Coding and Modelling Communication in Architectural Collaborative Design

Gerard Cesar Gabriel and **Mary Lou Maher**
University of Sydney, Australia

Although there has been some research done on collaborative face-to-face (FTF) and video-conferencing sessions involving architects, little is know 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.

Introduction

The idea of collaboration between architects using telecommunication technology is not new and dates back to the fifties. Back then Weiner, as cited by Kvan (1997) gave us an idea of how architects might use the fax technology to serve design communication in the future. "Architecture is primarily about communication" (Verzijl, 1997). In general, architects communicate their theories and ideas through their achievements in the built environment. First, those theories and ideas need to be communicated to the client(s), their colleague(s) and at times to the public at large (Sasada, 1995). According to Van Bruggen (1998, p. 27), architects do "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) and graphical representations.

Up till now, architects who collaborated with other colleagues did so mostly 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 telephone, and graphical representations were sent by Fax or as posted documents. Levine (1991) made the observation that telephone-based communication is usually very fast, but could also lead to serious communication breakdowns, considering that two and three-dimensional visual representations would have to be translated into 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 and even then it is very difficult to establish long distance frames of reference (Bly, 1988).

With recent developments in CAD and communication technologies, the way we visualise and communicate design representations is changing. Some architectural firms have started using modems and Internet connections to exchange information, transferring CAD files as well as design information, through E-mail and FTP. Consequently real time remote collaboration in design became the subject of numerous studies, resulting in a diversity of findings (see Mazilioglou et al, 1996; Olson *et al*, 1997; Vera *et al*, 1998).

A matter of great interest to architects, practitioners and researchers alike, is how computer technology might affect the way they think and work. The concern is not about the notion of 'support' alone, but about ensuring that computers do not disrupt the design process and collaborative activity 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 the collaborators use and what hindrances they encounter in their work (Finholt *et al*, 1990; Tang, 1991).

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. 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 more interruptions and successful collaborative sessions can take place without them.

Designing, as a more abstract notion, is different than having a business meeting using video conferencing. In design 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 it is 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 along side graphical representations for later retrieval and use.

Hence the main objective of this paper remains in developing a coding scheme to assist us in further investigating the possible effects of communication channels on verbal design representations in CMCD sessions as opposed to FTF collaborative design sessions between architects. The underlying aim is to establish a clearer notion of the collaborative needs of architects using computer-mediation as well as attempting to model verbal design communication in collaborative design. In turn this has the potential in assisting developers when design new collaborative tools.

In this paper we present a set of collaborative design experiments that explored three different communication environments. The first is FTF. The second type of communication uses computer mediation with full communication channels, audio-visual (video conferencing) as well as a shared whiteboard - CMCD-a. The third type uses computer mediation with limited communication channels; a text based virtual chat (VC) and shared whiteboard - CMCD-b. We present a coding scheme developed to analyse verbal design communication in order to compare FTF collaborative design with CMCD.

Background

Computer mediated collaborative design

In order to compare CMCD and FTF 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 utilize in order to convey design representations to their partner(s). When working FTF, 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. Sometimes they hastily proceed to build 3D massing models, made of polystyrene or cardboard (Kvan, 1994; Visser, 1993). 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 to clients to the general public.

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 what constituted the appropriate channels (Maziloglou *et al*, 1996; 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" (Sudweeks and Rafaeli, 1995). According to Greenberg *et al* (1992) some researchers maintain tele-presence as being the alternative to FTF collaboration (Egido, 1988; Johansen and Bullen, 1984), where distributed participants in a collaborative venture are given the feeling that they are present in the same meeting room. Whether or not seeing one's partner has an effect on performance seems to be highly dependent on the type of performed task (Olson *et al*, 1997).

Researchers in the Rococo project (see Maziloglou et al, 1996) found it difficult to compare conditions and draw conclusions between FTF and communication impoverished experiments. According to Maziloglou et al (1996) the impoverishment of the communication environment, by excluding the audio and video chan-

nels, did not seem to perturb the product designers who quickly adapted to the new situations thus making it difficult for the researchers to see any noticeable change. Where as Vera *et al* (1998) observed a slight decrease in low-level design (LLD) as opposed to high-level design (HLD) in text-based computer-mediated experiments compared to audio and video computer mediated experiments.

Recent developments in CSCW and GroupWare have seen an increased number of collaborative design tools accompanying the phenomenal growth of the Internet. This prompted several schools of architecture to set-up design studios based on digital collaborative environments, which attempted to replicate FTF environments (for a brief review of this work see Kvan *et al*, 1997). Likewise more research is being done into the field of 'shared workspaces' between designers to facilitate communication and collaboration (Maziloglou *et al*, 1996; Peng, 1993; Saad and Maher, 1996). Computer-mediated communication 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.

Protocol analysis

The first report of protocol studies on design activity was that of Eastman (1970) where he studied architects in the late 1960s. Architectural design continues to be a rich subject area for studies mainly looking at single designers (Akin, 1986; Foz, 1973; Goldschmidt, 1991; Hamel, 1990). A significant change was made in the 1980s by extending the conventional, single-subject, method of protocol analysis into of team design activity, (Cross *et al*, 1996; Vera et al, 1998).

According to Newell (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".

The Delft Protocol Analysis Workshop (Cross *et al*, 1996) presented a group of researchers with the opportunity to examine a two hour long videotape of a team of practicing 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, reconciliation of differences and manage their work.

Since we will be investigating collaborative communication resulting from the design process between architects, in this paper we propose a coding scheme specifically developed to code verbal design representations in collaborative design.

Method

Initially we carried out nine pilot experiments, three in each category (FTF, CMCD-a and CMCD-b as described above) which in many ways helped us refine the brief, test the preliminary coding scheme and further refine and develop it. Then we conducted a final series of one-hour experiments divided also into the three categories. The sessions were audio and video taped, transcribed and are being coded at present, into the custom developed coding scheme. Preliminary observations of the videotapes provided evidence that there were noticeable differences between all three categories.

Experiments

We conducted twenty-six one-hour experiments using fifty-two 5th and 6th year architecture students. The participants were paired and each pair participated in only one experiment from any of the three categories using the same brief. We conducted eight experiments in each of the FTF and CMCD-a categories and ten in the CMCD-b category. One brief was designed for all three categories in order to reduce the variables and it only differed in the way 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 site plan, a section through the site

	FTF	CMCD-a	CMCD-b
1) Time.	1 Hour/synchronous.	1 Hour/synchronous.	1 Hour/synchronous.
2) Location.	Participating subjects are located in same room.	Participating subjects are located in different rooms.	Participating subjects are located in different rooms.
3) Media.	Paper and pencil.	Computer hardware and software, (SC™ Inperson™/Netscape™)	Computer hardware and software, (SC™/Inperson™/Netscape /VC)
4) Brief	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.
5) Subjects.	5th and 6th year architecture students. Each pair participating only once.	5th and 6th year architecture students. Each pair participating only once.	5th and 6th year architecture students. Each pair participating only once.
6) Communication.	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 VC and whiteboard).
7) Data Collection.	Time stamped video plus audiotapes.	Time stamped video plus audiotapes.	Time stamped video. Text transcripts from VC.

Figure 1. The table of variables for the three types of experiment.

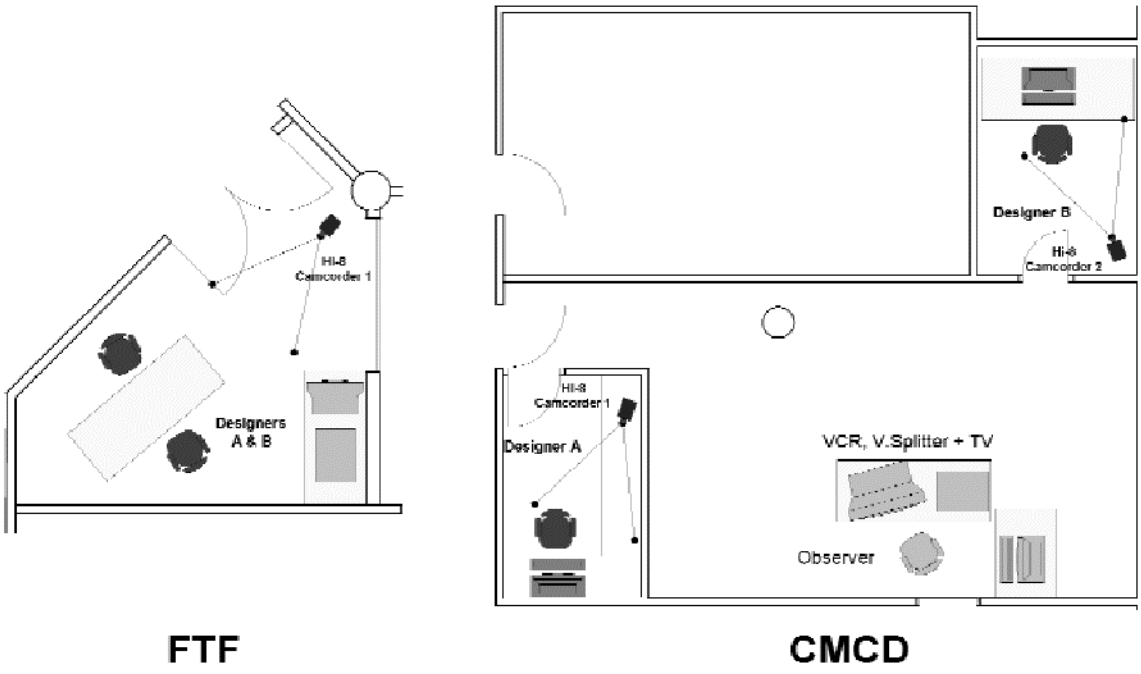

Figure 2. Environment settings for FTF and CMCD experiments.

and four coloured photographs. In both CMCD categories, the brief was presented to participants in the same format as FTF but was accessible through a Netscape™ window.

Variables

To reduce the number of variables as much as possible, only 5th and 6th year students were used as opposed to practising architects with varying degrees of experience. Figure 1 shows a list of the variables in all three categories. The major variable in the three categories was the type of media available to the designers in order to communicate their design ideas through graphical and verbal representations.

Apparatus and media

The eight FTF sessions were carried out in a room containing a central table with participants sitting on either side, as illustrated in figure 2. Each pair was given four A1 tracing sheets with a pair of black and blue felt pens in order to account for the sketches. They were each given a copy of the brief as well as extra A4 copies of the site plan and section, which can be used to trace over. A SonyTM Hi-8 CamCorder connected to VHS in the same room, was placed at an angle to capture both verbal and graphical interaction between the participants.

Two rooms separated by a third larger one were used for the eighteen CMCD sessions, illustrated in figure 2. Each room was equipped with a Silicon Graphics O2TM (SG) Unix workstation. The two SGs were connected along with the observer's terminal (in the central room) by a high speed Local Area Network (LAN). Two SonyTM Hi-8 CamCorders were positioned behind the SGs at a slight angle, in order to capture the screen activity taking place. The CamCorders were connected to a video splitter, which in turn out-putted to a VHS and a 34inch TV monitor for the observer.

The CMCD-a sessions used computer-mediated audio and video with a shared electronic whiteboard (they used the InpersonTM). The CMCD-b sessions used a chat-like environment to talk to each other by typing messages, and a shared electronic whiteboard (also using InpersonTM).

Brief

A City based painter 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, figure 3. 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 along with their teenage son (19), and daughter (17), was a simple list. Functions such as an entertaining area, a decent sized naturally lit workshop and Roof terrace overlooking the cliff were among the items included.

The owners require that the design be unique while reflecting and enhancing the natural attributes of the site.

Procedure

All the experiments were 1 hour long. The participants were briefed 10 minutes before the start and advised as to what was expected from them. They were also notified at the fifty-minute mark in order to start wrapping up their ideas. The pairs involved in the CMCD categories were given 10 minutes, after briefing, to familiarise themselves with the tools and environment. All participants were required to fill and sign a 'subject consent form', which clears the way for analysis and results to be published in the future while preserving their anonymity.

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 it and proceeded straight into designing. All experiments were both audio and video

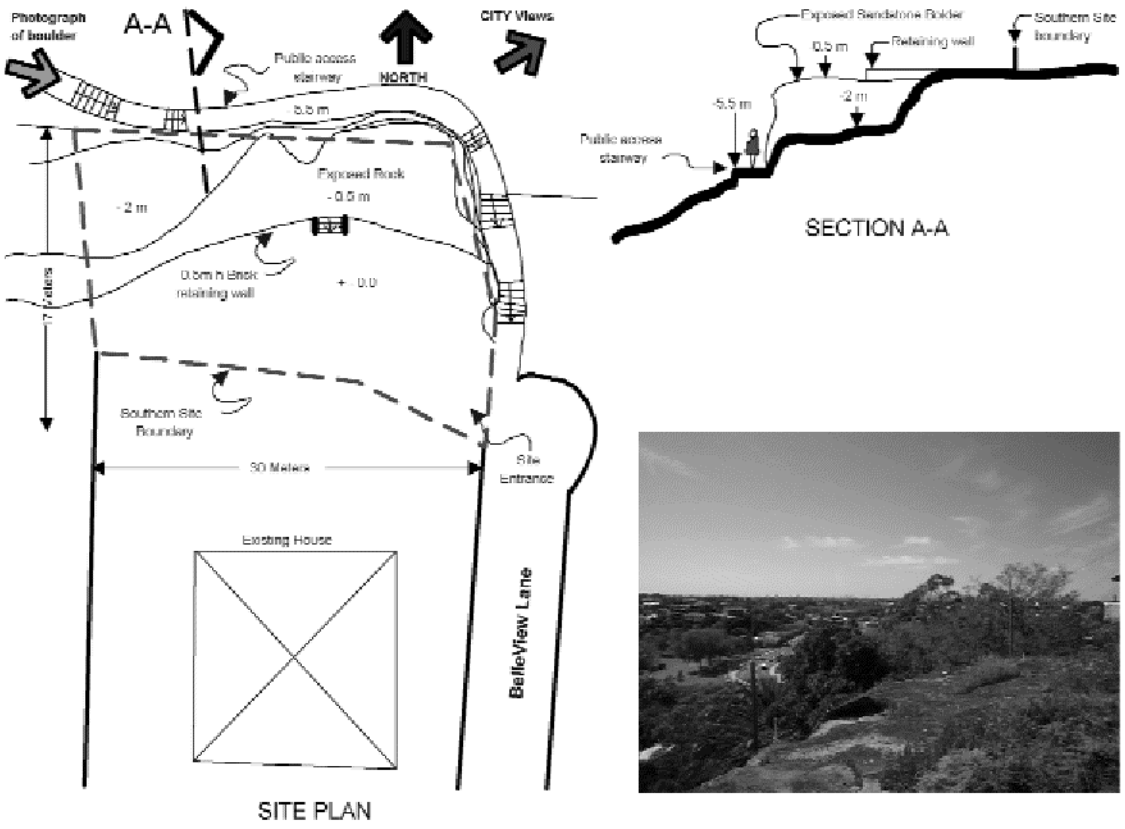

Figure 3. The site plan, section (NTS) and photograph (taken from site) showing aspect and views towards city.

taped to help in the transcribing and in later analysis stages.

Development of the coding scheme

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, p 225) protocols represent a particular type of qualitative data, but are not the actual data on which analysis is performed. Analysing these communication protocols involves the development of a coding scheme. A more traditional way of developing coding schemes was by segmenting protocols. Subsequently categories were developed after carefully reviewing the segmented protocols and coding each segment under a single category only (Purcell et al, 1996). 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.

The structure of a design representation protocol coding scheme can been derived in three ways: data generated structure, externally derived structure and theory derived structure (for a full review on this subject see Purcell et al, 1996, pp 225-227). Data generated structure in a coding scheme (or part of a coding scheme) is generated after the transcribed protocols

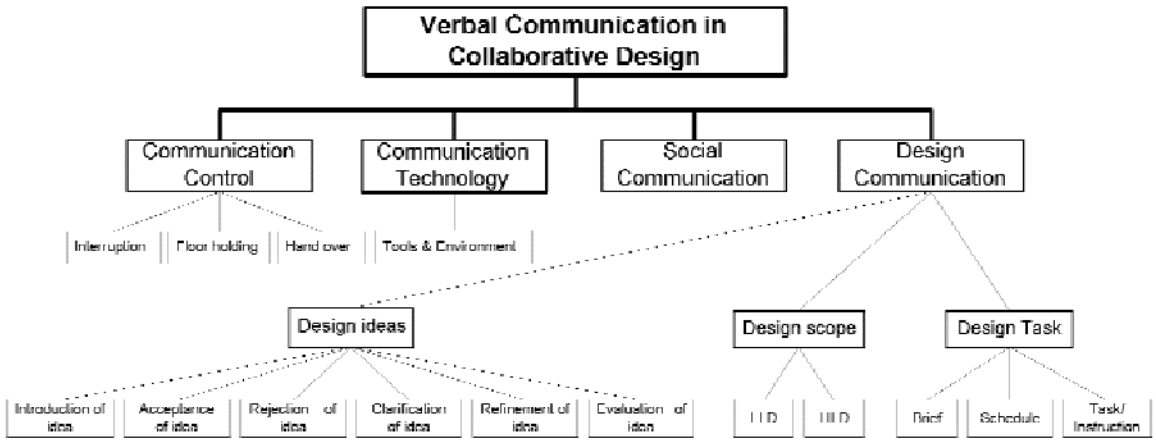

Figure 4. A hierarchical tree of the coding scheme: Verbal Communication in Collaborative Design.

have been parsed, segmented and reviewed. Externally derived structures occur when parts of an already established coding scheme are used to develop another one. Theory derived structure happens when part of a coding scheme is generated through a particular theory. In this paper we propose a coding scheme developed by using data, external and theory generated structures in order to code verbal design representations in collaborative design.

The initial data derived coding scheme, which transpired from the protocols of the pilot experiments was allowed to evolve during the preliminary analysis. 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). After reviewing literature on both design (Akin, 1986; Goldschmidt, 1991) and communication protocols (Kvan, 1994; Olson *et al*, 1997; Sudweeks and Albritton, 1996; Vera *et al*, 1998) it was apparent that 'parts' of these coding structures could be added to our coding scheme thereby further enriching it and the ensuing results. The third and final part of our coding scheme was derived from our theoretical views presented earlier. Finally the coding scheme had to be related to all three categories of experiments, in order to enable comparison and correlation of results.

Coding scheme structure

We considered four 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 dominance' (see O'Connail and Whittaker, 1997). Part of the fourth coding scheme investigated 'low level design' versus 'high level design' in computer mediated design sessions with full and limited communication channels (for more details see Vera *et al*, 1998).

Our coding scheme classifies communication in collaborative design into four types, which in turn are further broken down into sub-categories as illustrated in figure 4. The four types are communication control, communication technology, social communication, and design communication. These types are not intended to be exhaustive, but to indicate, through analysis, the

Verbal Communication in Collaborative Design		
Communication Control	Code	Description
Interruption	*INT*	Interruptions are associated with simultaneous speech (Levinson, 1983).
Floor Holding	*FLO*	Occurs when one speaker tries to take the floor while the other attempts to hold the floor while producing utterances that do not contain any information (Jefferson, 1984).
Hand-over	*HAN*	3 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"; c) naming the next speaker (Levinson, 1983).
Communication Technology		
Tools & Environment	*CTE*	Communication in regards to use of tools and collaborating environment
Social Communication	*SOC*	"Communication content dealing with interpersonal relationships" (Sudweeks and Albritton, 1996).
Design Communication		Description
Design Ideas		Verbal (audio and text) design representations
Introduction of idea	*IDE*	When participants directly or indirectly (in the form of a question) introduce a new idea.
Acceptance of Idea	*ACC*	When a participant makes it clear to the other participant that he/she accepts a particular idea.
Rejection of idea	*REJ*	When a participant makes it clear to the other participant that he/she does not accept a particular idea
Clarification of idea	*CLA*	When a participant clarifies his/her idea to the other participant in either question or answer forms.
Refinement of idea	*REF*	When participants spend time refining and further developing an idea. (Peng, 1994)
Evaluation of idea	*EVA*	When participants spend time evaluating an idea.
Design Scope		
Low-Level Design	*LLD*	When designers place individual elements, discussing colours etc ... (Vera, et al., 1998)
High Level Design	*HLD*	When designers make broad decisions which affect significant aspects of their later decisions (Vera, et al., 1998).
Design Task		
Brief	*BRI*	When participants referred back to brief.
Schedule	*SCH*	When participants worked or referred back to a schedule or program.
Task/Instruction	*TAS*	When participants handed over specific tasks to the other participant or Instructions on how or what to draw by one participant to the other

Figure 5. The coding scheme: Verbal Communication in Collaborative Design.

Verbal Communication in Collaborative Design: coded excerpt

	Type	Code	P	Utterance
1	Design Communication	*BRI*	*B*	It 's quite a small house.
2	Social Communication	*SOC*	*A*	So maybe ... (laughter)
3	Design Communication	*EVA*	*B*	It could be more like that.
4	Design Communication & Communication Cont.	*CLA + FLO*	*A*	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.
5	Design Communication & Communication Cont.	*EVA + IDE + FLO*	*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.
6	Design Communication & Communication Cont.	*CLA + HAN*	*B*	Mmmm.... So what would we have on the west?

Figure 6. Coded transcript excerpt from one of the FTF experiments.

relative amounts of communication in each category when comparing FTF and computer-mediated collaborative design. We are particularly interested in whether computer-mediation inhibits the ability to discuss design issues (ie, whether we would see less design communication), and whether there are significant differences in the way communication control occurs in the different collaborative environments.

Figure 5 elaborates on each type by summarising how we decompose them into more precise categories of communication.

'*Communication control*', includes '*Interruptions, floor holding and hand overs*. These theoretically and externally derived sub-categories will help identify possible differences, advantages/disadvantages between the three design communication mediums (FTF, CMCD-a and CMCD-b) represented in the three categories of experiments by showing either an increase or a decrease in levels of interruptions, floor holding and explicit hand overs.

'*Communication technology*' a data derived structure, looks at discussions held between participants related to the use of the tools and the collaborative environment and whether this classification increases or decreases by altering the communication channels in the different collaborative mediums.

'*Social communication*', a data and externally derived structure, looks at the amount of time spent discussing social talk in the three collaborative mediums.

'*Design communication*', a data, theoretically and externally derived structure distinguishes between 'design ideas', 'design scope' and 'design task'. Subcategories of this fourth classification are further detailed in figure 5. This classification is intended to show variations in design communication between the three different mediums and whether it suffers from the loss of certain communication channels.

Examples and observations from the transcribed protocols

We further illustrate the coding scheme through examples from each category of experiments. These samples were obtained using three tran-

Verbal Communication in Collaborative Design: coded excerpt

	Type	Code	P	Utterance
1	Design Communication & Communication Cont.	*CLA + HAN*	*A*	sure, and, how would you fit the sleeping emm ... the sleeping wing into this?
2	Design Communication & Communication Cont.	*CLA + INT*	*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)
3	Design Communication & Communication Cont.	*ACC + INT*	*A*	yeah, yeah (top)
4	Design Communication & Communication Cont.	*CLA + FLO*	*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
5	Design Communication	*REF + LLD*	*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
6	Design Communication & Communication Cont.	*CLA + HAN*	*B*	maybe? What do you think?
7	Design Communication & Communication Cont.	*CLA + FLO + LLD*	*A*	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 ...

Figure 7. Coded transcript excerpt from one of the CMCD-a experiments.

Verbal Communication in Collaborative Design: coded excerpt

	Type	Code	P	Utterance
1	Design Communication	*IDE*	*A*	It would make a great hearth - fire
2	Design Communication	*IDE + LLD*	*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
3	Communication Tech.	*CTE*	*A*	sorry started using yellow
4	Communication Tech.	*CTE*	*B*	I'll go green then
5	Design Communication	*EVA*	*A*	dont know the house but good idea for solidity, physically & metaphorically
6	Design Communication.	*EVA + LLD*	*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
7	Design Communication	*IDE + HLD*	*B*	well what about putting a rooftop pool in then?
8	Design Communication	*CLA + HLD*	*A*	are you thinking flat useable roofs
9	Design Communication	*CLA + HAN*	*B*	did you get that bit about the terrace?

Figure 8. Coded transcript excerpt from one of the CMCD-b experiments.

scribed protocols out of the twenty-six experiments. Figures 3, 4 and 5 display excerpts of coded examples from the FTF and the CMCD transcripts respectively. The following 'codes' were added to the text during transcription to help in the coding later on:

(TOP) when two participants spoke over each other, interrupting each other
(...) incomprehensible utterances
... denotes a slight pause
'A' and 'B' denote participants

After reviewing the videotapes and transcripts, preliminary observations showed some unexpected results between the three categories of experiments. Communication in the FTF category was 'spontaneous' and subjects seemed to talk all the time, mostly design communication as well as social communication (see figure 6). Like FTF, communication in CMCD-a was 'spontaneous' with subjects talking all the time while repeating sometimes the same verbal utterances (see utterances 4 and 7 in figure 7). The amount of time spent discussing design ideas decreased due to increased communication control, interruptions and floor holding as well as communication about the technology and social communication (see figure 7). Moreover we observed a slight increase in LLD in the CMCD-a sessions.

Communication in the CMCD-b category on the other hand was 'less spontaneous' then FTF and CMCD-a. Design ideas and HLD, in design scope, dominated the communication content with lower levels of communication control, communication technology and social communication (examples in figure 8). Another important observation is that subjects in the CMCD-b sessions were noticed occasionally scrolling up through the recorded text of their conversation. 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 soon after they were uttered.

These preliminary findings seem to agree with the findings of Vera *et al* (1998) when looking at the ratio of low to high-level design concepts discussed in the three environments. The nature of collaborative environments between architects does make a difference on the style of communication used. What designers need to decide then, is when they want socially and culturally face to face synchronous communication, and when they want and need synchronous or semi-synchronous remote communication (Mitchell, 1995).

Modelling communication in collaborative design

Understanding communication in collaborative design is essential for the effective development of communications software and technology for designers. Our preliminary observations show that there are differences in the way people communicate using different communication channels, but that these differences do not 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 produced a better record of the collaborative session than the full audio and video experiments.

We propose that a model of communication in collaborative design could follow from the coding scheme presented above. The model would classify communication according to the role it plays in the collaborative design process. 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. Each of these categories has relative importance depending on the communication channels available.

Preliminary observations alone do not produce a communication model. However these observations coupled with more substantial analytical results from our coding scheme will take us a long way towards developing a communication

model. Such a communication model provides the basis for comparing differences and similarities between FTF collaborative design and CMCD in the way communication channels are used in those ventures. This in return will further guide developers in producing communication and computer systems that can better support CMCD.

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