A Method to Improve CMC Usability and Reveal Communication Needs

Yun-Pei, LIU*, Chun-Di CHEN*, Andree WOODCOCK**, Stephen A. R. SCRIVENER**

**Industrial Design Department, Chang Gung University, 259 Wen-Hwa 1st Road, Kwei-Shan Tao-Yuan, Taiwan, 333, Taiwan, favian@ms36.hinet.net/cdcvic@mail.cgu.edu.tw*
*** Coventry University, VIDe Research Centre, School of Art & Design, Priory Street, Coventry, CV1 5FB, UK, a.woodcock@coventry.ac.uk./s.scrivener@coventry.ac.uk*

Abstract: The paper describes a method for the refinement of computer-mediated communication tools (CMC) supporting design communication and the identification of communication needs. We argue that previous CMC studies have failed to provide useful information about how to refine CMC systems for visual design communication due to weaknesses in typical approaches to studying CMC, i.e., the use of face-to-face working as the standard for CMC design and the adoption of comparative studies of different CMC environments. In contrast, we postulate that the real issue is not which resources are required for which groups and tasks in which situations, but how we can get the best from the communication resources available in a given environment.

A design trial was undertaken to generate data for analysing the visual design communication occurring via a proprietary CMC system that enabled speech to be coupled with visualisation. The results of the design communication analysis led to the conclusion that from the environment at their disposal, designers select that which is most effective and/or efficient for satisfying visual communication purpose at each given moment. Such an interpretation suggests that communication resource shifts occur because the shifted-from resource is less effective and/or efficient than the shifted-to resource, and that subsequent shifts analysis could reveal the strengths and weaknesses of the particular resources.

Based on the analysis of communication resource shifts, a design method for uncovering potential refinements to a given CMC system is proposed. This article will illustrate how using shift-analysis method to reveal the recommendations for enhancing the particular CMC system and the visual communication needs arising in collaborative concept development projects. In conclusion, we postulate on the applicability of this method for the design/redesign of other CMC systems.

Key words: *Industrial Design, Visual Design Communication, Computer-mediated Communication, CSCW*

1. Introduction

Industrial design requires group communication through and about visual information. As well as traditional communication tools, such as telephone and fax, computer mediated communication (CMC) is being used to support visual communication in design and a number of studies have explored its potential to supportdesigners' visual communication requirements. Earlier, [1] and [2] explored the requirements for systems to support design over distance by studying face-to-face collaborative design activity, focusing on communication coupled with drawings and gesture. Later, other design communicative materials, such as objects, physical and CAD models, and the studio environment were studied to uncover the needs of communication technology or activity in distal design [3, 4]. These researchers regarded that the communicative media and behaviour of face-to-face working was necessary for effective design communication, leading to often highly novel CMC environments designed to replicate face-to-face working, such as, ClearBoard [5].

Yet, [6] argued that studies comparing face-to-face and mediated environments failed to show significant effects due to impoverished communication or at best contradictory results, suggesting that face-to-face working should not be the standard for the design of mediated communication tools. Moreover, [7] postulated that social and situational factors have little effect on shaping the measurable outcomes of collaborative design, as designers could adapt to or adapt a communication environment to overcome social and situational impoverishment. Earlier, [8] concluded their distal collaborative design studies by suggesting that motivated designers would exploit the communication resources at their disposal to complete a task, even when this involves radical changes in work and communication methods. In summarising the results from previous CMC research, [9] argued that the real issue of CMC design is not what communication resource is best for what groups doing what tasks in what contexts, but how do we get the best out of the communication resource available in a particular context.

This article, taking forward this idea, will hence focus on visually-supported communication with a view to exploring the following:

1. How to identify the events in a communication environment where verbal design communication is supported by visualisation?
2. Why does visual coupling occur?
3. How does this analysis lead to a method for improving the usability of CMC for design communication?
4. What does this analysis reveal about the recommendations and the communication needs?

We start by observing design communication in a particular mediated-communication environment, through which a design trial allowing such observation was conducted. Given our interest in the visual aspects of design communication, our focus was on events where verbalisation is coupled with visualisation.

2. Uncovering the Visual Communication of Concept Design

A design trial was conducted for the investigation of the visual communication needs of design teams engaged in the concept design stage of an industrial design task based on the Delft Protocol [10]. Three design dyads designed a fastening device to enable a backpack to be carried on a mountain bike. Four participants were recruited, one participant, an experienced industrial design tutor at the University of Derby was common to each team. The other three participants were BSc Industrial Design students in their final year of study at Loughborough University.

At each location, a workspace was arranged resembling a typical studio environment including a desktop PC and a CMC system, - PictureTel enabling video and audio connections. The main on-line tool was a whiteboard - a shared drawing tool enabling participants to simultaneously see and edit a drawing. Each dyad conducted 4 one-hour weekly sessions over the CMC system (with individual work occurring between sessions), which connects the two sites via a basic rate ISDN line. All on-line sessions were video taped.

The system enabled visual communication via the medium of whiteboard or video (see Fig 1). The whiteboard supported two mechanisms of communication, drawing and gesture, while video supported three, namely drawing, gesture and object reference. This yields five media-mechanism combinations, i.e., whiteboard-drawing (WB-D) and -gesture (WB-G), video-drawing (VD-D), -gesture (VD-G) and -object manipulation (VD-O).

2.1 The Data

The primary data for analysis comprised the video and audio recordings of the on-line CMC sessions. The discourse captured on these tapes was transcribed, organised and labelled in terms of turns by individual speakers. These were sub-divided into those utterances that included reference to a real or imagined object and those that did not. The former group provided the ‘talking about things’ data. Having identified all such artefact-related turns, every word was categorised in terms of whether or not it was accompanied by visualisation. It is important to understand that ‘visual coupling’ is not just co-occurrence (i.e., talking and drawing at the same time) but that the words and accompanying visualisations should relate to each other.

2.2 Purposes of Visual Communication

Having identified the events of visual coupling, the reasons for these were investigated by analysing the verbal transcripts in conjunction with the video recording. The purpose of an utterance is different to the purpose served by visual coupling. The former is the reason for the communication while the latter concerns the way that specific visual information supports the communication..

Based on the previous studies about the purposes of using visual information in design communication [3][11], five purposes of visual coupling in design discourse were identified and defined with reference to dictionary sources, as follows:

- clarify - to make more comprehensible or easier to understand usually by further explanation,
- specify - to identify clearly and provide information about what is required,
- emphasise - to indicate something is particularly important or true; to draw special attention to it,
- annotate - to add notes to provide explanation or comment,
- identify - to associate something closely with another.

Having identified the purposes served by visualisation in supporting verbalisation, each instance of visually coupled term was assigned with a purpose.

The underlying purpose of the visually coupled analysis is that the identification of visual coupling purpose and an explanation of why, in each case, the selected medium-mechanism was chosen for (see later for an illustration of this process) can contribute to design by revealing the relative strengths and weaknesses of medium-mechanism combinations. The design goal should be to remove these differences, i.e. reducing the weaknesses and building on strengths. The following sections, therefore, will explain how to identify a medium-mechanism combination shift and the related strengths and weaknesses of the ‘shift-from’ and ‘shift-to’ medium-mechanism combinations in shift instances.

3. Analysing Medium-Mechanism Combination Shifts

Determining shifts in the design discourse required discovering occasions where there was a change from one media mechanism to another and then categorising the related events in terms of the purpose of the visual coupling. In the following excerpt from one of the design sessions, two shifts of medium-mechanism combination occur during the discussion of how the strap of rucksack could be tightened by a device attached to a pole (The terms coupled with visual information are underlined).

316	R	so you want something on this post there[WB-D], so we can move up in that direction[WB-D] or that direction[WB-D]
317	D	yeah
318	R	that'll take[VD-G] up[VD-G] the slack in the strap[VD-G]
319	D	no because, I mean, ok, you've got the post there[WB-D]…

Here, the word ‘direction’ at the end of Turn 316 is coupled with whiteboard-drawing (WB-D). The next visually coupled term ‘take’ in Turn 318, is coupled with video-gesture (VD-G). A further shift occurs in Turn 319. In Turn 318, ‘strap’ is coupled with video-gesture while the next visually coupled term ‘post’ in Turn 319 is coupled with whiteboard-drawing. Thus in this example, the designers shift from whiteboard-drawing to video-gesture and then revert to whiteboard-drawing.

3.1 Identifying the Purpose of a Shift

In the first shift, Fig 1, the designer, shown in the top left video window, moves his upturned palm upward, simultaneously bringing his fingertips together before dropping his closed hand slightly. Given the context of the turn, the gesture was interpreted as meaning to take something and transform it, and to represent an activity related to the terms ‘take up’. On inspection, the meaning of this turn could be understood by reading Turn 318 and adjacent turns without needing to refer to the gesture. Thus, this visual information was not necessary for the remote partner to understand what ‘take up’ meant in this context. Indeed, although the function of the pole was to ‘take up’, the gesture was not an illustration of the action of the pole or its effects. Hence, we concluded that the designer used the gesture to emphasise the meaning conveyed in his utterance, and the purpose of the switch from whiteboard-drawing to video-gesture was registered as being ‘to emphasise’.

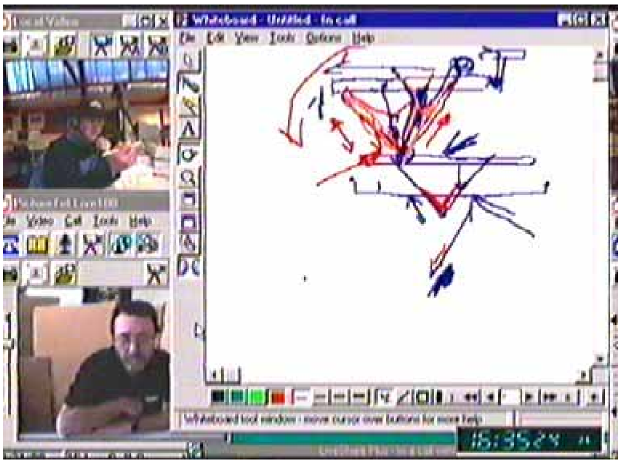

Fig. 1 Designer in Top-left Window Shifts from Drawing to Gesturing

3.2 Assessing Medium-Mechanism Shifts Benefits

The proposition set out above states that a shift occurs because the destination medium-mechanism is judged as being more efficient and/or effective for the need in hand than the source combination or any of the other available resources. Here, efficiency was defined as the ratio of useful work performed to the effort expended on achieving it, and effectiveness was defined as the extent to which this useful work achieved its intended purpose. This being the case, it should be possible to explain why one medium-mechanism is more efficient and/or effective than others in our example.

In the case where the designer used whiteboard-gesture to convey his intention, this medium-mechanism communication would have required the designer to move his digital pen and ‘click’ the pointer button on the whiteboard toolbar to select the pointer. He would then have had to pick the pointer up and drag it to achieve the desired effect. It is not difficult to see that this is likely to be less efficient than a direct hand gesture. We have argued that the purpose of the visual coupling was to emphasise the idea of ‘taking up’. In this instance the constraints in whiteboard-gesture might lead to the communication being misunderstood. First, unless the whiteboard-gesturing was completed in a blank area it might be interpreted as ‘to specify’ a part of the drawing to which ‘take up’ applied. Second, whether in white space or not, it might take the meaning ‘to clarify’ if the gesture was understood as describing the moving of a thing or its motion. We would argue that these latter misinterpretations are more likely in whiteboard-gesture as it is constrained to one plane. Hence, an argument can be made on grounds of effectiveness as well as efficiency.

Alternatively, the designer could have used whiteboard drawing to convey his intention, thereby incurring no medium-mechanism transfer costs. Here, it is difficult to make a case for transfer-efficiency gains, instead we must look for gains in effectiveness. First, whiteboard-drawing suffers from the same potential losses in effectiveness as those described above for whiteboard-gesture but with the added disadvantage that a permanent record of the communication is retained. This may have both immediate and long-term disadvantages. Drawing is clearly more concrete than transient forms of visual communication. A drawing has shape, size, line thickness etc., and these properties could be taken as meaningful, thus making it difficult to merely 'emphasise'. For example, video-gesture could be used to emphasise the idea that something should 'be thicker'. However, drawing, whether on whiteboard or paper, could be interpreted as meaning 'how thick' or 'where thicker'. Alternatively, the designer could have annotated the terms 'take up'. However, this would not have functioned to emphasise the action of taking-up. Emphasising by drawing, whether graphic or text also has the effect of filling the drawing surface with redundant information. Thus, in this instance, a case can be made for gains in effectiveness of video-gesture over whiteboard-drawing.

A shift from whiteboard-drawing to video-drawing would have incurred the same disadvantages in effectiveness of continuing with whiteboard-drawing, with additional costs in efficiency. First, there is the cost of medium transfer. Secondly, it would have been necessary to turn the camera to view the paper or to bring the paper to the camera. Finally, video-object suffers from even greater unwanted specificity than whiteboard-gesture or whiteboard- or video-drawing, and the greater effort required to locate and bring the appropriate object into view. This example illustrates that a case can be made on both grounds of efficiency and/or effectiveness for the selection of a particular medium-mechanism combination over other available resources to achieve a particular purpose at a given moment in a task. It also shows that the analysis of these transfers gives insights into the strengths and weaknesses of medium-combinations with respect to visual communication needs or purposes. The analysis described above was applied to all medium-mechanism shifts in all design sessions. In each case, the shift could be categorised using the 'purposes' scheme and explained in terms of gains in efficiency and/or effectiveness.

4. Using Efficiency and Effectiveness to Enhance System Design

One of the primary research aims was to provide insight into how to design more effective and efficient communication environments. The identification of visual coupling purpose and explanation of why, in each case, the selected medium-mechanism was chosen for this purpose can contribute to design. For example, the analysis reveals the relative strengths and weaknesses of medium-mechanisms. The design goal should be to remove these differences, i.e., to remove relative weaknesses and to build on strengths. Let's say, for example, that a shift from whiteboard-drawing to video-drawing arose because of the use of paper drawings produced between sessions. While highly efficient in this instance, video-drawing might be less effective than whiteboard-drawing because of the camera's lower resolution. Whiteboard-drawing could be improved by making it easier for designers to capture and transfer paper drawings, and video-drawing could be improved by using a higher resolution camera. Each medium-mechanism could be enhanced so that when process factors necessitated shifts in medium-mechanism combinations, high levels of efficiency and effectiveness could be maintained.

Such an analysis of all visual couplings (4221 in this study) is time consuming and unlikely to be of practical value in CMC system design. However, a method based on the detection and analysis of shifts between medium-mechanism offers a more viable alternative (in this study shifts between medium-mechanism occur in

13% of visually-coupled terms). The method may be summarized as firstly identifying the shifts between medium-mechanism combinations and their communication purpose; and secondly assessing each shift for relative gains in efficiency and/or effectiveness.

5. CMC Improvements

Using whiteboard-drawing – the most often used medium-mechanism in the trial as an example, the application of the shift-analysis method for CMC refinement is illustrated .

The primary strengths of whiteboard-drawing over other medium-mechanism combinations are its ability to provide clearer images. This feature can be improved still further by increasing the resolution of the monitor. Alternatively, the whiteboard image could be enhanced by using anti-aliasing technology or using vector graphics rather than bitmaps. In addition, the feature of enabling a new drawing to refer to existing drawings could be improved by allowing the users to find the drawing they want quickly, for example, by giving a thumbnail of each page for fast browsing.

The weaknesses of whiteboard-drawing suggest that whiteboard-drawing could be improved by allowing designers to rapidly capture existing paper-based drawings or object images for display on the whiteboard, e.g., giving additional document and object cameras which focus on the desktop and studio respectively. Moreover, the current operation to import such images onto the whiteboard is complicated. Thus, improvement could be made, for example by a mechanism enabling the user to snapshot the image from video and display it in the whiteboard with just one click.

In addition, the difficulty in using whiteboard-drawing against drawing on paper indicates that the system could be upgraded by enabling the users to draw on the whiteboard as if they were drawing on paper, e.g., providing a visible drawing trace on the digital tablet, and a pressure sensitive stylus to provide greater variability in stroke-making.

Also the use of whiteboard-drawing for emphasis results in marks that interfere with the existing drawing, thus limiting the use of the whiteboard for this purpose. Moreover, these marks could invite greater opportunity for registering unintended meaning when conveying ill-defined shapes, object qualities or actions. These weaknesses could be reduced by a drawing facility where the marks only persist temporarily.

6. Applicability of Shift-analysis Method

Rather than to improve the particular CMC system used in this trial, the shift-analysis method could be used more generally in terms of evaluating to what extent the approach used to produce this method can be used in a broad range of communication contexts. Briefly, applying the proposed shift-analysis method requires the system designer to identify the following components in respect of visually-coupled communication:

1. The medium-mechanism combinations available in a CMC environment for coupling communication with visual information,
2. The speech terms which can be coupled with a given of information type, e.g., the visual-coupling terms identified in this research, whereby visual information about object form, quality and actions is conveyed,
3. The occurrence of shifts between medium-mechanism combinations used for coupling speech with the identified information source,
4. The purpose of using an information type to support verbal communication at each shift,

5. And finally, the gains and losses in effectiveness and/or efficiency which explain why the selected medium-mechanism was the most appropriate for fulfilling that purpose at the moment of each shift.

In order to apply the method, it must be possible to satisfy the requirements of these foundational components. If this is not possible then the method cannot be applied. In new contexts, the system designer may have to revise the procedures to accommodate new medium-mechanism combinations, new coupling purposes and new types of information coupled.

7. Communication Needs

Rather than proposing a method for improving a particular CMC environment for visual design communication, this research uncovered the communication needs of collaborative concept design. The shift-analysis method proposed in this article is based on the criteria of effectiveness and efficiency. The consideration in efficiency is plain, i.e., less time-taking yet still gaining appropriate effectiveness for communication. Therefore, the communication needs summarised here will primarily relate to communication effectiveness, which can be summarised as follows:

Various precision for the communication of form or properties

Obviously, form or shape is often described during the concept development stage. Whether this needs to be defined precisely or loosely depends on the context and stage of the design. This in turn effects the way it which it might be communicated. For example, an analysis of a designer’s movement from whiteboard-drawing to video-gesture to clarify an ill-defined form, might lead to the conclusion that video-gesture is more effective, because the visualisation conveyed via video-gesture lacks precision, or because there is less likelihood of associating the gesture with other visual information. To communicate form would require a system that either matches the precision of the conceived form, or communicates the properties of imagined objects.

Sharing and retrieving information

Whiteboard-drawing is favoured for ‘annotation’ because this medium-mechanism combination could provide space accessible for both designers to record and share visual information. For example, shifts from video-gesture to whiteboard-drawing were observed for annotating the costs of the components and manufacturing for retrieval later during the session. Reasons for such shifts, argued from the point of view of effectiveness might conclude that whiteboard-drawing is favoured because the visual information in this medium-mechanism combination can be accessed and retrieved from both sites at later stages to facilitate discussion. In contrast, making a note on paper would limit accessibility by the remote site. So, the communication need from this analysis relates to the ability to have information which can be shared and retrieved later.

Joint working on design artefacts

Observing the shifts to whiteboard-drawing from other medium-mechanism combinations, say, video-drawing, for the purposes of clarification or specification, found that such shifts might occur because working on the same artefact enables new idea to be associated with and concretized in and by existing drawings so facilitating communication and co-ordination. The whiteboard was the only device that allowed this in the trials, which may account for its dominance. Here the communication need to be fulfilled is the need for designers to work at the same artefact.

Distinguishing between drawing and indicative marks

To specify what is being referred to on a drawing (on paper or whiteboard), designers used marks or gestures.

For example, shifts occurred from whiteboard-drawing to whiteboard-gesture when a designer wanted to specify what he was talking about. Here, whiteboard-gesture is more effective because, by using this medium-mechanism combination, no interference to the sketches in the whiteboard was yielded. This would lead to the expression of communication need for enabling the design contents to be distinguished from indicative marks.

Reference from real world

The purpose of identification was seldom observed during design communication in this trial. However, one characteristic of this purpose is the need to refer to an entity in the real world. For example, from a study of video-drawing to video-gesture for the purpose of identification, we might conclude that video-gesture is more effective because the gesture can provide visual information which represents the image in real scale (e.g., the length of an object) making the size of an object easier to understand. This would lead to the expression of a communication need for collaborative concept development design as being to make the reference to the real world possible.

8. Conclusions

Current approaches to CMC design emphasising face-to-face working as a model for telecommunication and attempting to tease out communication needs by comparing different communication environments, have not produced results that are particularly informative to CMC system designers. The real issue is not which resources are required, for which groups, for which tasks and in which situations, but how do we get the best out of the resources at our disposal. We have argued that users of any given multimedia communication environment select from the resources available, those which best satisfy their visualisation need, and which enable them to perform the task in the most efficient and/or effective manner. We have described a design method based on this observation that uses the interpretation of shifts between communication resources as a foundation for design improvements. Lastly we have shown how the methodology may be employed to enhance CMC system design and uncover communication needs.

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