The use of design activity for research into Computer Supported Co-operative Working (CSCW).

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Abstract

This paper describes current research at Loughborough University in the field of Computer Supported Co-operative Working (CSCW). The project, which is funded by the Information Engineering Directorate (IED) within the Science and Engineering Research Council (SERC), is titled 'Establishing the Communicational Requirements of Information Technology (IT) Systems that Support Humans Co-operating Remotely'. The research group have adopted a less cumbersome acronym for the project - ROCOCO which is derived from REmote COoperation and COmmunication. Design activity has been proposed as offering a suitable context for a study of co-operation and at the time of writing the first phase of the experiments - involving face to face or proximal co-operation - has been undertaken and the analysis begun. The ROCOCO project is about to embark on phase two involving remote co-operation.

This paper presents, in some detail, the construction and operation of a pilot study that allowed project members to assess and adjust the experimental design prior to the start of Phase One. A selection of initial findings illustrate the nature of the investigation to be undertaken. The paper also seeks to highlight the importance of CSCW research for the design community. The substance of the paper is concerned with a presentation of issues involved in an analysis of co-operation, involving as it does, verbal and non-verbal communication.

Co-operation

Co-operation, which may be defined as 'working together to the same end', is an evolutionary human characteristic. For this reason, Ruffie (1) is able to say that the power in Man's continuing evolution is in organisation. People working co-operatively together can produce a performance which is not only greater than, but is qualitatively different to the sum of each person's performance considered separately. This is the outstanding feature of successful co-operative working. Co-operation can be identified by a number of elements. They are:

* a goal that is common to all participants
* a reward system that rewards each participant
* goal-directed behaviour
* responses to the task that are distributed
* co-ordination
* latency and duration of response times (2).

A goal is defined as 'the intended state of an object, or the intended relation between two objects or more' (3). The choice of goals can also be affected by norms as is task performance.

Co - ordination is necessary in co-operation and can be effected by mechanical cues for example or by one person monitoring the performance of another. The task may require a response from all of the participants or the problem may be solved by a suitable response from just one participant.

Co-operation is not a fixed pattern of behaviour but is a changing, adapting process directed to future results (4). The representation (and understanding) of intent by every participant is a necessary factor in co-operation and so the role of communication in co-operation is critical. Grice's 'co-operative principle' may be observed, and his 'rules' of Quality, Quantity, Relevance and Manner can serve as guide-lines to establishing the requirements of communication in co-operation (5).

Communication in human-human co-operation is characterised by a number of features which include the presence of meta-communication, ie. communication about the communication itself, and by the offering of supplementary information. The most effective forms of human-human co-operation (as seen, for example, in the working of a surgical theatre team) possess all of the features described above, but there are simpler forms which do not exhibit all of these features, and may be in consequence less effective.

Human-Computer Co-operation

Oberquelle et al. (6) have researched the issues of communication between human and computer, especially those of the organisation of communication dialogues. The problems of human-computer communication have been examined by Stenton (7) who surveyed the approaches being used to describe user-computer dialogue, (especially the problems associated with dialogue management in co-operative machines), and Connolly (8) who has investigated the application of the principles of co-operation to the development of an agreed definition knowledge base. Furthermore Smyth and Clarke (9) have developed software based on the principles of human-human co-operation, and which exemplifies the underlying mechanisms of human-computer co-operation.

Computer Supported Cooperative Working (CSCW)

In current CSCW research, the emphasis is on the use of technology to support communication in human-human collaborative working. In the COSMOS project (10) for instance, communication is being examined by using structured messages, and the UNISON work (11) features a multi-medium communication link.

There is clearly a need to establish the requirements for the communication link necessary to support co-operative working. However, as Carasit and Grantham (12) showed in their analysis of COORDINATOR, over-emphasis on the communication technology, coupled with a less than full knowledge of the human's requirements in co-operative working, can lead to failure of attempts at CSCW.

The ROCOCO Project

The idea underlying the ROCOCO project is that the development of CSCW will eventually result in computer-based equipment which can support people working, at a distance, in a natural and co-operative way. This is a complicated issue and there are many facets of such working which need to be better understood if it is to be not only implemented but also accepted by the users. Integrity of communication in co-operation is essential. If communication between the partners is degraded or disrupted, then the complex pattern of co-operation will begin to break down and will ultimately cease. Thus one area that needs to be studied is the communicational requirements of the users of such systems. Hence the aim of ROCOCO is to establish the communicational requirements of IT systems that support humans co-operating remotely. The programme of work included a pilot study prior to the first phase which was concerned with pairs of designers working proximally, that is, face to face.

The pilot study

The pilot study allowed the research team to assess and adjust the experimental design prior to the beginning of phase one. The major goals of the pilot study were :

i. to ensure that the experimental task was of an acceptable type and sufficiently complex to enable co-operative behaviour and generate fully representative communicational requirements.

ii. to establish quantifiable measures, in the form of recordable subject behaviours, which would be adequate indicators of the communication process under proximal and remote working conditions.

iii. to identify the nature of the communication processes active during a representative experimental co-operative task.

iv. to test the equipment and procedures for task, communication and recording under controlled conditions.

The Experimental Task

Co-operation is context dependent, and work, eg. by Smyth and Clarke (9), shows clearly that a defined task (one which ideally, involves creativity in problem solving) is a necessary pre-condition for studies of co-operation. Design has been termed a problem-solving activity but more correctly it is a problem-resolving activity - that is to say, compromise must be sought between often conflicting requirements such as costs, production requirements, material limitations, legislation and human factors etc. Design activity, whether it be undertaken by an individual or by more than one person, employs modelling. Drawing, constructing and even talking may be considered familiar modelling techniques and these could be employed by

a design team for a variety of reasons including the development of a better understanding of the problem, the generation and manipulation of possible solutions, or the communication of proposals to others. Co-operation in design teams creates models which have developed as a result of joint activity. Such models have been termed 'shared prototype solutions' (SPS) and occurrences of SPS were recorded and examined as part of the analysis.

Professional design activity not only exploits co-operation, but increasingly demands it as tasks become more complex. Designing in teams increasingly requires the exploitation of computer based systems for reasons of cost and / or distance between partners. There is, therefore, an urgent need for research into CSCW within the design community. Product design is a good example of increasing complexity, where teams of specialists are expected to co-operate. It is this field that has provided the design subjects for this research. Middleton (13), confirms the use of design for the task since design can not only benefit greatly from co-operative behaviour, but also requires exceptional communication when co-operating partners are involved.

The experimental task needed to be consistent throughout the experiment, and sufficiently detailed to enable subjects to display a full range of design activities within the target time of one hour. A set of graded and standardised design tasks provided by Garner (14) met these requirements and they are to be used throughout the project. The particular task used in the pilot study required the designers to produce a design for a portable barbecue grill. At the start of each session, the subjects were given the design brief outlining the requirements for such a portable grill. The designers reported that they had found the task representative, acceptable, and intellectually stimulating, although in similar situations in their ordinary work they would have the opportunity to undertake research into, for example, standards, legislation, or market demands before coming to the generation and evaluation of proposals. Pressure of time also restricted the ability to model in three dimensions, placing greater emphasis on other modelling techniques such as drawing, but this is entirely realistic considering the project objectives for remote co-operation. The designers were also interested in the experiment, and expressed no concern about video cameras and microphones being present during the design task.

In the co-operative design process, certain features were observed which predominated. These are :

a) The Shared Prototype Solutions (SPS) discussed earlier. For this project SPS were commonly shared drawings in which were vested the proposed resolution of the requirements of the brief at any time during the design task. A given design task will produce a great number of SPS

b) Control of the design activity, which can be monitored via 'progression' cues in the discourse. In general, design activity displays iterative cycles, but progression is an observable (and expected) phenomenon, and

c) Control of Communication, primarily meta-communication. The emergence of these features is taken to indicate that the task is suitable for the main experiment. Two finalist undergraduate design students were used as experimental subjects because they were considered to possess a consistent and high level of task skill (they had already carried out design tasks for external clients effectively).

Measurements and Analysis

The measurements made in the pilot study yielded data at the ordinal level, and included, for example, counting the type and occurrence of utterances, counting and typing sketches, (per phase of progression), and summations of these data. Analysis included the extraction of patterns containing features common to the experimental task, elimination of patterns which contained features of non-generic tasks, and the identification of correlations, especially those which might support inferences of causality.

A detailed transcription from the audio track of the video recording was made for the complete pilot study. The transcription contained a verbatim report of what was said, by whom, to whom, and when. The raw data was analysed under four headings: graphic analysis, non-verbal communication analysis, discourse analysis, and utterance analysis. Elapsed time was used for the common reference base-line for integrating the data from the four different streams of analysis. The data was used to either support, enlarge, or abandon the initially generated hypotheses, or to generate new ones. The experimental data associated with the pilot study will not be included in the main experimental work.

It was known that the nature of the control, or management, of communication, would be different with two designers than with one, and that there would also be another change in the control function when the co-operative design task moves into the remote condition. The former feature must be differentiated from the latter, and the pilot study has enabled control of the proximal co-operative design situation to be understood. The study results also make it clear that the total time taken in communication management, and its distribution, will change from that in the proximal to that in the remote situation.

Communication modes can be categorised as being verbal and non-verbal. Research into verbal communication was split into discourse and communicative acts. Non-verbal communication exploited categories termed drawing, gesture, and pointing. (15, 16, 17). It is not possible in this paper to present and discuss all of the findings from the pilot study. However, a few significant observations will be outlined and these provide an insight to the nature of the research undertaken into both verbal and non-verbal communication.

Verbal Communication.

A detailed analysis was carried out on the verbal communications between the co-operating designers. Various categories were used for structuring the recording and analysis of experimental speech and text data. These categories included discourse (eg. hierarchical structure, conversation, and discourse progression) and communicative acts (speech acts, communicative functions, and content). (18)

Discourse : Conversation

Features of conversational analysis include Turn, ie. individual contribution to the dialogue, Competition Point, where participants compete for the floor, and Feedback, eg. "*What a brilliant answer*". (19, 20, 21, 22). Figure 1 shows how competition points were being scored during the design cycle. The frequency and distribution of competition points (plus other features not shown), indicate how important progressive two-way conversation is in this type of work, and is clearly part of the communicational requirements of the designer.

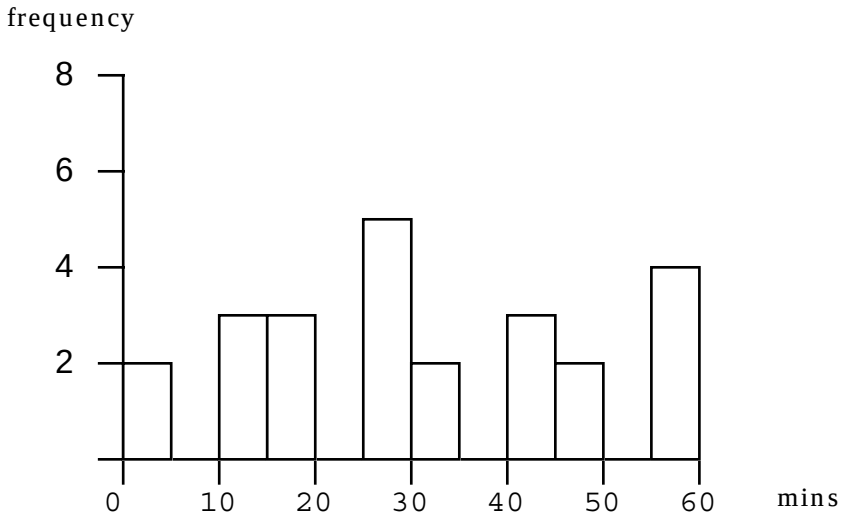

Figure 1 : Competition points scored over design cycle.

Discourse : Progression

Progression is used to identify development and progress being made along a route from the beginning of discourse to its logical conclusion. All utterances were placed in one of three categories : Problem-oriented, Solution-oriented, and Process-oriented. The first two categories derive from Lawson's classification of design strategies as either 'problem focussed' or 'solution focussed'. (23) The third category, 'process-oriented' was subsequently added by Garner to fill an observed gap in that classification for the current

research.
Figure 2 presents a progression 'profile' of one participating designer. It illustrates problem-oriented discourse peaking at one third of the time into the design cycle as the subjects establish the parameters of the set brief. Solution-oriented discourse displays a marked increase at about half-way through, and remains high for the remainder of the task. The early suspension of solution-oriented discourse would seem appropriate while the parameters of the task were being established. Figure 2 also displays a fairly low level of Process-oriented discourse, and this would be expected considering that the subjects were working in a generally familiar way, and with familiar equipment. Given these progression 'profiles', it will enable proximal co-

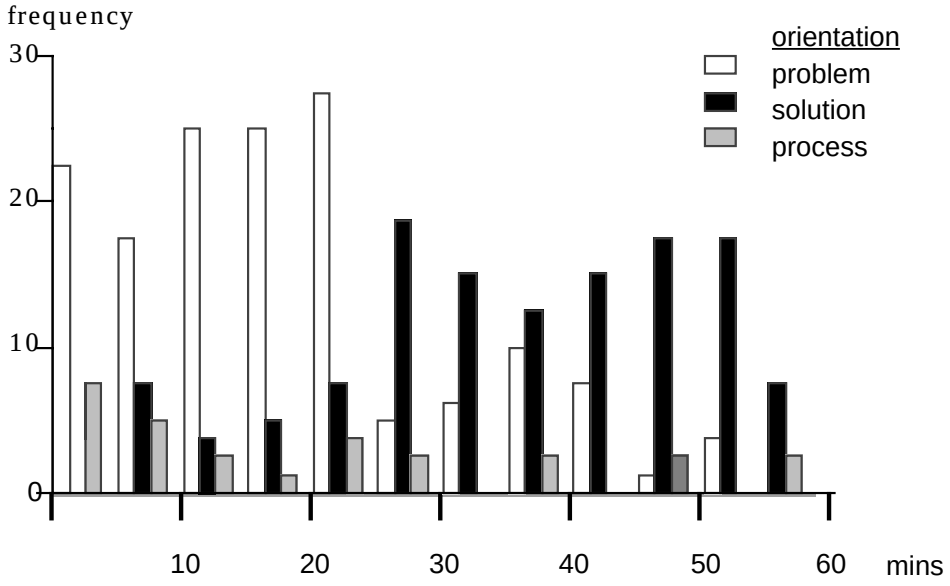

Figure 2 : Progression through design stages over design cycle (designer A)

operative tasks to be compared with those undertaken in the remote situation.

Communicative Acts

These include speech acts, communicative functions, subject matter, and deixis.

Speech Acts

Extensive and detailed recordings of speech acts were made. These acts typically include those categorised as being Representative, Directive, or Commissive (24, 25). Among commissive speech acts, which involve promising, undertaking, or guaranteeing are included the significant co-operative acts, (which commit both parties) and unilateral acts (which do not involve co-operation, but may affect the other participants).

Communicative Functions

In view of the detailed nature of the speech acts analysis, only a small number of extra categories relating to communicative functions were needed. These were the phatic function (aimed principally at the establishment maintenance of harmonious interpersonal relations between the persons involved eg. ' *Mhm. I'm with you.'* and '*How are you? '),* and the metalinguistic function, which refers to the linguistic communication itself, eg. *See what I mean? That's a weird sentence!* (26).

Subject Matter

The content of utterances is clearly of great importance, and the categories used in this part of the design and execution of recording and analysis included subject matter and deixis. (27). Subject matter relates to the subject of the utterance, and in the present use included the following: the brief (or task) at the detailed level eg. '*The motor would be about there'*. the brief at the strategic level eg. '*There are two ways we can go about this',* the environment, the participants themselves, and other matters (usually unrelated to the task directly). Figure 3 shows the distribution of utterance of detailed and strategic subject matter by both designers throughout the whole task. The first point to be noted is that detail and strategy utterances appear to be diametrically opposed. Secondly, there is a dip in detail subject matter at the 20 minute point, which is mirrored by a corresponding rise in strategic utterances. This feature occurs at the time when drawing activity temporarily

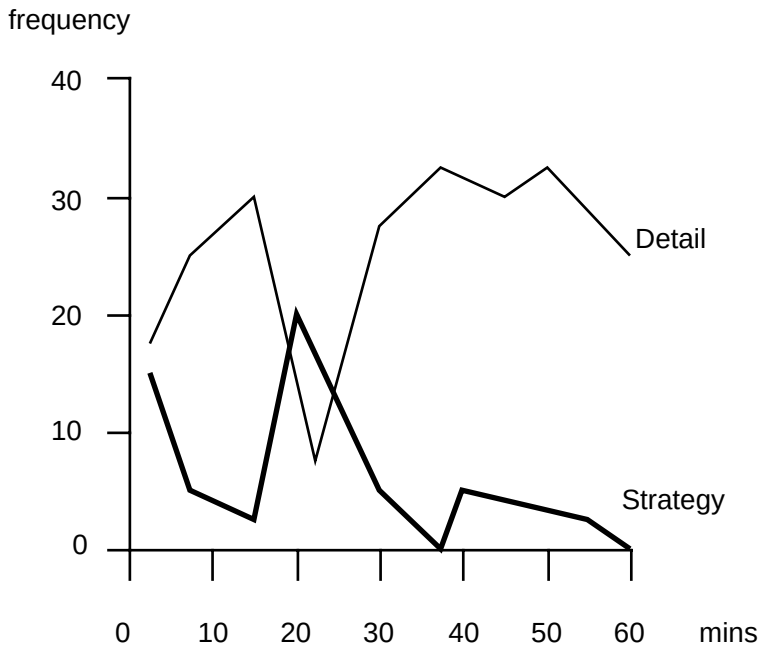

Figure 3 : Variation in detail and strategic content of sentences.
(for both designers over the whole design cycle)

gives way to discussion of the brief.

Deixis

Certain sentences may contain reference to some physical entity other than the participants themselves, by means of a deictic word, i.e. one whose interpretation can be determined only in relation to the context eg. "*I'll draw it in at this point here."* (other examples of such words are *he, she, it, this, that, here* and *there*). Figure 4 shows the distribution of deixis over the design cycle. The use of deictic words remains fairly steady over the design cycle up to the last ten minutes or so. Then there is a sudden increase. This may correlate with an increase in activity as the designers make checks on their SPS, realising that time is running out. Clearly, such a great use of deixis will have a profound impact on the communicational requirements of designers

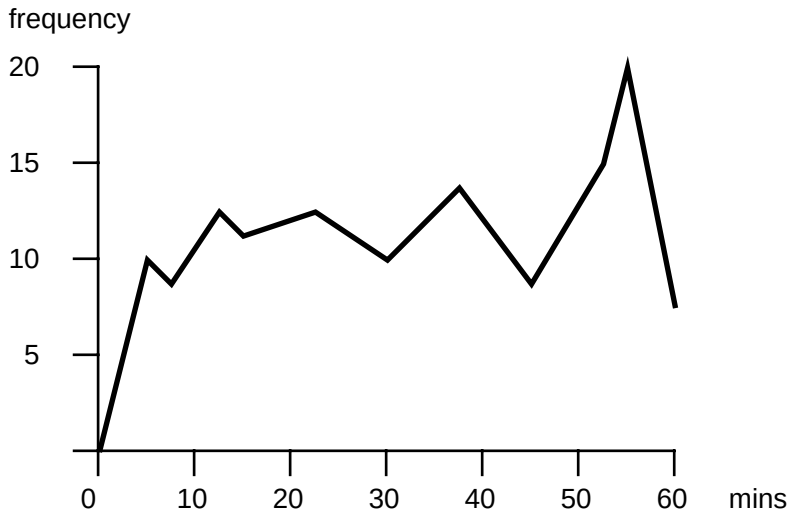

Figure 4 : Occurrence of use of deixis in speech for both designers over entire design cycle.

in the remote situation.

Non-Verbal Communication.

Drawing

The important functions that drawing can have for designer's have been documented by Garner (28). Terminology was developed to categorise and measure events in the drawing activity, and included the following: *Drawing sheet set , Drawing sheet, Drawing, Drawing packet, Drawing act,* and *Drawing act type.*

Analysis of the drawing data showed that there are some designer's acts which are 'private' (ie. they do not need to be available to the other person), some which must be made available to the other designer, and some which must be made available simultaneously to both. The most significant of these

being the SPS and those drawings which need to be frequently visited over the life of the design task.
One valuable part of the analysis examined the identification and recording of shared drawings, that is, which part of the drawing was shared, at what point in the solution process was it returned to, and how many times a particular drawing was visited. Figure 5 shows the distribution of visits made to different drawings during the design cycle. Some drawings are visited more often that others, and the significance of this is related to the content and function of each drawing. More importantly, Figure 5 indicates

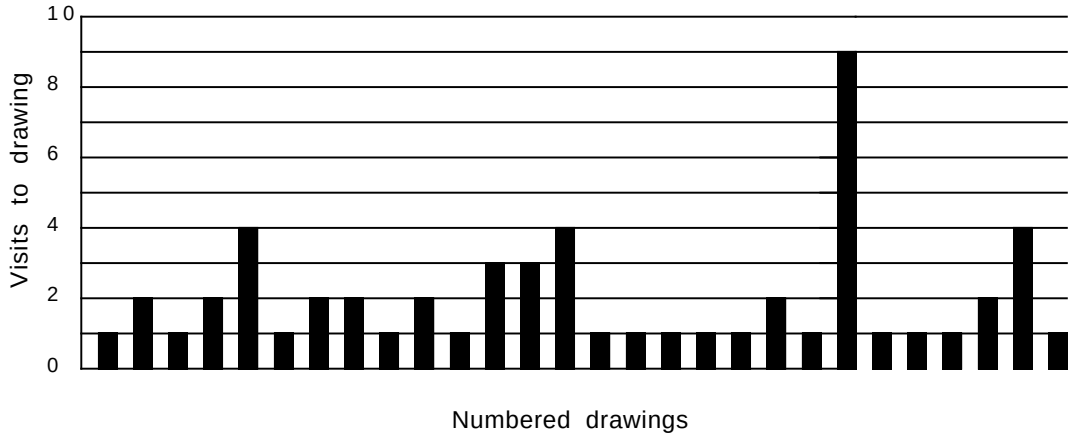

Figure 5 : Visits to drawings over a design cycle (designer B)

that the communicational requirements will demand the capability of holding and visiting a large number of drawings, not just one.

Gestures

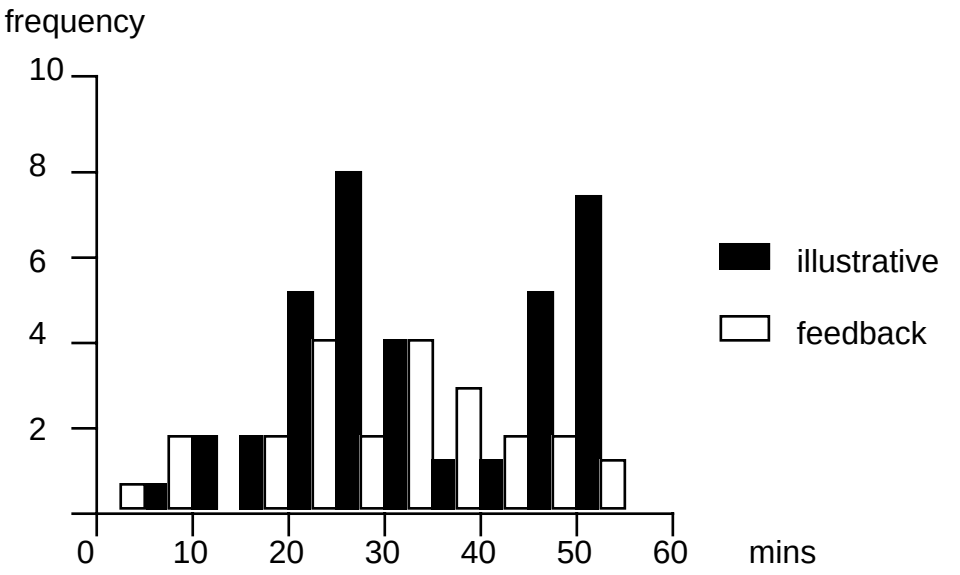

Figure 6 : Illustrative and feedback gestures for both designers, over whole design cycle.

Gestures were typically characterised as being 'illustrative', 'feedback'., or 'pointing'. Illustrative gesture was usually an indication of shape, size or orientation whereas feedback gesture was defined as a hand gesture used in conjunction with other channels to provide feedback. Figure 6 shows how illustrative gestures twice rose to a peak during the design cycle, while feedback gestures peaked once only, at the mid-point of the work. Feedback gestures become less used as the end of the cycle approaches, whereas illustrative gestures are still in evidence.

From this it can be seen that gesture is an important part of communication between the designers, and must feature in the communicational requirements.

Conclusions

This section outlines the main conclusions reached following the completion of the pilot study.

The results suggest that it is possible to generate communicational requirements expressed in terms of the accuracy, quantity and timeliness of the required information from, and to, the reference sources via the appropriate channels and media. The reference sources include the brief, the drawings and each other's knowledge. The knowledge that each designer has covers : the brief, the specific item being designed, design methods being used and other information such as knowledge of similar products currently available, characteristics of various materials and characteristics of potential users. Appropriate channels refer mainly to speaking, hearing and seeing. Appropriate media refer primarily to audio and video technology.

The designers accepted the brief and worked towards it as their common goal. The production of shared prototype solutions is taken as tangible evidence of a common goal. The designers mutually reinforced each other during the design cycles with utterances of agreement and encouragement ie. positive conversational feedback. This constitutes reward inherent in the process of reaching the common goal. They also found the task to be stimulating overall, and expressed satisfaction with their design achievements. This constitutes reward in the common goal reached.

The extent and content of utterance and drawings shows that the designers were working almost entirely to the brief and the production of a concluding SPS. This is a clear indication of goal-directed behaviour. The responses to the task were clearly distributed; co-ordination was mutually implemented, and the essential characteristics of time (eg. the timeliness of response) were also noted. Thus in all respects, the designers were working co-operatively. It is concluded that the proposed design task is of a type and sufficiently

complex to safely enable co-operative design behaviour.

Communicational Requirements

The design process with two designers co-operating remotely depends primarily on interleaved giving, taking, and exchanging information using a variety of media. This is the basis upon which the communicational requirements will be founded. Further, since some of a designer's acts must be made available to the other designer and some must be made available simultaneously to both, it is concluded that the communicational requirements must incorporate the capability to hold and freely visit a large number of drawings, not just one.

Subject behaviour during a representative experimental co-operative task was (with the exception of gaze) successfully recorded and analysed. The salient features (from which hypotheses can be made concerning communication) were identified. From the results of this analysis, it is concluded that the nature of the communication process has been characterised sufficiently well to form the foundation upon which the main experiment can be based.

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