

Does Computer Mediation Affect Design Representation?

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Abstract. 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 visualize 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.

Keywords. Design representation, collaborative communication, architecture, computer mediated collaborative design.

1. Communicating design ideas

“Architecture is primarily about communication” (Verzijl, 1997). In general, architects communicate their theories and ideas through their achievements in the built environment¹. 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 utterances (voiced or typed) and graphical representations.

When working face-to-face (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). As an example 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 little 3D massing models, made of polystyrene or cardboard (Kvan, 1994; Visser, 1993). This enables them to acquire an enriched 'experience' of

¹ This is also achieved through the printed media, in the form of published works by the numerous practicing architects as well as architect/theoreticians in academic circles.

the space they are working with and makes it easier to communicate their 'idea' to other parties involved in the design.

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 of ideas were sent by Fax or as posted documents. Recently, 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.

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 (Bly, 1988). Even then it is very difficult to establish long distance frames of reference.

Taking into consideration recent developments in computer and communication technologies, in this paper we seek to assess whether computer mediation might have any effect on design representation in collaborative ventures. We look at different communication channels utilised in architectural collaboration and how architects communicate design ideas through FTF and CMCD sessions. We also consider 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.

However having said this, it is important to clarify here that we will not be exploring the final design outcome as such, since this can be a subjective process. A process that has proved difficult to measure in an objective way with explanations of ideas and designs being often open to interpretation (See O'Connell and Whittaker, 1997, p.108).

We propose that architects will collaborate and relate design representations effectively, although with some differences, in computer mediated environments with full and limited communication channels as opposed to FTF. We argue that audio and video are not essential communication channels in CMCD and that successful collaborative sessions can take place without them.

To better understand the nature of collaborative communication and its role in complementing and enhancing design representation, we observed pairs of collaborating architects working in three different environments. FTF formed the first category, with CMCD-a as the second with full audio-video conferencing channels as well as a shared electronic whiteboard channel for graphic exchange. The third category, CMCD-b, had text as the only means of verbal communication. It had no audio and video channels, but included the whiteboard channel for graphic exchange.

We assume 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 than discussing other more concrete arguments using video conferencing. It is more important to 'see' what is being discussed at hand 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.

2. Design representation as a reflection of design ideas

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 has produced mixed findings. 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). Comparing final outcomes, Olson et al (1997) concluded that design work done by distributed groups using high-quality communication (both audio and video) and shared workspace, was indistinguishable in quality from FTF groups using the same workspace tool.

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 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.

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. Kliensuasser, as cited by Leslie (1996), has a similar view of the design as a "process of commitment and response that continues until the designer's conscience is satisfied". In an example on reflective designing, Schön (1983, p. 79) illustrates what he terms as the "language of designing". He explains how "drawing and talking are parallel ways of designing" and how "the verbal and non verbal dimensions are closely connected". Schön (1983, p. 81) maintains that

communication between the two subjects in his experiment² is not complete and remains unclear if the verbal communication is not closely linked with non-verbal communication. Extrapolating these views, we can say that design representation is an active participant in the 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.

3. The experiments

We conducted one-hour experiments divided into three categories, FTF, CMCD-a and CMCD-b (as described above). The sessions were video and audio taped, transcribed and coded into a custom developed coding scheme. Preliminary results of the analysed coded data and observations of the videotapes provided evidence that there were noticeable differences between all three categories.

3.1 Method

The fifty-two participating subjects in the experiments were 5th and 6th year architecture students from the Faculty of Architecture at the University of Sydney. The subjects were paired and each pair participated in only one experiment from either of the three categories using the same brief. We conducted eight experiments in the FTF and CMCD-a categories and ten in the CMCD-b category

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. *Table 1* shows a complete table 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. The FTF sessions used paper and pencil while co-located at the same table. The CMCD-a

² An experiment within a design studio of an architecture school where a studio master Quist reviews the work of his student Petra (Schön, 1983, p. 79).

sessions used computer-mediated audio and video with a shared electronic whiteboard (they used the Inperson software on a Silicon Graphics O2 workstation). The CMCD-b sessions used a chat-like environment to talk to each other by typing messages, and a shared electronic whiteboard (they used our Virtual Campus³ (VC) with the Inperson shared whiteboard on the O2s). All subjects in the CMCD sessions were located in separate rooms and connected through a LAN.

	FTF	CMCD-a	CMCD-b
1) Time.	1 Hour/synchronous.	1 Hour/synchronous.	1 Hour/synchronous.
2) Location.	Participating subjects located in same room.	Participating subjects located in different rooms.	Participating subjects located in different rooms.
3) Media.	Paper and pencil.	Computer hardware and software, (SG /Inperson /Netscape)	Computer hardware and software, (SG /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.	5 th 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 and audio.	Time stamped video and audio.	Time stamped video. Text transcripts from VC.

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

3.2. Task

The brief presented to the participants included a location map, a site plan, a section through the site and four photographs to and from the site. The duration of the collaborative experiment was one hour and the participants were notified at the fifty-minute mark to start wrapping up their ideas. They were also notified that a final design is not expected at the end of one hour, but that they were required to produce planning sketches in 2D and 3D if possible.

3.2.1 The Brief

A Sydney based painter recently acquired a site on top of a cliff in an inner-west suburb. 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 1. 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

³ 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>

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.

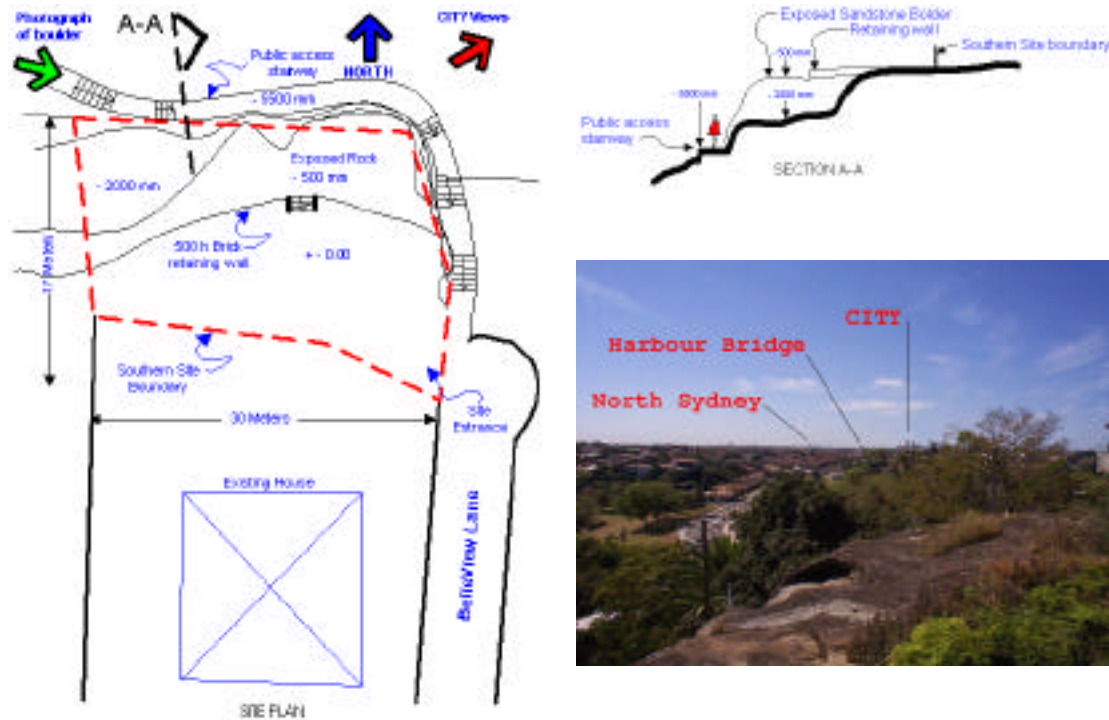


Fig. 1. The site plan, section (NTS) and photograph (taken from site) showing aspect and views.

4. Observations

The preliminary observations of the experiments gave us an overview of the differences in the three categories of experiments. To further assess the possible impact of computer mediation on design representation, we categorise our observations in three parts: 1) communication, 2) verbal design representation and 3) graphical representation.

We start by comparing collaborative communication⁴ differences across the three categories of experiments and whether the limitation of communication channels, in the CMCD category, impacts the design representation in any way. Three different coding schemes from separate research projects analysing communication (see O'Connell and Whittaker, 1997; Olson et al., 1997; Sudweeks and Albritton, 1996)

⁴ According to Sudweeks (Sudweeks and Albritton, 1996) “*Collaborative communication* is always communication, but *communication* is not always collaborative communication. The shared creation of meaning differentiates collaborative communication from communication. (...) The quality and quantity of collaborative communication are enhanced by tools that facilitate the shared creation of meaning.”

were investigated and accordingly we propose a loose classification of verbal utterances into three groups. These groups are; 1) *'task control'*, 2) *'design content'* and 3) *social 'chitchat'*.

Verbal (audio and text) design representations on the other hand, specifically investigate design content and how verbal representation in turn differs in the three categories of experiments.

4.1 Communication and design representation differences

Table 2 outlines observed differences in both communication and design representation between the three categories of experiments. After a quick look at the brief, subjects in all three categories proceeded to work on the design and development of ideas.

	FTF	CMCD-a	CMCD-b
Communication	Communication was 'spontaneous' and subjects seemed to talk all the time. Mostly design content as well as social chitchat.	Communication was 'spontaneous' and like FTF, subjects talked all the time repeating verbal utterances. Design content suffered through increased task control and social chitchat.	Communication was 'less spontaneous' than FTF and CMCD-a. Design content dominated with lower levels of social chitchat.
Verbal design representation	Design representations developed verbally (audio) and most of the time, subjects proceeded to clarify them graphically.	Design representations developed verbally (audio) and subjects did not always resort to graphical representation. Because some verbal (audio) representations were lost forever.	Design ideas developed verbally (text) and most of the time subjects proceeded to clarify them graphically. At other times, representations remained verbal, therefore participants had the chance to scroll back through text and review them whenever they needed too. This way they could re-analyse and re-interpret the design representation at hand when ever necessary.
Graphical design representation	Started sketching within 5 minutes and did so till the end. Most of the time working simultaneously and spontaneously on the same sketch.	Started sketching within 5 to 8 minutes and did so till the end. Sometimes working on separate pages and then looking up each other's pages to evaluate progress. Sketching was spontaneous and accompanied by simple annotations most of the time.	Started sketching within 5 to 8 minutes and did so till the end. Sometimes working on separate pages and then looking up each other's pages to evaluate progress. Sketching was less spontaneous and consequently appeared to be more elaborate accompanied by more elaborate annotations most of the time.
Ease/Difficulty and Comment	Smooth and straightforward. Sketching using traditional media (pencil and paper) allowed subjects to produce representation with more ease. Therefore verbal communication was simpler and comprised of more design content and less task control.	Some difficulty in the beginning adjusting to the new medium. Hardly used video channel and most of the time proceeded to cover it with the brief window for remainder of session. Higher levels of social chitchat and repetitions of verbal utterances, in order to establish and maintain on-line presence. Awkwardness of mouse, as a substitute to the pencil, seemed to make the subjects generate more repetitions and interruptions in order to clarify their design representations. This in turn resulted in higher levels of task control and less design content.	Some difficulty in knowing when the other person was writing. Difficulty in typing and drawing at same time, therefore subjects proceeded to annotate their sketches with verbal representations. Fewer words and more thinking/reflecting with subjects getting straight to the point. This resulted in richer verbal representation with more design content and markedly less task control as well as social chitchat.

Table. 2. Preliminary characterisation of communication and design representation differences in the three categories of experiments.

The subjects hardly encountered an impasse and the minor disagreements were promptly resolved as they proceeded to the next idea. Verbal (audio) communication in both the FTF and the CMCD-a sessions was ‘spontaneous’ and the subjects were observed speaking throughout the experiment. At times, in the CMCD-a sessions an idea would be represented in one utterance and at others a participant would continue talking and repeating him/herself on the same point, trying to enhance the representation of the idea. However this phenomenon of repeating oneself also appeared as an effort to ‘stay on-line’, maintain a presence, and break the silence.

On the other hand, in the CMCD-b sessions participants were less ‘spontaneous’ in their verbal (typed text) communication. It seemed that they were not perturbed by the ‘on-line silence’ and were observed to take their time thinking and reflecting while ‘typing’ their thoughts before sending them over. In a sense participants in the CMCD-b sessions appeared to be more thoughtful and reflective on ideas and their choice of words to explain their design representations to their partners. They conveyed their ideas to each other, with as little words as possible. A few times they were observed deleting a few words or rewording their “written verbal representations” before sending them. In other words, they were getting straight to the point rather than spending time on chitchat. Vera et al (1998) observed similar results with a slight decrease in low-level design⁵ as opposed to high-level design in their text-based computer-mediated experiments compared to their audio and video computer mediated experiments.

Another important observation is that subjects in the CMCD-b sessions occasionally scroll up through the recorded text of their conversation in the VC. They did so in search of 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 forever⁶ soon after they were uttered.

The ability to represent ideas graphically was observed to happen smoothly in all three categories. However participants in the CMCD-b category seemed to put more thought into their verbal representations compared to the other two categories. They were able to frequently represent their ideas verbally before proceeding to do so in sketch form. Our preliminary results indicate that at times verbal representation was successfully applied without following through to graphical representation.

⁵ According to Vera et al (1998) low-level design (LLD) can consist of placing individual elements discussing colours etc ... On the other hand, high-level design (HLD) is when designers make broad decisions which affect significant aspects of their later decisions.

⁶ 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.

1)- "my thought is that a more private studio with a connection to outdoor area and the view would be more appropriate. Maybe what we need is a workshop with storage at the bottom and a private studio on top? "

13:46:34⁷

2)- "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 integration 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"

11:59:06⁸

Graphical representations (for examples, see *figure 2*) were present at all stages of the three experiments without a significant increase or decrease in total numbers. Initial observations showed that participants in the FTF experiments started sketching within 5 minutes of starting the experiment and did so throughout the hour till the end. Their sketches included 2D as well as 3D diagrams and basic programs. The drawing task was shared, although at times, one participant 'held the floor' sketching while the other participant was evaluating the outcome or even, at times, being a spectator. Sketching on the same representation was very common all throughout the FTF sessions.

In the case of the CMCD-a sessions, the participants engaged in drawing activities 5 to 8 minutes into the experiments after reading the brief. As in the FTF sessions, their sketches included 2D, 3D representations along with some text. They mainly worked on the same page, but at times worked on separate pages and later visited each other's pages to evaluate design efforts by a request from their partners.

Sketching in the CMCD-b sessions started around 5 to 8 minutes into the experiment and was similar to the CMCD-a sessions. Sketches included 2D and 3D representations along with some annotations in order to clarify and re-enforce the graphical representations. The quantity of graphical representations in the CMCD-b sessions was approximately equal to the ones in the CMCD-a sessions (measured in terms of pages used in Inperson). A similar work pattern to the CMCD-a sessions was observed, with participants working on separate pages and occasionally checking each other's work.

While at times participants in the CMCD sessions struggled with the mouse as a drawing tool, they still managed to represent their ideas in clear sketch form through the shared whiteboard. After some difficulty in the beginning to adjust to the new environment they soon discovered some of the advantages to this communication medium. Facilities like cutting and pasting representations between pages as well as choice of colours and line thicknesses worked to their advantage.

Generally speaking, the participants in the FTF experiments found the collaborative communication process in the experiment to be fairly simple, smooth and

⁷ Excerpt taken without modification from VC transcript of experiment CMCDb-02, done on 28 August 1998.

⁸ Excerpt taken without modification from VC transcript of experiment CMCDb-07, done on 7 September 1998.

straightforward. This ease of use, however, was met with some degree of difficulty in the CMCD categories.

In the CMCD-a sessions, participants encountered some difficulties in adjusting to the new medium in the beginning, but soon settled in once they got the gist of it. They hardly used the video channel and they soon 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.

Participants in the CMCD-b sessions had some difficulties of their own and also took a few minutes to adjust to the new medium.



FTF



CMCD-a

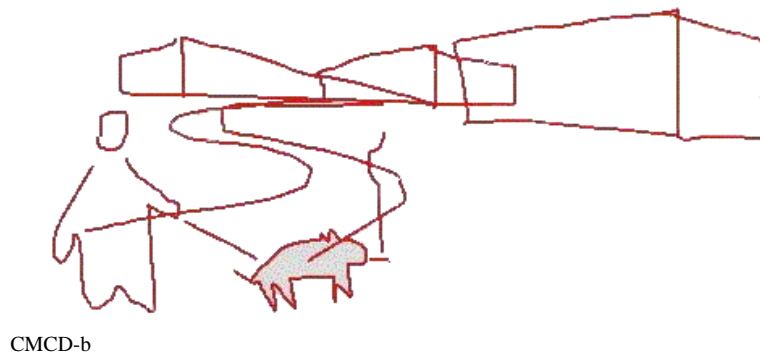


Fig. 2. Samples of graphical presentation from FTF, CMCD-a and CMCD-b experiments.

An important issue in the beginning was 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'. On the other hand, another difficulty was the inability to draw and verbally explain representations simultaneously. However they soon overcame that by quickly annotating their sketches with short notes. Thus linking their verbal representation to the graphical representation.

5. Conclusions.

Does computer mediation affect design representation? At this point in our research the answer is yes. Our earlier assumptions that some differences in design representations will occur between architects collaborating through computer mediated environments were correct. However some unexpected results were observed. Here we will discuss how both graphical and verbal representations were affected in the CMCD categories, compared to the FTF category.

Graphical representations, between categories, did not seem to be affected in the quantity or quality of ideas, but in the richness, elaboration and level of detail. This is mainly due to the variance in mediums between FTF, CMCD-a and CMCD-b. Sketching using pen and paper proved to be easier and at times quicker in delivering ideas than using mouse and whiteboard (See Gross, 1994), especially with curved lines and free forms. However drawing geometric forms and representations was easier in the CMCD sessions. The advantage in CMCD was in copying and duplicating whole representations in order to quickly edit and further develop them, compared to redrawing in the FTF sessions.

However it is in the verbal (audio and text) representations of design ideas that the primary difference between the categories occurred. This in turn appeared to affect the graphical representations in the CMCD categories.

In the FTF experiments, participants were spontaneous and sketched and spoke easily. The exchange of verbal (audio) representations was accompanied at times by graphical representations.

Social chitchat as well as task control, interruptions and floor holding seemed to occur more frequently in CMCD-a than in the other sessions. This meant that more time was spent repeating verbal utterances and competing for the floor than time spent developing design representations. This was partly due to an effort by the participants in establishing and maintaining on-line presence. Added to that was the awkwardness of the mouse as a sketching device while talking, which may have contributed to sketches that were incomprehensible most of the time. The participants in CMCD-a seemed to be emulating the use of a pen in FTF environments by illustrating their verbal utterances with graphical marks on the sketch.

Participants in the CMCD-b category were less spontaneous and became more reflective on their design ideas. Their collaborative exchange through verbal representations was somewhat richer than that of CMCD-a. It contained, on average, more design content and less task control. The semi-synchronous nature of the CMCD-b collaborative environment appeared to allow participants more time to reflect on ideas. Consequently their graphical representations appeared to be more elaborate and containing more annotations. Most of the time, their sketches responded to a well thought idea instead of a spontaneous reaction to the verbal representations at hand.

In summary, although the variation of communication channels did not affect the ability of the designers to collaborate, we observed significant differences in the graphical and text representation of the designs.

6. Acknowledgments.

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