD-b still found it possible to 'socialise' despite the limitations of the collaborative medium and the loss of two communication channels thought to have been vital in reproducing a FTF collaborative environment (amongst others, Harrison and Minneman, 1990).



*Figure 6.4 Distribution of social communication across the three categories of experiments.*

**FTF.** Utterances coded under social communication in the FTF category were not limited to discussions about the participants' social lives and their studies in particular, but included light humour and jokes. In the example shown below the participants joke about the idea that the block of land in the brief belonged to the experimenter:

**Toni:** It's probably Gerard's house! (both laugh)

**Alex:** It probably is. Some site details, Block is 560 metres

**Toni:** He's just getting it in a cheap design (both laugh)

**Alex:** This could be just like bargain basement time (both laugh) Do,do,dah,do ... "

**CMCD-a.** Similar to FTF, social communication in the CMCD-a category encompassed discussions about the participants' social lives, their studies as well as light humour and joking. In the example shown below the participants spend time discussing what their individual cursors in Inperson™ looked like:

**Alex:** (laughs) what's mine?

**Toni:** oh it's sort of a squiggly thing like my spiral earrings

**Alex:** oh really! Do you know what yours is? Yours is like this funny little man, looks like a Santa clause hat on top of his head

**Toni:** no it's not! (laughs)

**Alex:** yeah it is mmm, I'm going to draw it for you, hang on

**Alex:** where's the line, this is yours

**Alex:** oh no I can't I need a curvy line (both laugh)"

**CMCD-b.** Social communication in the CMCD-b category was again comparable to the other two categories. Nevertheless in keeping with the trend observed in the CMCD-b transcripts, even social communication was short, straight to the point, and witty. In the example below, both participants make fun of each other's ideas and work:

**Toni:** fabulous! not a drop more

**Alex:** perhaps just one more

**Toni:** fabulous

**Alex:** love your work"

## 6.4 Differences in Verbal Design Representation between the three categories of Experiments

In the second principal classification of differences we evaluate variations in verbal design representations and whether those variations were affected in any way by altering the communication channels in CMCD-b. Thus we report on general observed differences in verbal design representations as well as variations related to the fourth primary category of our final coding scheme, *design communication* and its three secondary subcategories, *design idea*, *design scope* and *design task*.

Design communication varied as predicted between the three categories of experiments as shown in *figure 6.1*. On the other hand, there was hardly any variation in *design idea*, with CMCD-b recording the highest mean of all three categories as shown in *figure 6.5* (**59.2%** FTF StDev 4.9%, **55.1%** CMCD-a StDev 7.1% and **59.4%** CMCD-b StDev 3.7%). Furthermore, CMCD-b recorded the highest mean in the distribution of *design scope* and the lowest of *design task* compared to the other two categories.

### 6.4.1 Variations in Design Idea

*Figure 6.6* illustrates how *design idea* with its ten tertiary sub-categories varied markedly between the three categories of experiments. However having said that, some expected as well as unexpected results emerged, for example the unexpected high levels of ‘*introduction of idea*’ in CMCD-b and of ‘*clarification of idea*’ in FTF.

**Introduction of idea** was expected to be more or less at the same level in all three categories, since we assumed it would be independent of the medium variable. However the resulting higher level in CMCD-b took us by surprise since it more than doubled those of the two other categories as illustrated in *figure 6.6*. In the FTF and CMCD-a categories ideas were at times introduced in an explicit way, e.g.:

**Alex:** AH YEAH, I have a great idea! ... Why don't we have an Adelphi pool? [the hotel designed by DCM in Melbourne]"

However participants explicitly uttering that they had an idea, in both FTF and CMCD-a categories, did not always end up introducing it or were interrupted while doing so, e.g.:

"**Toni:** OR, ... I've got an idea."

Another example:

"**Toni:** yeah, you just need to move the floor, wait a minute I've got an idea."

On the other hand most ideas were presented in a more subtle way in verbal mode and on some occasions in graphical form. Having said this, *introduction of idea* in FTF and CMCD-a occurred, most of the time, in long utterances that contained self-repetitions. This along with higher levels of *interruptions* in both those categories could have lead to lower levels of *introduction of idea*, e.g.:

"**Alex:** like yeah if it became a kind of emm ... sort of like very steel and kind of ... really industrial ... you know that you sort of have all these screens ... between like, between that, like you have got the workshop on the top but there are just like ... a series of screens, hidden kind of pull across or ... like push up, but then like if he doesn't want so much light he can change the screens to a more opaque screen or something like that (TOP)"

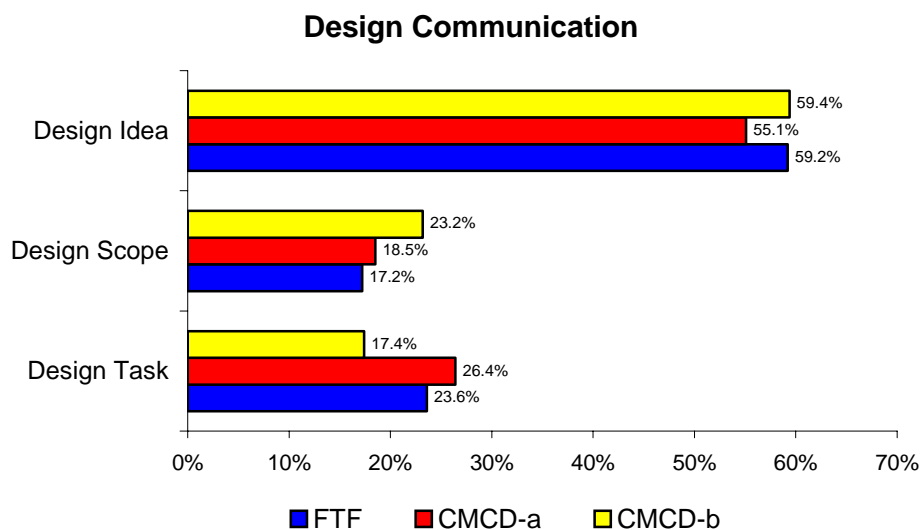


Figure 6.5 Distribution of design communication across the three categories of experiments.

**FTF.** Participants generally proceeded to introduce ideas straight after they read the brief and even at times while reading it. The utterances containing introduced ideas varied from a few words to a few sentences with a mean of **10%** (StDev

2.4%) of the *design idea* total as shown in *figure 6.6*. Some of the introduced ideas were wasted since they remained verbal (in audio form) and were not recorded graphically or even textually, e.g.:

**Alex:** It'd be nice if ... it'd be nice if the ... pool could sort of, sort of form one of the contours of the house, so it makes it level"

Another observation made across all FTF experiments was that participants introduced ideas, most of the time, in a spontaneous verbal way following the method of "draw-as-you-speak". In the following example, Toni introduces an idea both verbally and graphically in a simultaneous way:

**Toni:** what if the kitchen is there, a kitchen and laundry stuff behind there. All here ... entertaining thing and then, going up again to sort of the, roof terrace."

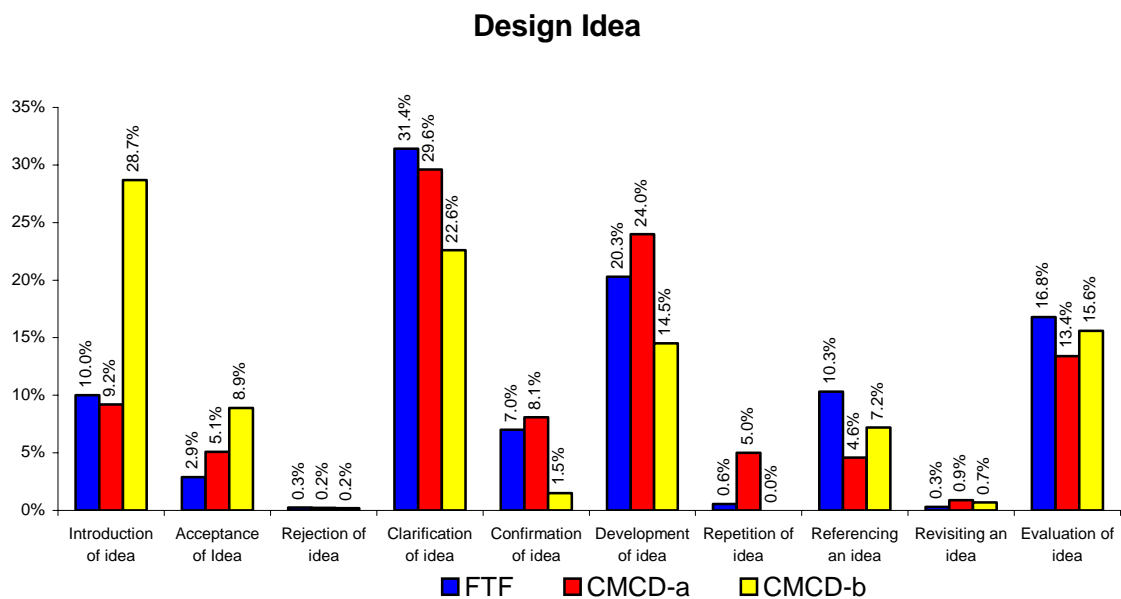


Figure 6.6 Distribution of design idea across the three categories of experiments.

**CMCD-a.** *Introduction of idea* was similar to FTF in many ways. Participating subjects were observed introducing ideas while reading the brief at the start of the experiments. *Introduction of idea* also occurred as part of a long utterance at times, punctuated with self-repetitions, e.g.:

**Alex:** Yeah. But the other thing is, if you want to draw up, if you, that would ... that would also create a double level at the bottom ... I'll just

change and close that. It would also ... a different colour now that would actually create here, um, the opportunity for ... two, two levels and here one."

Subjects in CMCD-a had a lower percentage of ideas introduced than both the other two categories out of the total number of utterances coded under *design idea* (9.2% StDev 1.4%) as shown in *figure 6.6*. In fact participants in the CMCD-a category seemed to emulate the way they design and communicate design ideas to their partners when in a FTF collaborative situation. They were spontaneous and also engaged in the method of "draw-as-you-speak" which was less effective than the FTF sessions. This had some adverse results on the quality and clarity of the produced sketches.

**CMCD-b.** In a way we predicted that architects would be able to collaborate and relate design representations effectively in computer mediated environments with limited communication channels as opposed to FTF environments. However the much higher level of introduced ideas in this category, compared to the other two (10% FTF, 9.2% CMCD-a and 28.7% CMCD-b StDev 3.6%),<sup>37</sup> prompted us to have a closer look at the data. Unlike participants in the FTF and CMCD-a categories, CMCD-b subjects were less spontaneous and their introduced ideas occurred most of the time as part of short and clear utterances, e.g.:

"**Toni:** so do you think it should be interlocking forms moving down the site or a more static composition? We could certainly use the cliff edge"

With no interruptions and with no means of directly telling whether their partners were reading the introduced idea or doing something else, participants appeared to communicate their ideas as if they were designing by themselves. That is they kept introducing ideas, whether they had a response or not, as if they were "thinking aloud".

Therefore rather than stopping at the first idea coming to mind, participants constantly introduced ideas recording them in writing as well as developing some of them graphically. This allowed them to revisit introduced ideas, if and whenever the need arose, to either develop them further, refresh their memories or totally discard them.

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<sup>37</sup> The mean of *introduction of idea* is calculated out of total text units coded under *design idea*.

**Acceptance and Rejection of idea** varied noticeably between the three categories of experiments as shown in *figures 6.6 & 6.7*. From our initial observations of the pilot experiments we had expected that not all introduced ideas would be accepted or rejected, and that only a small percentage would remain as introduced ideas only. However the final results showed significant levels of variation between the categories and a higher level than expected of introduced ideas remaining without being either accepted or rejected. While the level of acceptance of idea varied dramatically between the three categories of experiments, rejection of idea was minimal as illustrated in *figure 6.7*. This we think is mainly due to the participants being courteous as well as respectful of each other's ideas, and perhaps mindful of the fact that they are in front of a camera.

**FTF.** The lowest level of acceptance of idea, coded under *design idea*, occurred in FTF where rejection of idea was negligible, as shown in *figure 6.6*. In addition FTF also polled the lowest level of accepted introduced ideas out of the three categories of experiments. The ratio of acceptance to rejection of introduced ideas is illustrated in *figure 6.7*. Following are examples of acceptance of idea and rejection of idea respectively:

**Alex:** and then you got the ground like that, so that emm ... so that like you put a glass wall there... And have it kind of, so it looks like it's, it's ... it's one of these black glass things that's been buried... and it forms a pool

**Toni:** that's beautiful, that's a lovely idea and you still get a bit of light through as well."  
(ACC)

**Toni:** be like a very emm ... more traditional house maybe, a pitched roof or

**Alex:** no I don't think so!" (REJ)

**CMCD-a.** Participants in this category recorded a higher ratio of *acceptance of idea*, to *design idea*, than FTF as shown in *figure 6.6*. Furthermore CMCD-a recorded the highest score of accepted introduced ideas out of the three categories of experiments (*figure 6.7*) which could be due primarily to the fact that this category also recorded the lowest ratio of *introduction of idea* to *design idea*. In addition the novelty of the environment could have generated the need

to join in discussions, and respond to introduced ideas whether they were accepted or not. Therefore this could have played a part in generating less *online acknowledgement* and *interruptions* than FTF thus contributing to the higher level of accepted introduced ideas.

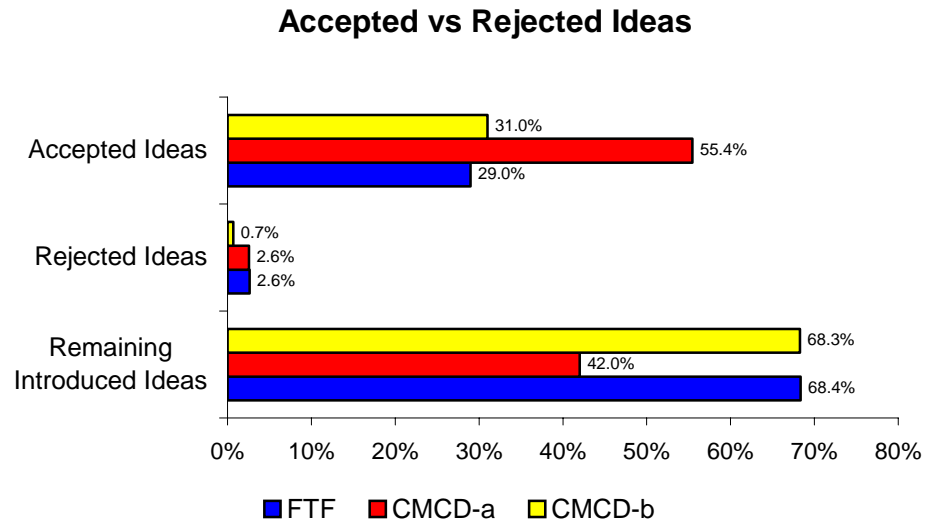


Figure 6.7 Ratio of acceptance and rejection of introduced ideas across all three categories of experiments.

However similar to FTF, rejection of idea was negligible (*figures 6.6 & 6.7*) and following are examples of acceptance and rejection of idea respectively:

**Toni:** open full roof should be completely glass so that when you're in the workshop you can see into the pool or something

**Alex:** yeah, that'll be excellent!" (ACC)

**Toni:** the first bedroom looking out onto that walkway ... not very nice, but that's fine I guess

**Alex:** no that's not right!" (REJ)

**CMCD-b.** With the highest ratio of *acceptance of idea* to *design idea*, CMCD-b still polled a higher ratio of accepted introduced ideas than FTF, as shown in *figures 6.6 & 6.7*. However this along with the novelty of the collaborative environment meant that it was always going to be a challenging task for participants of this category to respond to all proposed ideas. Following is an example of acceptance of idea:

**Alex:** I wonder if the garage & studio type could be combined; shed-like

**Toni:** good idea especially if we expand the idea of the garage into the "bloke's shed" and put in the tools"

Only one case of *rejection of idea* occurred in all of the CMCD-b experiments:

**Toni:** should the kids have a separate bldg for there bedrooms

**Alex:** that's all a bit 70's hippy!! nah, I reckon it should all be in one!"

**Clarification and Confirmation of idea** are closely linked and complement each other. However their respective frequency varied significantly across the three categories of experiments, as shown in *figure 6.6*, which far exceeded our initial expectations.

**FTF.** Initially we expected *clarification of idea* to be predominant in the CMCD environment. Therefore we were surprised to see the opposite happening with FTF coming highest out of all three categories of experiments as illustrated in *figure 6.6*. In addition to being the most frequently coded sub-category in design idea (**31.4%** StDev 5.8%), *clarification of idea* more than tripled *introduction of idea*. This meant that every introduced idea was clarified on average three times. In turn *confirmation of idea* in FTF came second highest (**7%** StDev 2.9%) in all three categories of experiment as well as having the second highest rate of confirming clarified ideas (22.3%).<sup>38</sup>

One reason for this high rate of *clarification of idea* in FTF could be attributed to the fact that utterances containing *introduction of idea* were too often interrupted or were too long and contained a higher level of self-repetitions. As a result this prompted the collaborating partners to ask for clarifications, which were in turn at times interrupted, e.g.:

**Alex:** (TOP) so it's cantilevered off... Oh fantastic, yeah that would be great, it would be great. So you are saying you can go down those stair and (TOP) "

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<sup>38</sup> The rate of confirmed clarified ideas was obtained by dividing the mean score of *confirmation of idea* by the mean score of *clarification of idea*.

A typical example of the sequence *introduction, clarification and confirmation of idea* is demonstrated in the following extract where ‘Toni’ introduces and then confirms an idea that ‘Alex’ wanted clarified:

**Toni:** Maybe everything can go round the roof terrace.

**Alex:** Oh, like how, like how... how would you go round the roof terrace? So what, so what you've got something in the middle. The roof terrace is like the central courtyard sort of thing?

**Toni:** Yeah that's it"

**CMCD-a.** Similar to FTF, *clarification of idea* more than tripled *introduction of idea* (figure 6.6) and came as the second most frequently coded sub-category in design idea (29.6% StDev 5.3%). On the other hand *confirmation of idea* was the highest (8.1% StDev 3%) in all three categories of experiment as well as having the highest rate of confirming clarified ideas (27.3%).

We believe the reasons for the high rate of *clarification of idea* are comparable to the ones in FTF since participants in CMCD-a subconsciously emulated in many ways the method they were used to designing with in FTF. That is the utterances containing *introduction of idea* also included a high level of self-repetitions and were often interrupted or were too long, thus prompting more clarifications, e.g.:

**Toni:** but so ... so do you reckon that means that they could have 2 stories up here or could they ... is it 2 stories from that area there? 'cause you could 'cause you could fit a third storey cut into (TOP)"

Following is an example of the sequence of *introduction, clarification and confirmation of idea*:

**Toni:** Maybe we could have the pool actually becoming a bit more like a natural, naturalised kind of landscape, and that enhances the ... the massiveness of the boulder that sort of blends with it as well, and you have a light structure above that to contrast the boulder, with the rest of the dwelling.

**Alex:** I didn't quite get ... what were you saying, contrast?

**Toni:** You know a light structure will contrast with the massiveness

**Alex:** Yeah ok"

**CMCD-b.** Unlike FTF and CMCD-a, *clarification of idea* was less than *introduction of idea* (figure 6.6) and came as the fifth highest most frequently coded sub-category in design idea (22.6% StDev 4%). Therefore with no interruptions and no evident self-repetitions participants in CMCD-b spent more time introducing new ideas to their partners in a clear and concise manner, which required very little clarification, if any. Having said that, *confirmation of idea* was the lowest (1.5% StDev 1.9%) in all three categories of experiment. Therefore CMCD-b produced the lowest rate of confirming clarified ideas (6.6%), e.g.:

"**Toni:** or should the workshop be more autonomous

**Alex:** yeah, maybe, the site is 17 m long, so it might be."

**Development of idea.** Contrary to our expectations once more, *development of idea* varied markedly between the three categories of experiments as shown in figure 6.6. Initially we had expected that participants in FTF would spend more time developing ideas than the other two categories would, but clearly that was not the case.

**FTF.** Participants in this category had the second highest level of *development of idea* (20.3% StDev 5.4%) compared to the other two categories. Having said that, utterances pertaining to *development of idea* were often too long, with participants digressing frequently, therefore necessitating a higher degree of attention from their partners in order to absorb and understand what was being discussed at hand. With no means of capturing this information and relying solely on memory, participants often found themselves asking for a clarification of the idea being developed. At times, and in a deliberate attempt to regain the conversational floor, participants interrupted long utterances in order to continue developing the idea themselves, e.g.:

"**Alex:** But has a relation like it is yeah, like a loft level that has kind of a definite relationship down there, that maybe it is not completely close like a bedroom and that kind of think like its' and

then you've got the kitchen sort of sitting inside there, so you could kind of see what is going on downstairs but it is away, still you know, you still feel that it has an amazing unity ... become (TOP)

**Toni:** Yeah, it does and it will also have a bit of separation from the living areas so it just, you need something to come in, maybe entering another way or"

**CMCD-a.** Participants in this category had the highest level of *development of idea* (24% StDev 6.1%) in all three categories of experiments. However similar trends to FTF emerged in the form of long utterances punctuated by spontaneity, digression and self-repetition with partners often interrupting each other in order to reclaim the conversational floor. As in FTF most of the information about *development of idea* was hardly recorded unless a graphical sketch was produced and at times annotated. Therefore in the case of an interruption, participants struggled to reproduce developed ideas.

The following extract illustrates how, at times, *development of idea* utterances were long with digression and self-repetition occurrences:

**"Toni:** maybe the pool should be related to the family areas too, you know... you know like it should mmm... at the moment well, we've got initial, sort of part of the entry sequence and all that sort of drama of walking over it and walking into the, into the house and things, but maybe it should mmm, ... also be... sort of ... sort of all the family stuff is happening down... at the other end, ... nothing is gonna happen to..."

**CMCD-b.** *Development of idea* was lowest in this category (20.3% FTF, 24% CMCD-a and 14.5% CMCD-b StDev 3.6%) mainly because participants in CMCD-b had spent more time on *introduction of idea*. However unlike FTF and CMCD-a, utterances related to *development of idea* contained no self-repetitions, no interruptions, virtually no digressions and went straight to the point, e.g.:

**"Alex:** I was thinking something quite long and skinny on the southern side with a bit of bulk on the west. How about - if emphasising the cutting and integrating with the rock, so you have a form, of sorts, which is somehow spliced and allows the rock/platform entertaining areas to come through the house."

**Repetition of idea** was negligible in all three categories of experiments with CMCD—a recording the highest level (5% StDev 4.4%) as illustrated in *figure 6.6*. Perhaps this was mainly due to the one-hour time limit of the experiments, therefore prompting participants to remain original in their ideas as much as possible.

**Referencing and revisiting an idea.** Initially we predicted those subcategories to be closely linked. We expected participants, when *referencing an idea* or speaking about a particular project or architect's work, to link it most of the time with ideas they were developing or had previously discussed, thus *revisiting an idea*. Although the latter did occur, the results in *figure 6.6* indicate it was much lower than we had expected.

**FTF.** 10.3% of communication on *design idea* was spent on *referencing an idea*, which makes it the highest out of the three categories of experiments. At the same time, less than 1% of communication on *design idea* was spent on *revisiting an idea*.

However we observed that *referencing an idea* was used most of the time to provide an example as back up when participants explained introduced ideas to their partners. At times it was contained within an utterance and at other times it flowed to a few utterances when participants spent time discussing a particular architectural project or reference. Having said that, the SteDev of *referencing an idea* was very high (14.1%). This is attributed to the fact that in one of the experiments, *referencing an idea* had a skewed score of 41% (see appendix G for results tables) of communication related to *design idea*, since the participants spent some considerable amount of time discussing numerous architectural projects.

In the following extract, Toni wanted to cantilever the house over the cliff and therefore came up with the following reference to better explain the idea to Alex:

**Toni:** no like the one in north by northwest [referring to the film by Hitchcock with the house cantilevered over the cliff]

**Alex:** I don't know it ... the movie

**Toni:** yeah

**Alex:** is that an old (TOP) is that a really old movie and it is on the beach and it looks like a Frank Lloyd Wright house?"

As an example of *revisiting an idea*, in the following extract Toni reminds Alex of an idea they had previously discussed:

**Toni:** It's hard to find ... though isn't it. Because it's like that other space we talked about. This lane thing's quite bizarre though isn't it, like, how could you come up with that. Oh Alex."

**CMCD-a.** *Referencing an idea* was lowest out of all three categories of experiments at **4.6%** (StDev 4.7%), while *revisiting an idea* was at less than **1%**, figure 6.6. Similar to FTF, *referencing an idea* was either contained in the one utterance or in a sequence of utterances, where participants spent time discussing a particular architectural project. In the following extract, Toni responds to Alex's query with the introduction of an idea by referencing the work of Dutch architect Rem Koolhaas:

**Alex:** I think so ... absolutely, yeah, ...because emm, yeah ... it's definitely private space. So how would you reflect that with materials? Would you have heavy materials on top of ... the lighter materials down below? I mean how, how would you do that?

**Toni:** I'm not ... I think it is pretty interesting, because we could do what, what Rem always does. You know when he has the solid tops ... the pilotis

**Alex:** yeah, yeah"

In the following extract Alex revisits an idea presented earlier by Toni:

**Alex:** on top of the living with an external stairs is that what you were saying before? Or no not really?

**Toni:** yep yep yeah"

**CMCD-b.** *Referencing an idea* registered the second highest level out of all three categories (**7.2%** StDev 3.9%) with *revisiting an idea* coming second,<sup>39</sup> as shown in figure 6.6. Unlike FTF and CMCD-a, *referencing an idea* was limited most of the time to the one utterance.

In the following extract, Alex responds to Toni's *introduction of idea* by accepting and further developing it while referencing the work of Australian architect Glenn Murcutt:

"**Alex:** that is a good idea we can place the service zone along the south wall on the ground level and have the upper level a 'gallery corridor' a bit of a 'g. murcutt' diagram that he used in some of the houses designed?"

In the following extract and as an example of *revisiting an idea*, Toni goes back to a previously introduced idea:

"**Toni:** back to the pivoting point discussed before"

**Evaluation of idea.** In all three categories of experiments, *evaluation of idea* maintained very close levels as illustrated in *figure 6.6* (**16.8%** FTF, **13.4%** CMCD-a and **15.6%** CMCD-b). However there was a noticeable difference in the ratio of evaluated ideas to introduced ideas, in all three categories, as illustrated in *figure 6.8*.

**FTF.** *Evaluation of idea* in FTF was first in terms of TU mean coded under *design idea* (**16.8%** StDev 5.8%). However the FTF category of experiments had the highest proportion of evaluated introduced ideas compared to the other two categories, as illustrated in *figure 6.8*. This meant that more introduced ideas were evaluated even though those introduced ideas might not have been accepted in the first place. At times participants were observed evaluating their own introduced ideas within the same utterance, e.g.:

"**Alex:** Like all, like going outside ... somehow going outside before like going to work as you go outside to go to work ... like you go out the door, and you go to your thing rather than ... yeah, I think this is a nice idea. But, but yeah, I think I like that, that you have to go outside."

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<sup>39</sup> Revisiting an idea had a mean of **0.7%** since only three out of seven pairs of participants revisited ideas explicitly.

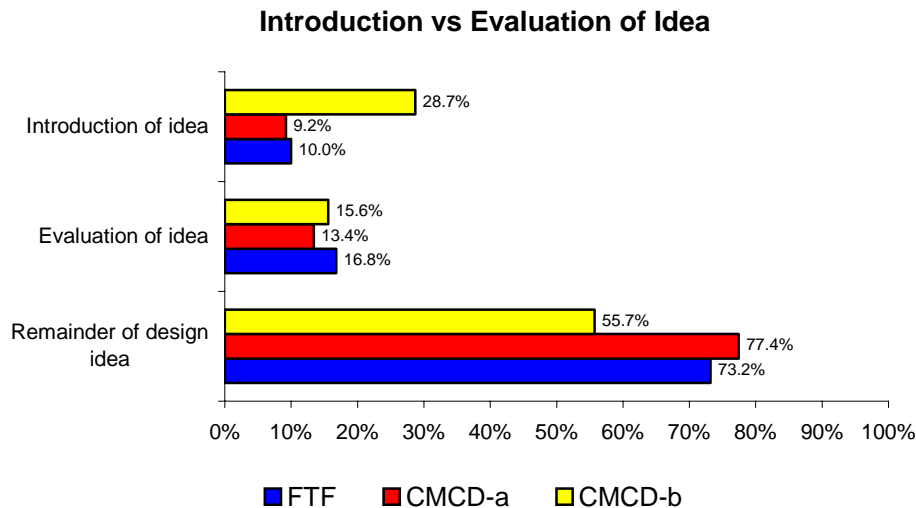


Figure 6.8 Introduction vs evaluation of idea across all three categories of experiments.

However the predominant trend saw participants evaluating each other's introduced ideas, as well as their own mostly after their partners had a say, e.g.:

**Alex:** But it could be like, if it's two storeys, you have these sort of service things behind ... So that in section it's sort of like ... You mean the house is sort of over, sort of the living space of the house sort of go over like that.

**Toni:** Hmmmm

**Alex:** So that they're two useable living spaces looking out towards the views.

**Toni:** OK that sounds, actually that doesn't sound too bad. Makes sense too. So push, what's it's almost like a services sort of spine, like that bit."

**CMCD-a.** While this category had the lowest level of *evaluation of idea* out of all three categories of experiments (**13.4%** StDev 2.7%), it still registered the second highest ratio of evaluated ideas to introduced ideas (*figures 6.6 & 6.8*). This translated into more time spent by participants evaluating introduced ideas even though those introduced ideas might have never been accepted. However in a similar point to FTF, participants were observed at times evaluating their own introduced ideas within the same utterance, e.g.:

**Toni:** and then maybe, the bedroom areas above or, I suppose you really wouldn't want bedroom areas below because, it's too much on that public access way, isn't it?"

Again the predominant trend in CMCD-a was similar to FTF with participants evaluating each other's introduced ideas, e.g.:

**Alex:** Yeah. An external space? Could be an external space?

**Toni:** Yeah. A (TOP) yeah. Because it could be that there's this big roof and it doesn't really have to be all completely internally. Oh, how it could be that you really didn't enter into this part of the house until you got to this point here.

**Alex:** Yeah that makes sense, yeah. So the working is quite independent ... I think it works out very well this way."

**CMCD-b.** Although this category had the second highest level of *evaluation of idea* out of all three categories of experiments (**15.6%** StDev 3.2%), it registered the lowest ratio of evaluated ideas to introduced ideas, as illustrated in *figures 6.6 & 6.8*. This meant that while participants spent more time on *evaluation of idea*, a large percentage of introduced ideas remained unevaluated. Part of the reason behind this was described earlier through the higher ratio of *introduction of idea* to total of *design idea*. That is participants in the CMCD-b sessions seemed to think aloud and proceeded to type whatever ideas came to their minds. In doing so, more utterances containing introduction of idea were produced, which at times were taken as comments and therefore not requiring any clarification or evaluation.

Having said that, a similar scenario to FTF and CMCD-a occurred when participants were at times evaluating their own introduced ideas, e.g.:

**Toni:** I wouldn't get hung up on the south light there's always the blank wall option to the north or parking more of the building in front of it. I think that would be good."

However, and as in the other two categories, the predominant tendency was one of evaluating each other's introduced ideas, e.g.:

**Alex:** what sort of arrangement across the site? Strung out along east west axis?

**Toni:** that would work well with solar access."

### 6.4.2 Variations in Design Scope

As predicted *design scope* with its two tertiary sub-categories, *low level design* (LLD) and *high level design* (HLD) varied markedly between the three categories of experiments, as illustrated in *figure 6.9*. There were similarities between the FTF and CMCD-a categories with the close levels of LLD, which more than doubled their close levels of HLD. On the other hand, and in line with our predictions as well as the findings of Vera et al. (1998),<sup>40</sup> the CMCD-b category recorded a dramatic decrease in LLD as well as increase in HLD.

**FTF.** *Design scope* communication in FTF was dominated by LLD (67.2%<sup>41</sup> StDev 7.2%) as opposed to HLD (32.8% StDev 7.2%) as shown in *figure 6.9*. Following are some examples of LLD and HLD:

**Alex:** Where would the entrance be, would you enter through, coming through the garage and have the entrance door here somewhere?" (LLD)

**Toni:** Just orientation. Orientate the thing first ... So city views of that, that's north. So if you were going to take advantage of more, like the city views would be the ones that you would want to sort of maximise or ... mmm" (HLD)

**CMCD-a.** Similar to the FTF category, *figure 6.9* illustrates how communication related to *design scope* was dominated by LLD (71.2% StDev 11.5%) compared to HLD (28.8% StDev 11.5%). Although the StDev in the CMCD-a category was higher than the FTF category, the overall trend showed a consistently higher level of LLD to HLD across all seven experiments. The similarities in the levels of *design scope* between FTF and CMCD-a could be attributed to the 'spontaneity' of verbal communication and the self-repetition of ideas and clarifications. This at times could be seen as an effort to 'stay on-line' and break the silence. Following are some examples of LLD and HLD:

**Toni:** well if we wedge this into the rock, which there is nothing to say we can't, so that it sort

<sup>40</sup> Vera et al. (1998) observed a slight decrease in LLD as opposed to HLD in text-based computer-mediated experiments compared to audio and video computer mediated experiments.

<sup>41</sup> The levels of the LLD & HLD tertiary sub-categories are calculated as the mean of the total TU coded under *design scope*.

off, just mostly sandstone and with glass to the end or something opening up..." (LLD)

"**Alex:** ok, well the pool area, and the terrace and the entertainment area should all connect." (HLD)

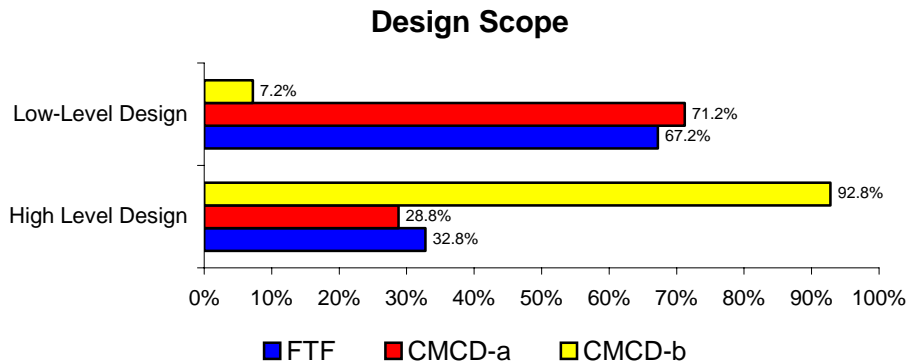


Figure 6.9 Distribution of design scope across the three categories of experiments.

**CMCD-b.** As we predicted, figure 6.9 illustrates the dramatic difference in *design scope* between CMCD-b and the first two categories. Communication related to *design scope* was dominated by HLD (92.8% StDev 8.4%) compared to LLD (7.2% StDev 8.4%). While the StDev of LLD was higher, the overall trend showed a consistently much higher level of HLD to LLD across all seven experiments of the CMCD-b category.

Participants in this category were less 'spontaneous' in their verbal (typed text) communication and did not seem to be perturbed by the 'on-line silence' produced by the collaborative medium. This in turn could have assisted them in being more reflective since they were observed taking their time while typing their thoughts. In other situations, participants were observed rewording their utterances with the right choice of words to explain their design representations to their partners. Following are some examples of LLD and HLD:

"**Toni:** connected yet a little detached. In the section I put a large wall between the studio and the living ... then maybe the studio should go there"  
" (LLD)

"**Alex:** what sort of house do you think this man wants? You are right to think that the studio and living spaces should be separate. Perhaps open plan with a separate building." (HLD)

### 6.4.3 Variations in Design Task

The third and final secondary sub-category of *design communication*, *design task*, also showed variations between the three categories of experiment with CMCD-a recording the highest mean of all three categories as shown in *figure 6.5* (23.6% FTF, 26.4% CMCD-a and 17.4% CMCD-b). *Figure 6.10* illustrates how *design task* with its six tertiary sub-categories varied markedly between the three categories of experiments, mainly between FTF and CMCD-a on one hand and CMCD-b on the other, with CMCD-b recording the highest levels in five out of six subcategories.

**Brief.** The occurrence of this tertiary sub-category, the second highest in *design task*, varied slightly between all three categories of experiments with CMCD-b recording the highest level as illustrated in *figure 6.10*. Once the experiment started all participants proceeded to read the brief, check the site plan and the photographs provided with the brief. Having said that, there were some exceptions with some participants observed investigating the site, the photographs provided and then skimming fairly quickly through the brief. Those participants however did not belong to a single category but were spread across all three categories of experiments. This allowed us to conclude that this phenomenon was not due to the varying communication channels, but to participants who were anxious to get started on the design. Another interesting phenomenon that occurred in all three categories was referencing of ideas while initially reading the brief. The rocky nature of the site was conducive in bringing about the memories of projects built on similar sites, like for example 'Falling Water' by Frank Lloyd Wright and the cliff house in the Alfred Hitchcock thriller 'North by Northwest'.

**FTF.** Participants in this category generally proceeded to read the brief straight away and at times paused to present an idea to their partners or to discuss the brief. Most of them revisited the brief throughout the one-hour experiment, especially the ones who skimmed through it in the first place. The TU coded under *brief* in FTF had the lowest mean of all three categories as illustrated in *figure 6.10* (29% StDev 5.8%). Following is an example of TU coded under *brief* in FTF:

**"Toni:** Double garage, cool! Could get a double garage in there somewhere. Bit of a waste. Swimming pools ... oh OK (laughs). Is there any other func-

tion that we think would enhance it, and compliment the brief inside?"

**CMCD-a.** Similar to the FTF category in many ways, participants read and revisited the brief on numerous occasions and in similar patterns. CMCD-a scored the second highest mean of the three categories as illustrated in *figure 6.10* (**29.7%** StDev 8.1%) e.g.:

"**Alex:** sort of, and it is sort of, mmm, what do we do, because we've got that walkway, where's that photo of it? Let's have a look at the photo ... are you looking at the photo?"

**CMCD-b.** The TU coded under *brief* had the highest mean of the three categories as illustrated in *figure 6.10* (**32.5%** StDev 14.4%). Comparable to the other two categories, participants used the brief in similar ways in that most of them read it first up while others chose to scan through it and revisit it later when the need arose. The following example of a TU coded under *brief* shows a participant pausing to reference an idea inspired by the brief:

"**Alex:** yeah, and if you look at the four photos, the boulder kind of lurches out over the public pathway: there could be some scope for long FLW<sup>42</sup> balconies along it..."

**Schedule and Task.** Contrary to what we had initially anticipated, participants in all three categories hardly resorted to any meaningful scheduling or program developing as illustrated in *figure 6.10*. What is more significant, is that they did very little scheduling if any, at the commencement of the experiment, with most of them resorting to ad-hoc program developing at various stages of the collaborative sessions.

On the other hand *task* received a bit more attention than scheduling especially with participants from the CMCD-b category as shown in *figure 6.10*.

**FTF.** *Figure 6.10* illustrates that the level of *schedule* in this category out of the total TU coded under *design task* was minimal (**5%** StDev 3.8%), with no clear trend emerging.

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<sup>42</sup> The participant was referring to the Falling Water house by Frank Lloyd Wright.

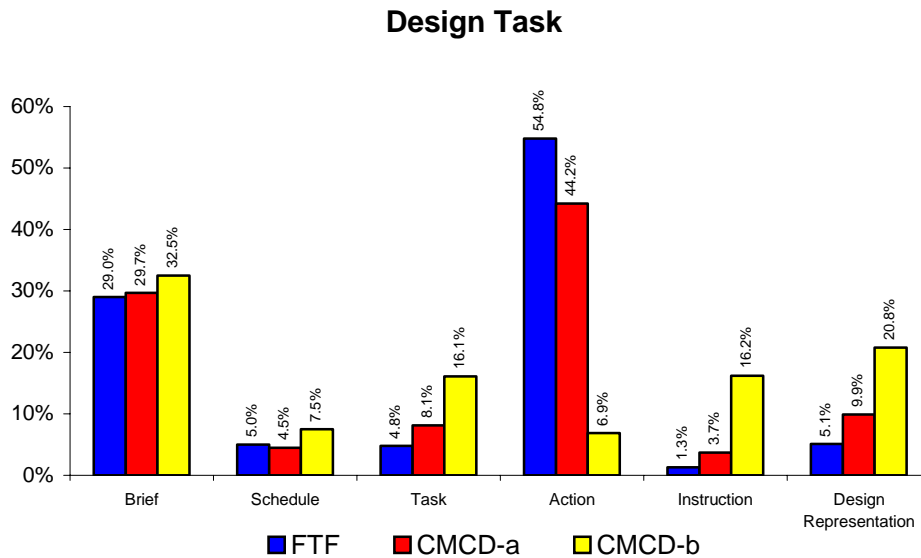


Figure 6.10 Distribution of design task across the three categories of experiments.

The participating subjects were observed delving straight into design once they read or skimmed through the brief. On a couple of occasions individuals from different sessions were observed writing down a list of brief requirements on the provided detail paper which they later used as a check list. *Task* on the other hand, scored a similar level to *schedule* (4.8% StDev 1.5%) and was also distributed across the sixty minutes. Following are examples of *schedule* and *task* in FTF:

**Toni:** Mmmm ... that could be ... I suppose there'd have to be a design so we have to have it, you know by the hour we have to have some sort of nice drawn drawings on that...

**Alex:** Yeah we'll get those happening" (SCH)

**Alex:** should we draw the plan again?" (TAS)

Although the example, given here on *schedule*, mentions the participant's awareness of the experiment's time limit, it was only uttered around the fifty-minute mark of the session.

**CMCD-a.** *Schedule* and *task* showed similar levels and distributions to FTF as illustrated in figure 6.10 (4.5% StDev 3.4% for *schedule* and 8.1% StDev 4% for *task*). However the high StDev in both of those tertiary sub-categories indi-

cates again that there was no clear trend emerging with some participants not even using either of them. Following are some examples:

**Toni:** what time is it? What time did we start?  
We're probably nearly outside ten minutes and we  
still have to (TOP)

**Alex:** oh shit we'd better hurry!" (SCH)

**Toni:** so we've got like ... can I draw, can I draw  
a concept diagram Alex?" (TAS)

**CMCD-b.** Participants in this category scored the highest level in *schedule* (7.5% StDev 4.8%) since they were less spontaneous in their collaborative communication than participants of the other two categories. In a way this also meant that communication was more structured to better deal with the new environment and the novel way of communicating. *Figure 6.10* shows that CMCD-b subjects seemed to rely more on *task* than participants of the other two categories (16.1% StDev 6%). This assisted them in keeping their partners informed of their intended moves within Inperson™ as well as their design intentions, e.g.:

**Alex:** I'm going to go to pg 12 and do some sketching.  
Maybe we should draw the bubble diagram rather  
than write the rooms to start with as a program?"  
(SCH & TAS)

**Action and Instruction.** As mentioned earlier, both of those tertiary sub-categories varied noticeably between FTF and CMCD-a on one hand and CMCD-b on the other. Action was the only subcategory of *design task* where CMCD-b scored the lowest level out of the three categories. On the other hand the opposite happened in the *instruction* subcategory, with CMCD-b scoring the highest level.

**FTF.** The TU coded under *action* in FTF had the highest mean of all three categories as illustrated in *figure 6.10* (54.8% StDev 5.2%). Verbal representations of an idea, and clarification or development of an idea were, most of the time, accompanied with graphical representations, with participants using their fingers or pens to point out the issues discussed to their partners. Instruction was negligible in FTF (1.3% StDev 1.1%). Following are examples of *action* and *instruction* respectively:

"**Alex:** yeah, ... so if that, if the house ... it has to be bigger then maybe the house is over here ... over this place here, over this part which sort of so that you get a two storey section here... doing this..." (ACT)

"**Toni:** you draw what you think you're seeing in your mind and I draw what I see." (INS)

**CMCD-a.** Similar to FTF, *action* scored a high level (**44.2%** StDev 7.2%) and instruction was negligible (**3.7%** StDev 2.3%). As a substitute to the finger and pen as pointing devices, participants used the cursor on the screen supplemented with audio instructions in order to indicate the graphical representations being discussed with their partners. Following are examples of *action* and *instruction* respectively:

"**Alex:** Oh that's great, so in plan ... so we can just have the pool coming straight off there. I reckon there's definitely room for a flying swimming pool over there ... off that edge." (ACT)

"**Toni:** yeah, so you can do the short section on this page ... maybe we should work out the plan while we are here then we can probably do..." (INS)

**CMCD-b.** Compared to the other two categories, *action* scored the lowest level (**6.9%** StDev 4.7%) while *instruction* scored the highest (**16.2%** StDev 6.6%). As a substitute to the finger, pen and cursor used in FTF and CMCD-a in order to indicate or direct the attention of their partners to a particular graphical representation, participants in this category used a combination of indicators, like orientation and annotation of sketches.

*Instruction* seemed to be directly associated with *hand-over* whereby participants requested further information from their partners, in a form of 'turn taking', through an instruction. Most of the time, those instructions were short and straight to the point. Following are examples of both *action* and *instruction*:

"**Toni:** perhaps the bed wing can skirt around the cliff edge to the NW." (ACT)

Another example:

"**Alex:** yes and partially glass (trafficable in line with your glazed bottom pool)." (ACT)

"**Alex:** show me then!" (INS)

**Design representation.** The occurrence of this tertiary sub-category varied noticeably between the three categories of experiments with CMCD-b recording the highest level as illustrated in *figure 6.10*. In a way we had anticipated a higher level of *design representation* in the CMCD sessions as opposed to FTF.

**FTF.** The TU coded under *design representation* in FTF had the lowest mean of all three categories as illustrated in *figure 6.10* (**5.1%** StDev 3.1%). The high StDev however indicates the level of skewed data in this particular sub-category showing no emerging trend. Following is an example of *design representation* in FTF:

"**Toni:** Oh I'm not sure mate. I haven't got a great deal of ideas as to what the building actually is like ... so I think drawing this section through here will be particularly difficult."

**CMCD-a.** *Design representation* showed a higher level of distributions than FTF as illustrated in *figure 6.10* (**9.9%** StDev 3.4%). Participants seemed to rely more on *design representation* in order to clarify issues they would have probably not discussed in FTF, e.g.:

"**Toni:** should we draw arrows on those bedroom doors showing which way they all open up onto the terrace?"

**CMCD-b.** Participants in this category scored the highest level in *design representation* as illustrated in *figure 6.10* (**20.8%** StDev 9.8%). Most probably this was due to the fact that participants in this category were less spontaneous in their collaborative communication than their colleagues in the other two categories. This also meant that they had to be more accurate in their verbal as well as graphical design representations in order to relay design information. Following is an example of *design representation* in CMCD-b:

"**Toni:** hey, why don't we try the 3d stuff on another blank page?"

## 6.5 Correlation of Analysed Coded Data with Questionnaire Results

The post experiment questionnaires were produced in order to survey the participants' opinions on their 'collaborative experience' while it was still fresh in their minds.

For this reason and as mentioned in chapter four, these questionnaires were not intended to be comprehensive on communication, instead they were meant to complement the experiments already undertaken and allow participants to add any valuable information relating to their experience.

In the following sections of this chapter, the compiled data are correlated with the results of the analysed coding schemes. This in a way assisted us in checking the consistency of the coding schemes as well as providing valuable insight towards the collaborative environment directly from the participants. The questionnaires of all three categories of experiments as well as the ensuing results are available in appendix D.

### *6.5.1 Useability of Audio and Video Channels in Computer-Mediated Collaborative Design Environments with Full Communication Channels*

The participants of the CMCD-a category of experiments were asked to rate the use of the audio and video channels in degrees of their usefulness. The audio channel was rated, by the fourteen participants, at 100% 'very useful, used it frequently'.<sup>43</sup> On the other hand, the same CMCD-a participants rated the video channel<sup>44</sup> as 57% 'not useful, used it very little or not at all'; 21% as 'useful, used it at certain times'; 7% as 'very useful, used it frequently' and 14% answered the open-ended question as illustrated in *figure 6.11*, e.g.:

"Nice to be able to have visual contact though not really used."

Another example:

"Good to establish initial contact, but used it less & less as hour progressed - concentrated on the drawing to communicate."

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<sup>43</sup> "How do you rate the use of the audio channel in the experiment? (CMCD-a)" question 11 - appendix D.

<sup>44</sup> "How do you rate the use of the video channel in the experiment? (CMCD-a)" question 10 - appendix D.

Having said that, the participants' response to the question of whether they tried to maintain eye contact or made an effort to do so<sup>45</sup> correlated favourably with our results and observations. In the FTF experiment; 21% of participants answered 'Yes' they maintained eye contact; 14% answered 'No'; 29% answered 'Not sure' and 36% picked the open-ended answer as illustrated in *figure 6.11*, e.g.:

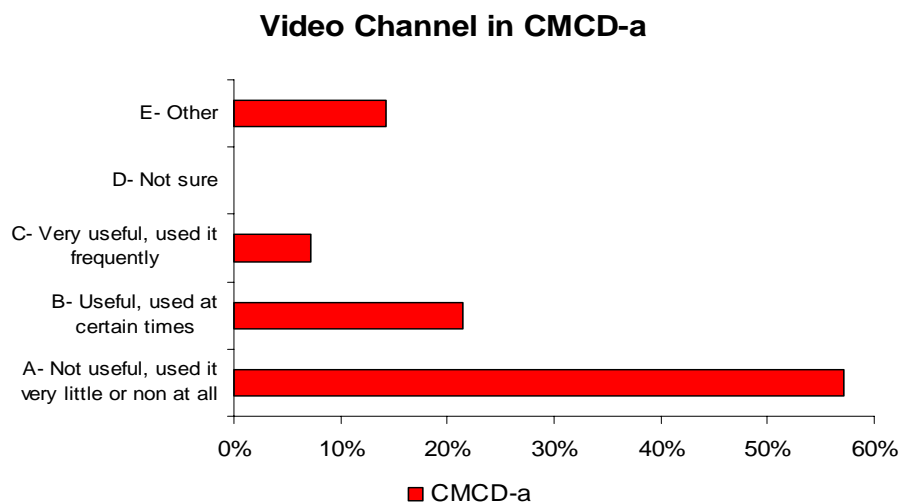
"Idea time yes, Producing drawings no"

Another example:

"Sometimes when conversing, other times eyes were on drawings."

Another example:

"Mainly concentrating on the paper."



*Figure 6.11 Rating of video channel in the CMCD-a category.*

On the other hand, only 7% of participants in the CMCD-a category answered 'Yes' to having maintained eye contact and 86% answered 'No', while 7% answered using the open-ended answer as illustrated in *figure 6.12*, e.g.:

"Looked at the design most of the time. Occasionally looked at face to see reaction to suggestion (eg: smile)."

<sup>45</sup> "Did you maintain eye contact, or made an effort to do so, during the experiment? (FTF - CMCD-a)" question 9 – appendix D.

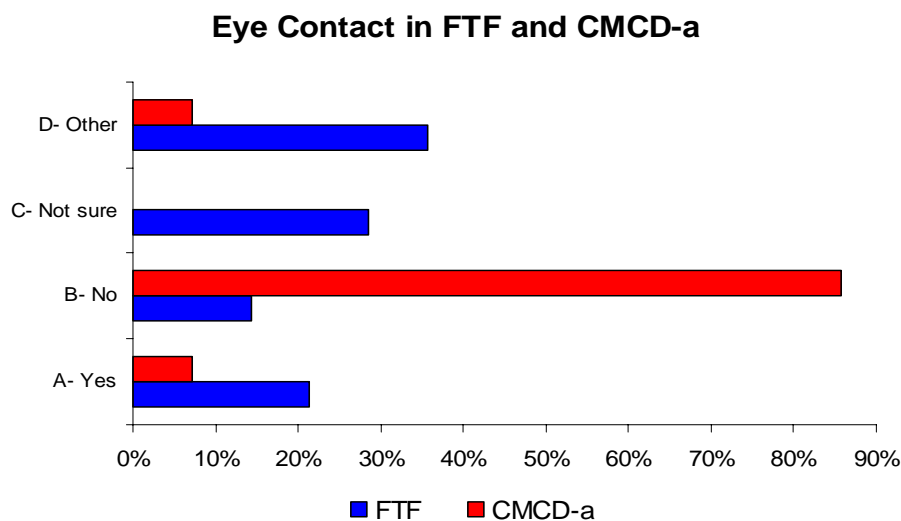
### 6.5.2 Useability of Text Based Channel in Computer-Mediated Collaborative Design Environments with Varied Communication Channels

In order to receive feedback on the collaborative environment in CMCD-b, participants of this category of experiments were asked to rate the use of the text channel in degrees of usefulness. The fourteen participants surveyed, rated the text based verbal communication channel<sup>46</sup> at 29% ‘Useful, used it at certain times’; 57% ‘Very useful, used it frequently’ and 14% answered the open-ended question as illustrated in *figure 6.13*, e.g.:

“The changing between text and brief was very difficult but when drawing was ok.”

Another example:

“Better to communicate directly on whiteboard. Talk screen not big enough.”



*Figure 6.12* Percentage of maintaining eye contact in both FTF and CMCD-a categories.

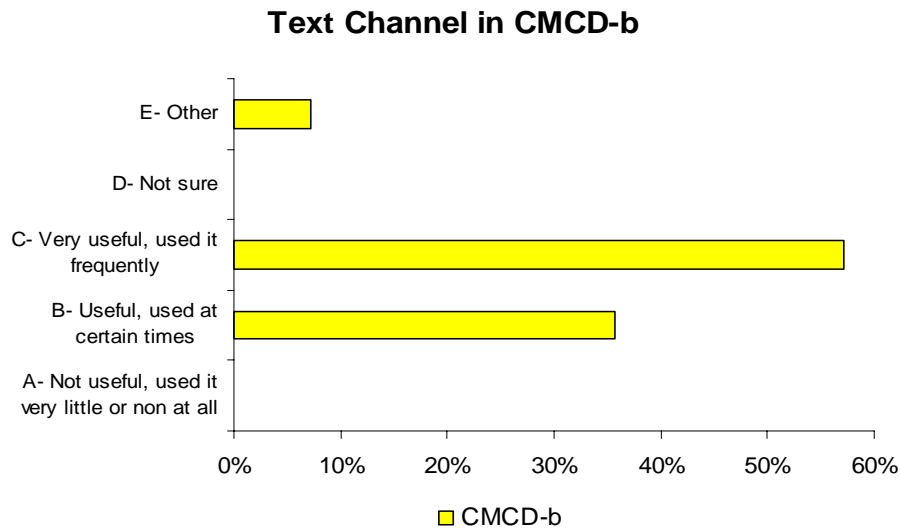
In response to whether they had scrolled back through the transcripts at any time during the experiment,<sup>47</sup> 50% of CMCD-b participants answered ‘Never’; 36% answered ‘A few times’; while 14% answered ‘Not sure’ as illustrated in *figure 6.14*. On the other hand their response to whether they had glanced back at the conversa-

<sup>46</sup> “How do you rate the use of the text-based channel in the experiment? (CMCD-b)” question 12 – appendix D.

<sup>47</sup> “Did you at any time during the experiment scroll back up through the conversation text of the MOO looking for certain clues or ideas that were already said? (CMCD-b)” question 13 – appendix D.

tion text in the MOO<sup>48</sup> was 10% ‘Never’; 70% ‘A few times’; 10% ‘A lot’ and 10% answered using the open-ended answer as illustrated in *figure 6.15*, e.g.:

“Yes, looking for clues, ie question 13”



*Figure 6.13 Rating of text channel in the CMCD-b category.*

### 6.5.3 Useability of Graphics Channel in Computer Mediated Collaborative Design Environments

As measure of gauging the usefulness of the shared graphics channel (Inperson™), participants of both CMCD categories were surveyed on how they rated the use of the whiteboard in the experiments.<sup>49</sup> In the CMCD-a category, 14% answered with ‘Useful, used at certain times’; 64% answered with ‘Very useful, used it frequently’; 14% answered with ‘Not sure’ and 7% chose the open-ended answer as illustrated in *figure 6.16*, e.g.:

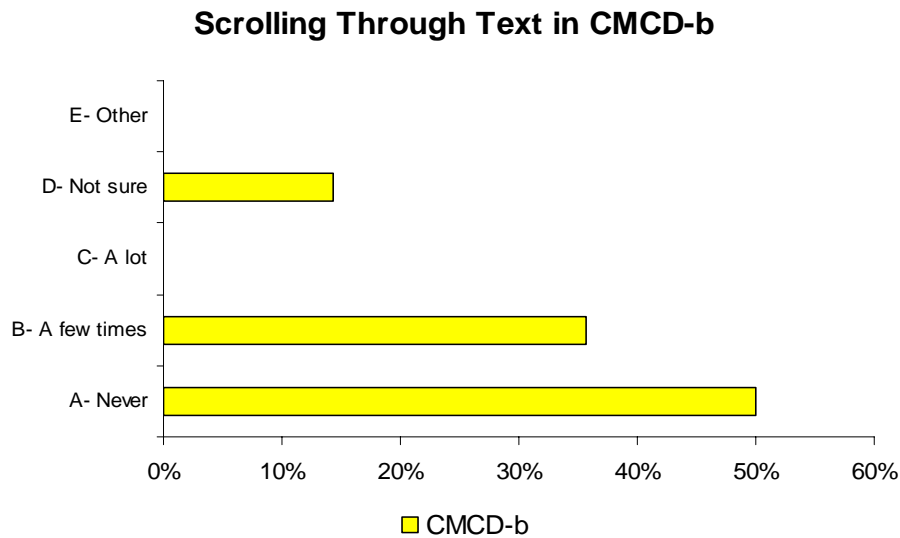
“Essential.”

On the other hand, 14% of participants in the CMCD-b category answered with ‘Useful, used at certain times’; 71% answered with ‘Very useful, used it frequently’ and 14% answered with the open-ended answer as illustrated in *figure 6.16*, e.g.:

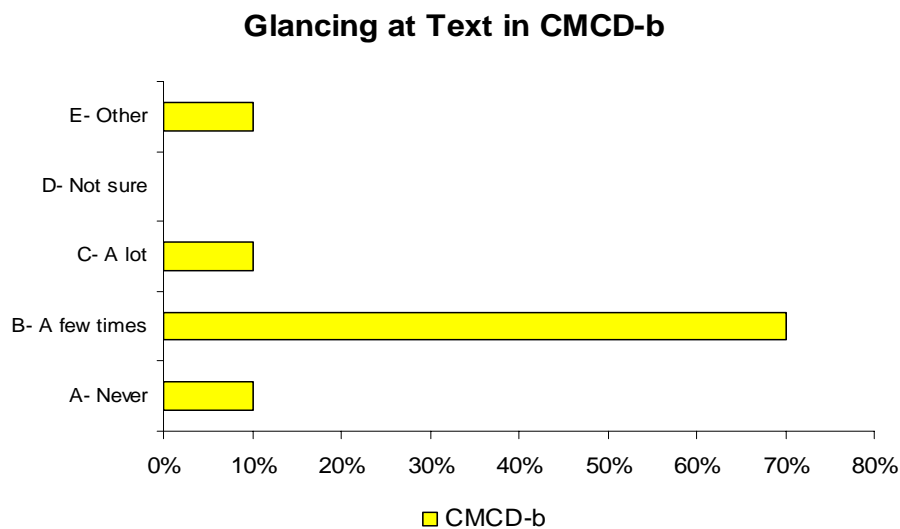
“Useful but frustrating to draw with these tools, especially the mouse.”

<sup>48</sup> “Did you at any time during the experiment glance back at conversation text in the MOO that you had previously read or even typed? (CMCD-b)” question 14 – appendix D.

<sup>49</sup> “How do you rate the use of the whiteboard in the experiment? (CMCD-a & b)” question 16 – appendix D.



*Figure 6.14* Percentage of participants scrolling back through text of transcripts in the CMCD-b category.



*Figure 6.15* Percentage of participants glancing back at text of transcripts in the CMCD-b category.

## 6.6 Conclusion

In this chapter we reported on the quantitative and qualitative results of the analysed coded transcripts obtained from the experiments held and discussed in previous chapters of this thesis. Measures and characterisations were presented in the form of observed differences in communication and verbal design representations. The results

of the analysed DCP were then correlated with the results obtained from the questionnaires.

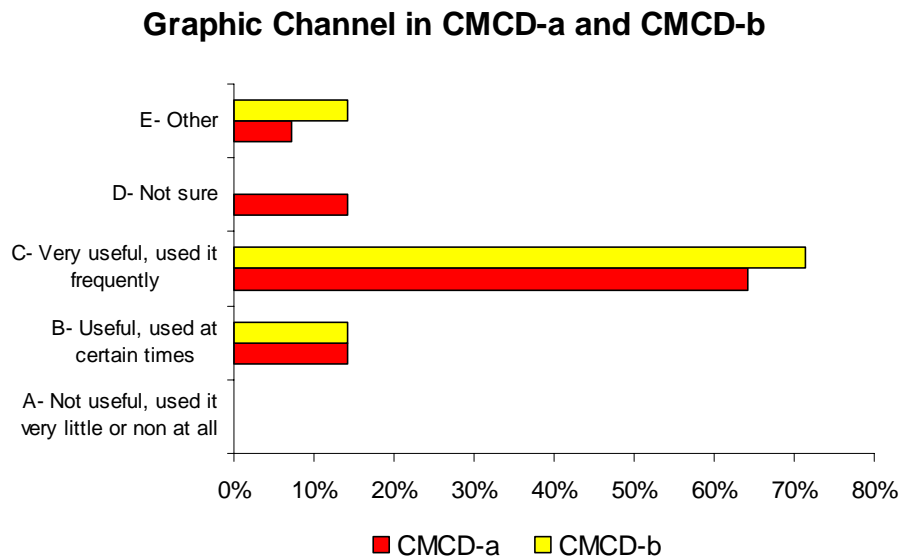


Figure 6.16 Rating of graphics channel in both CMCD-a and CMCD-b categories.

The result of our analysis as well as our observations, gathered from the videotapes, indicate to us that there are differences in the way architects communicate using different communication channels; namely the use of different collaborative environments can produce different types of communication. However it is important to note here that these differences do not seem to affect the ability of the designers to establish a collaborative working relationship. In fact, some of the differences show that computer-mediation may in some cases, be more appropriate than a face-to-face meeting. For example, we observed that the text-based communication experiments (CMCD-b) produced a better record of the collaborative session than the FTF and CMCD-a experiments.

The following summary is not meant as a comprehensive list of differences between the three collaborative environments, but instead is intended to highlight some of the important differences analysed and observed:

**Spontaneous vs Reflective.** Participants in the FTF and CMCD-a categories were spontaneous, responding to their partners' comments straight away, often interrupting them from completing what they had to say. On the other hand, participants in the CMCD-b category were less spontaneous and thus became more reflective on their design ideas. Consequently, their collaborative ex-

change through verbal representations was somewhat richer and straight to the point compared to that of FTF and CMCD-a.

**Communication Control vs Design Communication.** Collaborative design communication in the CMCD-b category was generally richer in design communication and contained less communication control while maintaining a similar level of social communication. The fact that there was hardly any repetition and no interruptions meant that less *clarification of idea* was needed. On the other hand, collaborative design communication in the FTF and CMCD-a categories contained more interruptions and self-repetitions, which in turn caused a lower level of *introduction of idea* and a higher level of *clarification of idea* to occur. In addition, the produced record, of the collaborative CMCD-b sessions, gave better recognition of individual contributions than that of the FTF or CMCD-a environments. Also another interesting difference here as well, between FTF & CMCD-a environments on one hand and the CMCD-b environment on the other, is the aspect of listening. Participants in the CMCD-b category were not compelled to answer on the spot or even nod in acknowledgement for every single utterance made. Instead they took their time to reflect on their partner's proposals and answer accordingly.

**Eye contact.** Dispelling the myth that eye contact is essential in collaborative design ventures, we observed that participants in both FTF and CMCD-a hardly had any direct synchronous eye contact and when it happened it was very brief and their gaze went back to the problem at hand. To a large extent, the results of the questionnaires correlate with our findings.

The three categories of communication for architectural collaboration explored in this thesis are indicative of the alternatives available to architects these days. However what is not clear to architects, is why they would choose one category over another. Therefore the choice of using different mediums (FTF, CMCD-a or CMCD-b) should not be only motivated in overcoming distance,<sup>50</sup> but to go 'beyond being there' and test new grounds and possibilities in collaborative design.

For example participants in the CMCD-b sessions introduced and recorded more ideas, in general terms, in the first hour than the other two categories. This means that if brain storming was needed as well as getting the resulting ideas recorded, one would contemplate using a CMCD-b environment regardless of the distance.

We propose that each category has its own strengths and difficulties for architectural collaboration. Therefore each category should be selected on the basis of the type of communication that would be most effective for the stage and tasks of a particular design project.

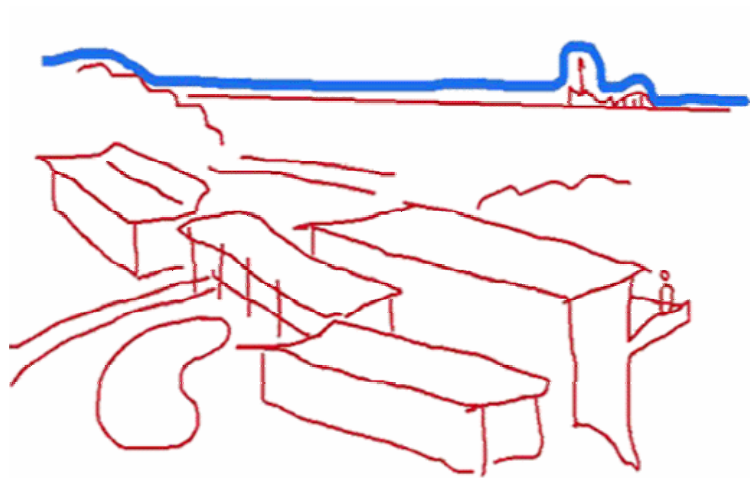
However having said that, further research is needed in order to better understand computer-mediated communication in collaborative design, which in turn is instrumental for the effective development of collaborative communication software and technology for designers in general and architects in particular.

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<sup>50</sup> As in the past it was a measure of overcoming distance.

# Chapter 7

## Discussion and Future Work



Chapter seven revisits the salient points presented in this thesis. It summarises the major issues presented mainly the three categories of collaborative environments and the importance of the various communication channels in such ventures as well as general observations made on differences in graphical representations. Finally it presents the major contributions of this dissertation as well as some opportunities for further research and development.

## 7.1 Summary of Issues

This dissertation addresses the lack of formal research on the effects computer-mediated communication might have on verbal design representations between collaborating architects. Previous research into communication channels used in CMCD environments has shown that there is little agreement on whether audio and video channels are essential in such ventures as well as on what constitutes the appropriate channels. Therefore this thesis investigates the requirements of successful remote collaborative communication in order to enhance our understanding of the nature of collaborative design communication taking place between architects.

We argue that successful CMCD does not necessarily mean emulating close proximity environments. The use of different communication channels affects the type and style of synchronous collaborative communication as well as producing different qualities. We show that collaboration through computer-mediated environments is possible without the use of audio and video channels and that architects are able to collaborate and communicate design representations not only effectively in this way but with some advantages.

This thesis demonstrates a methodology for researching, understanding and supporting CMCD processes. It investigates the possible effects on communication in general and collaborative design communication in particular brought on by varying the communication channels. It does so by reporting on three categories of collaborative design experimental studies involving sixty eight, 5th and 6th year architecture students from the Faculty of Architecture at the University of Sydney. Those three categories of experiments are FTF; computer-mediation with full communication channels, comprising audio-visual as well as a shared whiteboard - CMCD-a; and computer-mediation with limited communication channels, comprising a text based chat medium through the virtual campus and a shared whiteboard - CMCD-b.

This thesis also presents a specialised coding scheme, for analysing verbal design communication, in order to compare possible differences in collaborative design communication both in FTF and CMCD environments. It describes a procedure for coding and analysing protocol data to extract an understanding of collaborative design communication requirements and future development of support services. This dissertation also validates the use of design communication protocols as a method for

studying collaborative design communication between multiple designers at work as opposed to protocol studies of single designers in the past. The analysed results obtained from the coded transcripts of the three categories of experiments illustrate the differences in collaborative design communication between the three collaborative mediums.

Finally this dissertation demonstrates that successful CMCD is possible under varying circumstances thus generating different communication types and styles, giving architects more choice when faced with a collaborative venture regardless of distance.

## 7.2 Observations on Graphical Design Representations in the three Categories of Experiments

While this thesis was mainly concerned with investigating communication and verbal design representations and how they might vary between the three categories of experiments, general observations on graphical design representations were made and are presented in this section.

Graphical representations, between the three categories, did not seem to be affected in quantity or quality of ideas, but rather in richness, elaboration and level of detail. This is mainly due to the variance between mediums and the different drawing tools used to produce the sketches.

Generally speaking, the participants in the FTF category found the collaborative process and by extension the production of graphical representations to be fairly simple, smooth and straightforward. However this ease of use was met at first with some degree of difficulty in the CMCD categories but this improved as the hour progressed and participants got used to the environment.

Sketching using traditional media (pen & paper) proved to be easier and at times quicker in delivering ideas, in the way of “draw-as-you-speak”, rather than using mouse and whiteboard, especially with curved lines and free forms.

On the other hand although participants in the CMCD sessions struggled at times with the mouse as a drawing tool, they still managed to represent their ideas in sketch form through the shared whiteboard. However after some initial difficulties in adjusting to the new environment they soon discovered some of the advantages of this communication medium over FTF. To start with, the choice of colour and line

thickness as well as the line, rectangle and circle tools, made drawing geometrical forms and representations much easier in the CMCD sessions. Also the added functionality of copying and duplicating whole representations, even between pages in order to quickly edit and further develop them, compared favourably to redrawing in the FTF sessions.

**FTF.** Initial observations showed that participants in the FTF experiments started sketching within five minutes of beginning the experiment and did so throughout the hour. Their sketches included 2D as well as 3D diagrams and basic programs. *Figure 7.1* illustrates an example of a sketch produced in a FTF session using pen and paper. The drawing task was shared between the collaborating subjects in all sessions. At times, a participant ‘held the floor’ sketching while the other was evaluating the outcome or just being a ‘spectator’.

Most of the time participants were observed working simultaneously and spontaneously while speaking and sketching freely. It was also common to see both participants working and sketching on the same representation throughout the FTF sessions. The exchange of verbal (audio) representations was accompanied at times by graphical representations. However purely discussed verbal (audio) representations, which did not translate into illustrations, were lost forever.

**CMCD-a.** In the case of the CMCD-a sessions, participants engaged in drawing activities five to eight minutes into the experiments after having read the brief. As in the FTF sessions, their sketches included 2D and 3D graphical representations along with some text while working mainly on the same page. At times participants were observed working on separate pages and later visiting each other's ‘work space’ to evaluate design efforts.

Sketching was spontaneous and at times, accompanied by simple annotations. The participating subjects seemed to instinctively emulate the FTF environment by simultaneously illustrating their verbal utterances with graphical sketches. This along with the added awkwardness of using the mouse as a drawing tool may have contributed to sketches that were incomprehensible most of the time, as illustrated in *figure 7.2*, thus prompting verbal clarifications on many occasions, e.g.:

**Alex:** yeah. Is this part in section, is this part mmm, like the edge of the rock or something or is it? ... What's it doing?

**Toni:** This rock edge is along here ... and mmm"

Another example:

**Alex:** Oh what, what (laughs). Oooh, that's the section, is that a section, is this a section?

**Toni:** Yeah."

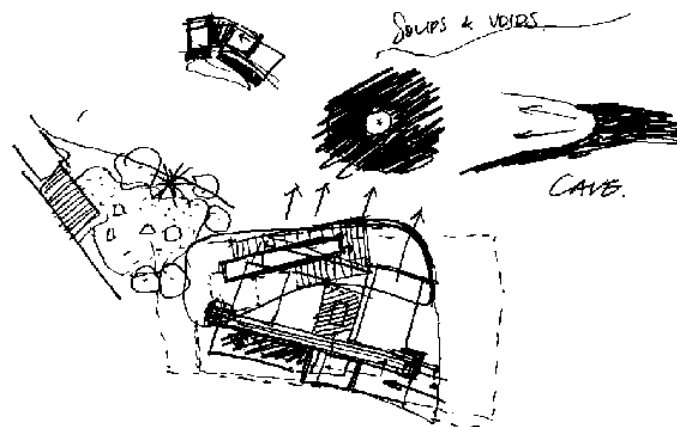


Figure 7.1 Sample of graphical representation from FTF experiment.

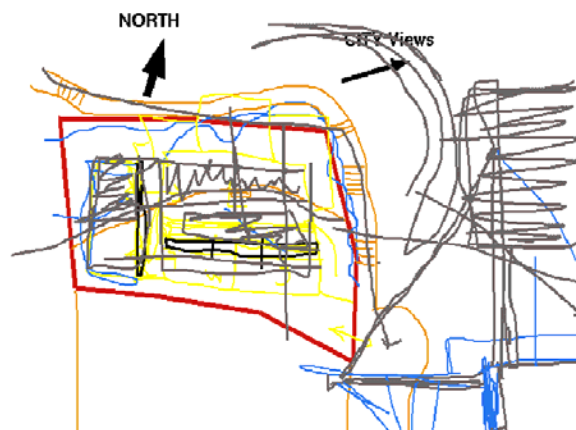


Figure 7.2 Sample of graphical representation from CMCD-a experiment.



*Figure 7.3 Sample of graphical representation from CMCD-b experiment.*

**CMCD-b.** As in the preceding category, participants in the CMCD-b sessions were engaged in sketching within five to eight minutes of commencing the experiment. Sketches included 2D as well as 3D representations along with some annotations in order to clarify and re-enforce the graphical representations at hand. The quantity of graphical representations in the CMCD-b sessions was approximately equal to the amount in the CMCD-a sessions.<sup>51</sup> A similar work pattern to the CMCD-a sessions was observed, with participants working on the same page most of the time. They were also observed working on separate pages and occasionally checking out each other's work.

The semi-synchronous nature of the CMCD-b collaborative environment appeared to allow participants more time to reflect on their design ideas, so they were less spontaneous. This was also apparent in their graphical representations, since participants were seen sketching what was needed to graphically relay and further strengthen their verbal representations.<sup>52</sup> Consequently their graphical representations appeared to be more elaborate and refined containing more detail, straight to the point ideas, and annotations. Therefore most of the time, their sketches responded to well thought out ideas instead of spontaneous reactions to the verbal representations at hand as illustrated in *figure 7.3*.

## 7.3 Contributions

The major contributions of this research to the field of computer-mediated collaborative design can be summarised as follows:

**Validation of the hypothesis** that successful computer-mediated collaborative design does not require emulating close proximity environments. Participants of the CMCD-b category were able to collaborate and relate design representations effectively, with some important differences. The results obtained from this thesis corroborate our predictions that audio and video are not essential communication channels in CMCD environments, since successful collaborative sessions took place without them. This was achieved by replacing the au-

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<sup>51</sup> This was measured in terms of pages used in Inperson™, which averaged around six pages per experiment.

<sup>52</sup> Another example of a sketch produced in a CMCD-b session, in addition to the sketch illustrated in figure 7.3, can be seen on the first page of this chapter.

dio and video channels with a text based channel while retaining the shared drawing space channel.

**Developing a specialised coding scheme** for ‘verbal communication in collaborative design’. The unavailability of an adequate coding scheme prompted us to develop a specialised coding scheme which researchers, in the future, could build on in order to further investigate collaborative communication between designers in general and architects in particular. This in turn enabled us to uncover, from the transcripts, valuable information and trends as well as to clarify differences between the three categories of experiments. Judging by the high percentage of agreement in the results between the two coders, we conclude that the specialised coding scheme promoted a high level of understanding, detail and clarity of collaborative communication taking place in the collaborative environments presented in this thesis.

**Rigorous analysis of verbal collaborative communication** during collaborative design sessions between architects in three different collaborative environments, using qualitative and quantitative measures. This methodology enhances our understanding of verbal collaborative communication taking place by demonstrating similarities and differences between FTF and CMCD environments.

**Demonstrating that different types of collaborative environments** produce different types of communication as well as different types of post collaborative documentation in both verbal and graphical modes. This in turn presents architects with alternatives and suggest that the choice in using different collaborative mediums should not only be motivated by overcoming distance, but by going ‘beyond being there’.

## 7.4 Future Research

The work presented in this dissertation is a start towards studying, understanding and supporting computer-mediated collaborative design. We hope that the framework, methodology and results reported will be employed to study other communication scenarios in other phases of the design process which will be useful in building better support systems. Therefore this section is intended to highlight some suggested di-

rections for future research in the development of computer-supported collaborative design. The possible future research directions are:

**Further study of alternatives in collaborative design environments.** This includes the possibility of investigating CMCD in a FTF environment. With more architects using computers to formulate design ideas in the preliminary conceptual stages, more research could be carried out on CMCD sessions in a FTF environment. Therefore two people working in a FTF environment yet using computers as a shared working space and repository for their sketches and drawings would be an interesting alternative to using the traditional medium. Similarly, more research could be carried out on CMCD environments, this time using different tools such as synchronised web browsers as well as substituting the mouse with a drawing tablet thus allowing users to produce sketches with more ease. Furthermore more extended studies could be carried out along the same lines as this thesis either through longer experimental collaborative sessions between students or through multiple collaborative sessions between students or even practising architects in their own work environments.

**Developing a model of design communication.** The logical step following the development of the specialised coding scheme would be to look at developing a model of synchronous verbal design communication. Such a model of collaborative communication could be presented as deconstructing the various activities occurring in collaborative design communication in architecture. The proposed model would classify communication according to the role it plays in the collaborative design process. For example at the top level, the model would distinguish between communication that has the purpose of controlling the flow of communication, clarifying the use of the technology, socialising, or progressing the design. Such a communication model could broaden the characterisation of differences and similarities between FTF collaborative design and CMCD in the way communication channels are used in those ventures. This in turn would further guide developers in producing communication and computer systems that could better support CMCD.

**Creating new collaborative design environments.** The development of an integrated-shared whiteboard that can capture verbal (textual) and graphical design representations simultaneously would be very useful. Such a system would allow users to tag textual utterances thus relating them to graphical ex-

pression while keeping the overall conversation synchronised. In other words an annotated sketch could be automatically and sequentially tagged. This way when users click or even point to the tagged annotation, the text in the conversation window scrolls back to that particular utterance thus preserving the sequence of the collaborative session as well as the context in which the idea was first introduced.

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# Appendix A.

## Abstracts of Published Research Papers

The following published research papers identify some of the research aspects of this thesis:

1. **Gabriel, Gerard C. and Maher, Mary Lou.** (1999a) "Coding and Modelling Communication in Architectural Collaborative Design." Proceedings of the Media and Design Process: ACADIA '99, Association for Computer Aided Design in Architecture, Sal Lake City, Edited by Osman Ataman and Julio Bermudez. pp. 152-166

Design representation is not only used to document the final design for construction; it is essential for the development and communication of design ideas. With recent developments in CAD and communications technologies, the way we represent and visualise designs is changing. In this paper we canvass the results of experiments examining the effect of different communication channels in collaborative sessions between architects. We consider the effect on verbal and non-verbal design representations. The experiments were conducted in three different environments: 1) face-to-face (FTF), 2) computer mediated collaborative design with full communication channels (CMCD-a), and 3) computer mediated collaborative design with limited communication channels (CMCD-b). The initial observations in all three categories show significant differences in collaborative communication as well as design representation.

2. **Gabriel, Gerard C. and Maher, Mary Lou.** (1999b) "Does Computer Mediation affect Design Representation?" Proceedings of the 4th International Design Thinking Symposium on Design Representation, Massachusetts Institute of Technology, Edited by Mine Ozkar. Department of Architecture, MIT, pp. III.53-62.

Although there has been some research done on collaborative face-to-face (FTF) and video-conferencing sessions involving architects, little is known about the effects these different mediums have on collaborative design in general and collaborative communication and design representation in particular. In this paper we argue that successful computer-mediated collaborative design (CMCD) does not necessarily mean emulating close proximity environments. In order to investigate this view, we carried out experiments examining the effect and significance of different communication channels in collaborative sessions between architects. The experiments were conducted in different environments and classified into three categories. The first category is FTF. The second computer mediated collaborative design sessions with full communication channels CMCD-a. The third category was conducted also through computer mediated collaborative design sessions but with limited communication channels CMCD-b. A custom coding scheme is developed using data, external and theoretically derived coding categories as a base. Examples of how the proposed coding scheme works are given from all three categories of experiments. The coding scheme provides the basis for modeling and understanding communication in collaborative design.

# Appendix B.

## Subjects Consent Form



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NSW 2006 Australia

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**Gerard Cesar Gabriel**  
PhD Candidate

Email: gerard@arch.usyd.edu.au

Wilkinson Building (GO4)  
148 City Road  
University of Sydney  
Chippendale NSW Australia  
Date: 01 August 1998

### Subjects Consent Form

I, (name) \_\_\_\_\_

of (address) \_\_\_\_\_

hereby agree to participate in this research study entitled "**collaborative communication in computer mediated architectural design**", which is conducted by Gerard Gabriel (PhD candidate) and Mary Lou Maher (Assoc. professor, Faculty of Architecture) at the University of Sydney.

I have read and understood the subject information sheet on the above mentioned subject of research study.

I am satisfied with the information given to me on the research project and I have been given the opportunity to discuss any questions or concerns with the researchers.

I know I may contact Gerard Gabriel (PhD candidate) on (02) 9351 6865 or Mary Lou Maher (supervisor) on (02) 9351 4108 if I have any further questions. If I am concerned about the conduct of the study, or feel my questions have not been adequately answered I may request to speak to Ms Gail Briody, Ethics Officer, the University of Sydney, who may be contacted on (02) 9351 4811.

I understand that the audio and video recordings made for the collaborative communication experiments may be used for research purposes and in the dissemination of research. I understand that participation is entirely voluntary and I can withdraw from the experiment at anytime without consequence to myself.

I hereby agree to such material being used for the purposes of research so long as my anonymity is preserved. I have been offered a copy of this consent form.

**Name** (please print): \_\_\_\_\_

**Signature:** \_\_\_\_\_ **Date:** \_/\_\_\_\_\_/\_\_\_\_\_/\_\_\_\_\_

**Name of Witness** (please print): \_\_\_\_\_

**Signature:** \_\_\_\_\_ **Date:** \_/\_\_\_\_\_/\_\_\_\_\_/\_\_\_\_\_

**Name of Investigator** (please print): \_\_\_\_\_

**Signature:** \_\_\_\_\_ **Date:** \_/\_\_\_\_\_/\_\_\_\_\_/\_\_\_\_\_

**Experiment:** FTF-\_\_\_\_ CMCD-A\_\_\_\_ CMCD-B\_\_\_\_

# Appendix C.

## Subjects Information Form



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**Faculty of Architecture**  
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148 City Road  
University of Sydney  
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**Date:** 01 August 1998

### Subject Information Sheet.

#### **Collaborative Communication In Computer Mediated Architectural Design.**

Although researchers have studied face-to-face (FTF) and video mediated collaborative sessions between designers, they are still divided on the final outcome. There is little agreement on whether video and audio channels are essential in such ventures as well as what constituted the appropriate channels for a collaborative venture between designers to succeed.

This research deals with issues concerning collaborative communication in architectural collaboration through computer mediated collaborative design sessions (CMCD). For this purpose one hour experiments were devised and a single adequate design brief was developed to be used in all experiments.

The experiments are divided into three categories. The first comprising the FTF experiments, where students are paired and collaborate on the design problem in the same location, on a desk opposite each other. The second category is carried out through computer mediated collaborative design experiments with full communication channels (CMCD-a). CMCD-a sessions will have full audio & video conferencing plus a shared drawing space (whiteboard) as communication channels. The third category is comprised of limited computer mediated collaborative design experi-

ments (CMCD-b). The communication channels in the CMCD-b sessions are limited to using the Lambda MOO as a chat medium plus a shared drawing space (whiteboard). In both CMCD categories the paired students are situated in different rooms and collaborate on the design problem through networked workstations.

The study will be conducted by Gerard Gabriel (PhD candidate) and Mary Lou Maher (Assoc. Prof., supervisor) here at the Faculty of Architecture.

The objectives of this research are to a) understand more clearly the nature of collaborative communication taking place between collaborating architects; b) observe whether the limitation of communication channels in a CMCD environment will have any effect on the flow and quality of synchronous collaborative communication; c) develop a coding scheme specifically suited for synchronous collaborative communication in architecture; and d) develop a model of synchronous collaborative communication in architectural computer mediated collaborative design sessions.

If you agree to participate in this experiment, you will be given a brief of an architectural problem and you will be asked to collaborate and communicate your ideas with your partner for the period of one hour. At the fifty minute mark, you will be both notified of the time and that you should start wrapping up your ideas. After the experiment is finished you will be asked to complete a questionnaire sheet that will take no longer than ten minutes. Computer Aided Drafting (CAD) experience is not essential for the CMCD experiments. The shared drawing space used, (whiteboard) is very intuitive and simple to use. A period of around ten minutes will be given to CMCD participants to familiarise themselves with the software before beginning the experiment.

A final design is not expected at the end of one hour, instead it will be helpful if you can produce some basic 3D massing models or sketch plan(s) with external sketches (if possible).

Participation in this study is entirely voluntary. You are under no obligation to participate, and may withdraw your consent to participate at any time without consequence to you. If you are interested in participating in the study, Gerard Gabriel will be happy to discuss it further with you and answer any queries you may have. Please feel free to contact Gerard Gabriel on (02) 9351 6865.

Thank you.

Ms Gail Briody, Ethics Officer, the University of Sydney, may be contacted on (02) 9351 4811 if you have any concerns regarding this study.

# Appendix D.

## Post Experiment Final Questionnaires and Results



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Date: 01 August 1998

**Collaborative Communication In Computer Mediated  
Architectural Design.**

### Post Experiment Questionnaire.

**Name** (Optional): \_\_\_\_\_

**Signature:** \_\_\_\_\_ **Date:** \_\_/\_\_/\_\_\_\_/

**Experiment:** FTF-\_\_                      CMCD-A\_\_                      CMCD-B\_\_

Participation in this questionnaire is entirely voluntary. You are under no obligation to participate, and may withdraw at any time without consequence to you.

Please answer the following questions by selecting one answer.

---

**1) Is this the first time you participate in such an experiment? (FTF - CMCD-a & b)**

	<b>FTF</b>	<b>CMCD-a</b>	<b>CMCD-b</b>
a- Yes.	100 %	100%	93%
b- No.	0%	0%	7%
c- Other	0%	0%	0%

**2) Have you previously used video conferencing software? (CMCD-a & b)**

	<b>CMCD-a</b>	<b>CMCD-b</b>
a- Yes.	0%	0%
b- No.	100%	100%
c- Other	0%	0%

**3) How would you rate your skills at using computers in general? (CMCD-a & b)**

	<b>CMCD-a</b>	<b>CMCD-b</b>
a- Average.	57%	57%
b- Good.	29%	29%
c- Very good.	0%	0%
d- Other	14%	14%

**4) How would you rate your skills at using CAD as well as Graphics packages? (CMCD-a & b)**

	<b>CMCD-a</b>	<b>CMCD-b</b>
a- Average.	50%	50%
b- Good.	21%	29%
c- Very good.	14%	0%
d- Other	14%	21%

**5) How did you find the brief? (FTF - CMCD-a & b)**

	<b>FTF</b>	<b>CMCD-a</b>	<b>CMCD-b</b>
a- Easy.	31%	46%	38%
b- Adequate .	46%	54%	62%
c- Difficult.	0%	0%	0%
d- Other	23%	0%	0%

**6) Question removed since it was part of Pilot Study and is no longer relevant.****7) How did you find communicating Face-to-Face? (FTF)**

	<b>FTF</b>
a- Difficult.	0%

b- Took some time to get used to it.	0%
c- Easy.	100%
d- Other	0%

**8) How did you find communicating through a computer mediated environment? (CMCD-a & b)**

	<b>CMCD-a</b>	<b>CMCD-b</b>
a- Difficult.	0%	14%
b- Took some time to get used to it.	36%	15%
c- Easy.	50%	7%
d- Other	14%	29%

**9) Did you maintain eye contact, or made an effort to do so, during the experiment? (FTF - CMCD-a)**

	<b>FTF</b>	<b>CMCD-a</b>
a- Yes.	21%	7%
b- No.	14%	86%
c- Not sure.	29%	0%
d- Other	36%	7%

**10) How do you rate the use of the video channel in the experiment? (CMCD-a)**

	<b>CMCD-a</b>
a- Not useful, used it very little or non at all.	57%
b- Useful, used at certain times.	21%
c- Very useful, used it frequently.	7%
d- Not sure.	0%
e- Other	14%

**11) How do you rate the use of the audio channel in the experiment? (CMCD-a)**

	<b>CMCD-a</b>
a- Not useful, used it very little or non at all.	0%
b- Useful, used at certain times.	0%
c- Very useful, used it frequently.	100%
d- Not sure.	0%
e- Other	0%

**12) How do you rate the use of the text based channel in the experiment? (CMCD-b)**

	<b>CMCD-b</b>
a- Not useful, used it very little or non at all.	0%
b- Useful, used at certain times.	36%

- |                                     |     |
|-------------------------------------|-----|
| c- Very useful, used it frequently. | 57% |
| d- Not sure.                        | 0%  |
| e- Other                            | 7%  |
- 13) Did you at any time during the experiment scroll back up through the conversation text of the MOO looking for certain clues or ideas that were already said? (CMCD-b)**
- |                 | <b>CMCD-b</b> |
|-----------------|---------------|
| a- Never.       | 50%           |
| b- A few times. | 36%           |
| c- A lot.       | 0%            |
| d- Not sure.    | 14%           |
| e- Other        | 0%            |
- 14) Did you at any time during the experiment glance back at conversation text in the MOO that you had previously read or even typed? (CMCD-b)**
- |                 | <b>CMCD-b</b> |
|-----------------|---------------|
| a- Never.       | 10%           |
| b- A few times. | 70%           |
| c- A lot.       | 10%           |
| d- Not sure.    | 0%            |
| e- Other        | 10%           |
- 15) Do you think communicating through the text based chat system helped you structure and develop your design thoughts before sending messages? (CMCD-b)**
- |              | <b>CMCD-b</b> |
|--------------|---------------|
| a- Yes.      | 57%           |
| b- No.       | 14%           |
| c- Not sure. | 21%           |
| d- Other     | 7%            |
- 16) How do you rate the use of the whiteboard in the experiment? (CMCD-a & b)**
- |   | <b>CMCD-a</b> | <b>CMCD-b</b> |
|---|---------------|---------------|
| a- Not useful, used it very little or non at all. | 0%            | 0%            |
| b- Useful, used at certain times.                 | 14%           | 14%           |
| c- Very useful, used it very frequently.          | 64%           | 71%           |
| d- Not sure.                                      | 14%           | 0%            |
| e- Other  | 7%            | 14%           |
- 17) Do you think that it will be possible for architects to collaborate through such a medium? (CMCD-a & b)**
- |  | <b>CMCD-a</b> | <b>CMCD-b</b> |
|--|---------------|---------------|
|--|---------------|---------------|

---

a- Yes.	93%	64%
b- No.	7%	7%
c- Not sure.	0%	7%
d- Other	0%	21%

Thank you very much for your participation.

Gerard Cesar Gabriel

Following are answers related to the 'other' choice of all the questions in all three categories of experiments.

<b>Experiment</b>	<b>Answer to question No:</b>
CMCD-A-01 a	10) Not useful, nice to know the other person was there though
CMCD-A-02 b	9) No, occasionally looked at face to see reaction to suggestion (eg: smile)
CMCD-A-03 a	3) Not as good 4) Not as good
CMCD-A-05 b	8) The voice connection was a bit stuttered, other than that, the need for eye contact was not required, was good 16) Essential
CMCD-A-06 b	10) Good to establish initial contact but used it less & less as hour progressed – concentrated on the drawing to communicate
CMCD-A-08 b	3) Below average 4) Below average
CMCD-B-01 a	8) It is frustrating if the computer doesn't do what you want it to 12) The changing between text and brief was very difficult but when dwg was ok
CMCD-B-01 b	4) Never experienced cad
CMCD-B-02 b	12) Better to communicate directly on whiteboard. Talk screen not big enough 17) Not only possible but highly necessary with the globalisation of professionals
CMCD-B-04 a	14) Yes, looking for clues, ie Q 13 17) Eventually yes. I think it will take longer to design than say FTF but the power of being able to draw over each others work etc... is very useful in coming up with ideas.
CMCD-B-04 b	8) Fun but frustrating
CMCD-B-06 a	3) Below average 4) Not good 17) Possible, given the time
CMCD-B-06-b	8) Took some time but it is more easy to use than I expected
CMCD-B-07 b	8) Slow and difficult, lacking in many aspects of communicating 16) Useful but frustrating to draw with these tools especially the mouse
CMCD-B-08 b	3) OK
CMCD-B-09 a	15) It was more difficult to get the other person to understand what I was referring to with the moo text 8) Easier than I thought
FTF-01 a	9) Idea time yes; Producing dwgs no
FTF-01 b	9) For ideas mainly
FTF-02 a	9) Sometimes
FTF-03 a	5) Fairly clear, yet would have been better to have spoken to the client as well 9) Sometimes when conversing, other times eye were on drawings
FTF-04 b	5) Clear, but perhaps more information on lifestyle and personality 9) Main concentrating on the paper
FTF-05 a	5) Very interesting plus beautiful project
FTF-05 b	5) OK but it would be good to have more about the artist style of living

# Appendix E.

## Lists of Students Names Who Participated in Both Pilot and Final Experiments

Following are two lists of 5th and 6th year architecture students from the University of Sydney who participated in the pilot and final experiments for this thesis. I am forever indebted for their participation, assistance and feedback. I wish them all the luck in their future achievements.

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### Participants in the Pilot Experiments September 1997 (6th year)

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Mr BUCHANAN, ANDREW John	Ms LEUNG, BELINDA LING YEE
Ms DAWES, BELINDA JOY	Ms LO, JUNE TAK CHUNG
Mr DAY, MATTHEW LUKE	Mr MARIOTTI, BRIAN MARCO
Mr DRAYTON, RODNEY Suart	Ms OBRIEN, KATE
Ms FITZGERALD, Sarah Patricia	Mr PLAYOUST, Nicholas Marc S.
Ms HANSEN, SHERALEE Patricia	Mr PRABHU, TUSHAR
Mr HONES, NATHAN JON	Ms ROWE, HARRIETTE Cayley
Ms HUGHES, RACHAEL EMILY	Ms SAUNDERS, EMILY
Ms LAWES, KITSY ANNE	Ms STEVENSON, JANE Elizabeth

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## Participants in the Final Experiments September 1998 (5th and 6th year)

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Ms AITKEN, Rachel	Mr MACHAALANI, Roland
Mr ALLIKER, Joseph	Ms MAGGIE, Lum
Ms ANCHER, Anna	Ms MALES, Sheena
Ms BAKKER, Catherine	Mr MCLEAN, Paul
Mr CHEN, Tony	Ms McNEILL, Jane
Mr CHHOEU, Winston	Ms MITROVIC, Annetta
Mr CORKILL, Morgan	Ms MULLIN, Sharon
Ms FALSONE, Belinda	Ms NELSON, Sasha
Ms FARAH, Latifi	Ms NIVEN, Jodie
Mr FITZGERALD, Liam	Mr OBRIEN, Matthew
Mr FLETCHER, Thomas	Mr OCONNOR, David
Ms FONG, Coralie	Ms OUANO, Evariz
Ms GERVAY, Elisabeth	Mr PEDERSEN, James
Ms GOODWIN, Carolyn	Ms PRINEAS, Eva Marie
Mr GOWTY, David	Mr PROTUDER, Barry
Ms GROVE, Sky	Mr ROSEN, Kris
Ms HELYAR, Tricia	Ms SENZAMICI, Leane
Ms HETHERTON, Madeleine	Mr SMITH, Richard
Mr JOHNSTON, Benjamin	Ms TASHJIAN, Taleen
Mr KALLOS, Constantine	Mr TAY, Ming
Mr KOH, Jason	Ms TUNG, Sonia
Ms KWONG, Christine	Mr VOUTZOUNIS, Kon
Mr LAI, David	Mr YAP, Adrian
Ms LE VAN, Lisa	Mr YUE, Jeffrey
Mr LONGBOTTOM, Brian	Ms ZACHOS Maria

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# Appendix F.

## Design Brief



The University of Sydney

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chitecture

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PhD Candidate

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Chippendale NSW Australia

### The Cliff House, Earlwood.

#### The Brief and Site:

A Sydney based painter/artist recently acquired a site on top of a cliff in an inner-west suburb of Sydney. He stumbled across the location by taking the wrong turn one day and ending up in a cul-de-sac, on top of a boulder with breath taking views. To the owner a dwelling represents more than a shelter or a place to live in. He prefers to think of it as a space comprising certain functions, some of which are living, working and entertaining.

Far from being a novel idea, the house as a shelter that combines the working and living environments dates back a few centuries. Numerous contemporary architects have relished such unique opportunities to investigate and develop their own architectural theories.

The brief set out by the owners Ziad and Maya with their teenage son, Omar 19 and teenage daughter Pia 17, is a simple list of functions that includes, but is not exclusive to the following items:

- 1)- Living area for the family
- 2)- Kitchen and appropriate amenities.
- 3)- Master bedroom plus en suite.
- 4)- 2 bedrooms for the children with shared bathroom.
- 5)- A decent sized naturally lit workshop.
- 6)- Roof terrace overlooking the cliff, where the vistas to the east include Botany Bay.
- 7)- Single or double garage if possible.
- 8)- Swimming pool.

- 9)- Any other function you think can enhance and complement the brief and the site.
- 10)- The owner requires that the design be unique while reflecting and enhancing the natural attributes of the site.

A final design is not expected at the end of one hour, but you are required to produce, some basic 3D massing models and/or sketch plan(s) with external sketches (if possible).

Thank you for your involvement and good luck.

### The Site

The site is situated at the end of Bayview lane on top of the cliff in Undercliff, *figure 1.0*. It is mainly formed of a large blackened sandstone boulder with some unique attributes, one of which the extended vistas (That can never be blocked by any future development). Another attribute is that the site enjoys a northerly aspect.

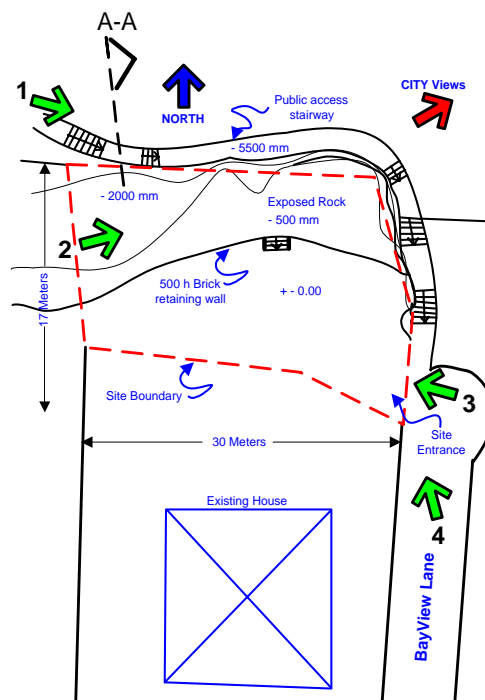


Figure 1.0: Site plan not to scale.



**1** The Sandstone boulder as seen from the public stairway.



**2** The City views looking northeast as seen from the back (western) fence of the property. Harbour Bridge and city in background.



- 3** The view from the entrance to the property. Uninterrupted Vistas to the west, with Cooks river and golf course seen below the cliff.



- 4** Open vistas all the way to the Blue Mountains, looking north-west approaching the entrance from Bayview lane.

# Appendix G.

## Extracted Normalised Data Tables from QSR-NUD\*IST™

All the coding results obtained from QSR-NUD\*IST™, of each sub-category in each experiment, were exported in table form. Those tables are presented in the following appendix along with their normalised values as well as calculated arithmetic means, medians and standard deviations.

# The Four Primary Categories

	Documents	Communication control	Communication Technology	Social Communication	Design Communication
<b>FTF</b>	FTF-01	0.11	0.01	0.09	0.79
	FTF-02	0.11	0.01	0.07	0.82
	FTF-03	0.20	0.01	0.05	0.74
	FTF-04	0.13	0.01	0.16	0.71
	FTF-05	0.15	0.00	0.06	0.78
	FTF-06	0.20	0.01	0.06	0.73
	FTF-07	0.23	0.01	0.06	0.70
	<b>Mean</b>	0.161	0.008	0.079	0.752
	<b>STDEV</b>	0.049	0.004	0.037	0.046
	<b>Median</b>	0.152	0.007	0.065	0.741
<b>CMCD-a</b>	CMCD-a01	0.22	0.08	0.06	0.63
	CMCD-a02	0.22	0.05	0.08	0.66
	CMCD-a03	0.23	0.05	0.05	0.68
	CMCD-a04	0.24	0.07	0.11	0.57
	CMCD-a05	0.22	0.10	0.10	0.58
	CMCD-a06	0.16	0.06	0.05	0.73
	CMCD-a07	0.15	0.12	0.05	0.68
	<b>Mean</b>	0.205	0.075	0.073	0.647
	<b>STDEV</b>	0.036	0.026	0.027	0.056
	<b>Median</b>	0.220	0.071	0.061	0.656
<b>CMCD-b</b>	CMCD-b01	0.06	0.05	0.02	0.88
	CMCD-b02	0.09	0.08	0.05	0.78
	CMCD-b03	0.03	0.07	0.00	0.90
	CMCD-b04	0.05	0.09	0.05	0.82
	CMCD-b05	0.05	0.06	0.06	0.83
	CMCD-b06	0.04	0.05	0.10	0.81
	CMCD-b07	0.03	0.03	0.03	0.90
	<b>Mean</b>	0.049	0.062	0.045	0.845
	<b>STDEV</b>	0.020	0.019	0.034	0.047
	<b>Median</b>	0.045	0.065	0.045	0.831

# Communication Control

	Documents	Interruption	Floor Holding	Hand Over	Online Acknowledgement
<b>FTF</b>	FTF-01	0.364	0.076	0.167	0.394
	FTF-02	0.387	0.000	0.120	0.493
	FTF-03	0.518	0.004	0.053	0.425
	FTF-04	0.381	0.000	0.082	0.536
	FTF-05	0.355	0.029	0.123	0.493
	FTF-06	0.310	0.118	0.043	0.529
	FTF-07	0.549	0.018	0.031	0.402
	<b>Mean</b>	0.409	0.035	0.088	0.467
	<b>StDev</b>	0.089	0.045	0.050	0.060
	<b>Median</b>	0.381	0.018	0.082	0.493
<b>CMCD-a</b>	CMCD-a01	0.191	0.042	0.153	0.615
	CMCD-a02	0.197	0.039	0.137	0.627
	CMCD-a03	0.251	0.048	0.281	0.419
	CMCD-a04	0.423	0.024	0.149	0.404
	CMCD-a05	0.354	0.044	0.175	0.427
	CMCD-a06	0.454	0.007	0.078	0.461
	CMCD-a07	0.333	0.047	0.194	0.426
	<b>Mean</b>	0.315	0.036	0.167	0.483
	<b>StDev</b>	0.105	0.015	0.062	0.096
	<b>Median</b>	0.333	0.042	0.153	0.427
<b>CMCD-b</b>	CMCD-b01	0.000	0.000	1.000	0.000
	CMCD-b02	0.000	0.000	1.000	0.000
	CMCD-b03	0.000	0.000	0.875	0.125
	CMCD-b04	0.000	0.000	0.750	0.250
	CMCD-b05	0.000	0.000	1.000	0.000
	CMCD-b06	0.000	0.000	1.000	0.000
	CMCD-b07	0.000	0.000	1.000	0.000
	<b>Mean</b>	0.000	0.000	0.946	0.054
	<b>StDev</b>	0.000	0.000	0.098	0.098
	<b>Median</b>	0.000	0.000	1.000	0.000

# Communication Technology

	Documents	Tools and Environment
<b>FTF</b>	FTF-01	0.009
	FTF-02	0.008
	FTF-03	0.018
	FTF-04	0.008
	FTF-05	0.000
	FTF-06	0.013
	FTF-07	0.014
	<b>Mean</b>	0.010
	<b>StDev</b>	0.006
	<b>Median</b>	0.009
<b>CMCD-a</b>	CMCD-a01	0.120
	CMCD-a02	0.065
	CMCD-a03	0.048
	CMCD-a04	0.086
	CMCD-a05	0.116
	CMCD-a06	0.087
	CMCD-a07	0.158
	<b>Mean</b>	0.097
	<b>StDev</b>	0.037
	<b>Median</b>	0.097
<b>CMCD-b</b>	CMCD-b01	0.068
	CMCD-b02	0.082
	CMCD-b03	0.091
	CMCD-b04	0.108
	CMCD-b05	0.083
	CMCD-b06	0.054
	CMCD-b07	0.053
	<b>Mean</b>	0.077
	<b>StDev</b>	0.020
	<b>Median</b>	0.082

# Social Communication

	Documents	Social and Interpersonal
<b>FTF</b>	FTF-01	0.14
	FTF-02	0.10
	FTF-03	0.07
	FTF-04	0.22
	FTF-05	0.10
	FTF-06	0.09
	FTF-07	0.09
	<b>Mean</b>	0.110
	<b>StDev</b>	0.052
	<b>Median</b>	0.101
<b>CMCD-a</b>	CMCD-a01	0.10
	CMCD-a02	0.12
	CMCD-a03	0.06
	CMCD-a04	0.16
	CMCD-a05	0.15
	CMCD-a06	0.08
	CMCD-a07	0.07
	<b>Mean</b>	0.104
	<b>StDev</b>	0.039
	<b>Median</b>	0.096
<b>CMCD-b</b>	CMCD-b01	0.10
	CMCD-b02	0.02
	CMCD-b03	0.06
	CMCD-b04	0.06
	CMCD-b05	0.08
	CMCD-b06	0.13
	CMCD-b07	0.06
	<b>Mean</b>	0.074
	<b>StDev</b>	0.036
	<b>Median</b>	0.063

# Design Communication

	Documents	Design Idea	Design Scope	Design Task
<b>FTF</b>	FTF-01	0.66	0.13	0.21
	FTF-02	0.58	0.16	0.26
	FTF-03	0.55	0.18	0.27
	FTF-04	0.67	0.12	0.20
	FTF-05	0.59	0.20	0.21
	FTF-06	0.58	0.19	0.23
	FTF-07	0.57	0.18	0.25
	<b>Mean</b>	0.592	0.172	0.236
	<b>StDev</b>	0.049	0.031	0.027
	<b>Median</b>	0.600	0.167	0.233
<b>CMCD-a</b>	CMCD-a01	0.47	0.22	0.32
	CMCD-a02	0.61	0.26	0.13
	CMCD-a03	0.47	0.21	0.32
	CMCD-a04	0.51	0.14	0.35
	CMCD-a05	0.56	0.17	0.27
	CMCD-a06	0.59	0.15	0.25
	CMCD-a07	0.65	0.12	0.23
	<b>Mean</b>	0.551	0.185	0.264
	<b>StDev</b>	0.071	0.049	0.072
	<b>Median</b>	0.560	0.167	0.273
<b>CMCD-b</b>	CMCD-b01	0.54	0.17	0.29
	CMCD-b02	0.59	0.25	0.15
	CMCD-b03	0.59	0.22	0.19
	CMCD-b04	0.57	0.25	0.18
	CMCD-b05	0.65	0.26	0.09
	CMCD-b06	0.64	0.21	0.15
	CMCD-b07	0.58	0.26	0.16
	<b>Mean</b>	0.594	0.232	0.174
	<b>StDev</b>	0.037	0.034	0.061
	<b>Median</b>	0.589	0.250	0.160

# Design Idea

	Documents	Introduction of Idea	Acceptance of Idea	Rejection of Idea	Clarification of Idea	Confirmation of Idea	Development of Idea	Repetition of Idea	Referencing of Idea	Revisiting of Idea	Evaluation of Idea
<b>FTF</b>	FTF-01	0.09	0.04	0.00	0.38	0.12	0.13	0.00	0.00	0.00	0.25
	FTF-02	0.11	0.02	0.01	0.35	0.05	0.19	0.00	0.03	0.00	0.23
	FTF-03	0.08	0.03	0.00	0.29	0.07	0.26	0.01	0.10	0.01	0.14
	FTF-04	0.06	0.03	0.00	0.21	0.05	0.14	0.01	0.41	0.01	0.10
	FTF-05	0.14	0.02	0.00	0.31	0.05	0.23	0.01	0.06	0.00	0.19
	FTF-06	0.10	0.04	0.00	0.30	0.10	0.26	0.01	0.02	0.01	0.15
	FTF-07	0.12	0.03	0.00	0.36	0.06	0.22	0.00	0.09	0.00	0.11
	<b>Mean</b>	0.100	0.029	0.003	0.314	0.070	0.203	0.006	0.103	0.003	0.168
	<b>STDEV</b>	0.024	0.009	0.003	0.058	0.029	0.054	0.004	0.141	0.003	0.058
	<b>Median</b>	0.104	0.027	0.003	0.310	0.055	0.216	0.006	0.057	0.005	0.152
<b>CMCD-a</b>	CMCD-a01	0.08	0.03	0.01	0.32	0.08	0.26	0.09	0.02	0.00	0.13
	CMCD-a02	0.11	0.08	0.00	0.21	0.05	0.27	0.03	0.08	0.01	0.16
	CMCD-a03	0.10	0.05	0.00	0.25	0.04	0.32	0.13	0.00	0.00	0.10
	CMCD-a04	0.10	0.04	0.00	0.36	0.08	0.22	0.02	0.00	0.01	0.16
	CMCD-a05	0.08	0.03	0.00	0.29	0.08	0.27	0.04	0.09	0.01	0.11
	CMCD-a06	0.09	0.06	0.00	0.35	0.13	0.20	0.03	0.01	0.01	0.11
	CMCD-a07	0.08	0.07	0.00	0.30	0.10	0.13	0.02	0.11	0.02	0.16
	<b>Mean</b>	0.092	0.051	0.002	0.296	0.081	0.240	0.050	0.046	0.009	0.134
	<b>STDEV</b>	0.014	0.021	0.002	0.053	0.030	0.061	0.044	0.047	0.006	0.027
	<b>Median</b>	0.085	0.047	0.002	0.299	0.084	0.259	0.026	0.016	0.010	0.130
<b>CMCD-b</b>	CMCD-b01	0.23	0.08	0.00	0.28	0.00	0.15	0.00	0.10	0.02	0.13
	CMCD-b02	0.29	0.13	0.00	0.20	0.00	0.16	0.00	0.09	0.00	0.13
	CMCD-b03	0.25	0.09	0.00	0.26	0.05	0.19	0.00	0.04	0.00	0.12
	CMCD-b04	0.33	0.11	0.00	0.24	0.00	0.15	0.00	0.02	0.00	0.15
	CMCD-b05	0.33	0.05	0.02	0.21	0.02	0.10	0.00	0.09	0.02	0.17
	CMCD-b06	0.29	0.07	0.00	0.16	0.02	0.09	0.00	0.13	0.02	0.22
	CMCD-b07	0.30	0.09	0.00	0.23	0.01	0.17	0.00	0.04	0.00	0.16
	<b>Mean</b>	0.287	0.089	0.002	0.226	0.015	0.145	0.000	0.072	0.007	0.156
	<b>STDEV</b>	0.036	0.026	0.007	0.040	0.019	0.036	0.000	0.039	0.009	0.032
	<b>Median</b>	0.291	0.086	0.000	0.229	0.014	0.152	0.000	0.086	0.000	0.152

# Design Scope

	Documents	Low Level Design	High Level Design
<b>FTF</b>	FTF-01	0.583	0.417
	FTF-02	0.734	0.266
	FTF-03	0.726	0.274
	FTF-04	0.569	0.431
	FTF-05	0.722	0.278
	FTF-06	0.723	0.277
	FTF-07	0.648	0.352
	<b>Mean</b>	0.672	0.328
	<b>StDev</b>	0.072	0.072
	<b>Median</b>	0.722	0.278
<b>CMCD-a</b>	CMCD-a01	0.834	0.166
	CMCD-a02	0.556	0.444
	CMCD-a03	0.838	0.162
	CMCD-a04	0.797	0.203
	CMCD-a05	0.696	0.304
	CMCD-a06	0.580	0.420
	CMCD-a07	0.725	0.275
	<b>Mean</b>	0.712	0.288
	<b>StDev</b>	0.115	0.115
	<b>Median</b>	0.725	0.275
<b>CMCD-b</b>	CMCD-b01	0.056	0.944
	CMCD-b02	0.000	1.000
	CMCD-b03	0.250	0.750
	CMCD-b04	0.000	1.000
	CMCD-b05	0.074	0.926
	CMCD-b06	0.056	0.944
	CMCD-b07	0.059	0.941
	<b>Mean</b>	0.072	0.928
	<b>StDev</b>	0.084	0.084
	<b>Median</b>	0.056	0.944

# Design Task

	Documents	Brief	Schedule	Task	Action	Instruction	Design Representation
<b>FTF</b>	FTF-01	0.27	0.10	0.04	0.56	0.00	0.03
	FTF-02	0.27	0.06	0.04	0.54	0.01	0.10
	FTF-03	0.36	0.02	0.03	0.49	0.01	0.08
	FTF-04	0.22	0.07	0.07	0.59	0.03	0.01
	FTF-05	0.27	0.00	0.05	0.63	0.02	0.03
	FTF-06	0.27	0.09	0.05	0.54	0.02	0.04
	FTF-07	0.38	0.02	0.05	0.48	0.01	0.06
	<b>Mean</b>	0.290	0.050	0.048	0.548	0.013	0.051
	<b>StDev</b>	0.058	0.038	0.015	0.052	0.011	0.031
	<b>Median</b>	0.266	0.055	0.050	0.543	0.009	0.037
<b>CMCD-a</b>	CMCD-a01	0.17	0.04	0.09	0.54	0.03	0.13
	CMCD-a02	0.39	0.01	0.08	0.46	0.01	0.05
	CMCD-a03	0.32	0.11	0.06	0.40	0.04	0.07
	CMCD-a04	0.26	0.05	0.16	0.37	0.05	0.11
	CMCD-a05	0.24	0.02	0.10	0.49	0.02	0.14
	CMCD-a06	0.30	0.02	0.04	0.49	0.03	0.12
	CMCD-a07	0.40	0.05	0.04	0.34	0.08	0.08
	<b>Mean</b>	0.297	0.045	0.081	0.442	0.037	0.099
	<b>StDev</b>	0.081	0.034	0.040	0.072	0.023	0.034
	<b>Median</b>	0.299	0.042	0.078	0.464	0.030	0.112
<b>CMCD-b</b>	CMCD-b01	0.14	0.14	0.28	0.02	0.14	0.28
	CMCD-b02	0.18	0.03	0.13	0.08	0.21	0.38
	CMCD-b03	0.46	0.08	0.13	0.08	0.08	0.17
	CMCD-b04	0.34	0.07	0.14	0.07	0.28	0.10
	CMCD-b05	0.43	0.11	0.11	0.04	0.11	0.21
	CMCD-b06	0.50	0.00	0.15	0.04	0.19	0.12
	CMCD-b07	0.23	0.10	0.19	0.16	0.13	0.19
	<b>Mean</b>	0.325	0.075	0.161	0.069	0.162	0.208
	<b>StDev</b>	0.144	0.048	0.060	0.047	0.066	0.098
	<b>Median</b>	0.345	0.083	0.138	0.069	0.140	0.194