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Collaborative Activity and Technological Design: Task Coordination in London Underground Control Rooms

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Despite technical advances in CSCW over the past few years we still have relatively little understanding of the organisation of collaborative activity in real world, technologically supported, work environments. Indeed, it has been suggested that the failure of various technological applications may derive from its relative insensitivity to ordinary work practice and situated conduct. In this paper we discuss the possibility of utilising recent developments within social science, and in particular the naturalistic analysis of organisational conduct and interpersonal communication, as a basis for the design and development of tools and technologies to support collaborative work. Focussing on the Line Control Rooms on London Underground, a complex multimedia environment in transition, we begin to explicate the informal work practices and procedures whereby personnel systematically communicate information and coordinate a disparate collection of tasks and activities. These empirical investigations form the foundation to the design of new tools to support collaborative work in Line Control Rooms; technologies which will be sensitive to the ordinary conduct and practical skills of organisational personnel in the London Underground.

Introduction

Recently there are been significant developments in technologies to support the work of groups of users: shared text editors have been designed to assist people

write documents at the same time while using computers at different locations (e.g. Olson, Olson, Mack and Wellner 1990), shared drawing tools have been developed for groups of designers (e.g. Bly 1988), systems have been built so that groups can represent and structure arguments, ideas and designs (Lee 1990), and others aim to support group meetings, group decision making and group communication (Winograd and Flores 1986, Cosmos 1988). These technological developments incorporate innovations in computer architectures, computer networks, audio and video communications. Yet. despite all of these developments, the application of the technology often fails (Grudin 1988, Markus and Connolly 1990). As Galegher and Kraut (1990) outline in the introduction to a recent book on CSCW the technology often 'fails to reflect what we know about social interaction in groups and organizations' (Galegher and Kraut p6). To cope with this problem they call for social scientists to become involved in the design of tools for CSCW.

It may appear strange that such a call is made, given the significant amount of work on social aspects of communication and collaboration that is addressed to a CSCW audience. Although some of this work has described abstract properties of groups there have been several detailed empirical studies set in real-world environments. For example, Linde (1986) has explored the communicative work that takes place in a helicopter cockpit, Hutchins (1990) has described the collaborative use of charts, range-finders and other artifacts to navigate a large vessel and Nardi and Miller (1990) have shown the collaborative aspects of working with computer spreadsheets in an office environment. Though this work has revealed some of the organization of collaborative work implications for the development of technology appear to be difficult to draw. The reasons behind this appear to be in the nature of the technology rather than the results of the study. The technology used in the settings studied by social scientists is usually of quite a different nature to that being currently developed in CSCW and it is often not possible to put the new technologies into real-world, naturalistic settings. This has meant that evaluations of CSCW systems have mostly been carried out as experiments in laboratory settings.

This paper attempts to bridge this gap by describing the details of communicative and collaborative work in a real-world environment which incorporates technology similar to that being developed in the field of CSCW. In common with Suchman and Trigg's (1989) study of communication in an airline terminal operations room this paper aims to show that social scientists can be involved in the design of tools for CSCW. Focusing on the social organisation of cooperative work in a control room, the ways in which various personnel coordinate multiple tasks and utilise a complex array of tools and technologies are explored. This begins to reveal the nature of the interaction between the controllers and their work practices. In particular, the ways in which they collaborate and mutually monitor each others work and communication has implications for the design of further developments to

the technology in the control room and to the general design and implementation of shared tools.

Methodological background

The investigation of cooperative work supported by complex technologies demands a rather different conceptual and methodological orientation than that commonly found within research on human-computer interaction. The analysis is no longer primarily concerned with the individual and the system, but rather the interaction between different personnel as they coordinate a range of tasks and utilise various tools. The ability to coordinate activities and the process of interpretation and perception it entails, inevitably relies upon a social organisation; a body of skills and practices which allows different personnel to recognise what each other is doing and thereby produce appropriate conduct. Following recent developments in the psychology of work, we might conceive of this organisation as a form of 'distributed cognition'; a process in which various individuals develop an interrelated orientation towards a collection of tasks and activities (cf. Hutchins 1989, Olson 1990, and Olson and Olson 1991). Yet even this relatively radical reconceptualisation of the relationship between the individual, his activity and the system does not capture the situated and socially organised character of cooperative work. It is not simply that tasks and activities occur within a particular cultural framework and social context, but rather that collaboration necessitates a publicly available set of practices and reasoning which are developed and warranted within a particular setting, and which systematically inform the work and interaction of various personnel.

Whether one subscribes to a theory of distributed cognition or a more sociological conception of cooperative work, it is clear that we need to move away from laboratory studies of cognition, "which have deliberately stripped away the supporting context of the everyday world, in an effort to study 'pure' internal processes" (Olson 1990) and begin to explore task coordination and computer support in real world, everyday work settings. Fortunately, recent developments in social science, namely ethnomethodology and conversation analysis, provide a methodological framework with which to begin to explore the situated and social character of collaborative work. Utilising audio and video recordings, augmented by field observation the process of coordinating multiple activities whilst utilising various tools and technologies can be subjected to detailed and systematic analysis. Drawing on this naturalistic framework, it is hoped that we will not only begin to generate findings concerning the social and interactional organisation of collaborative work, but provide a distinctive method for user-centered design.

The technology in the control room

The Bakerloo Line, London Underground is currently undergoing extensive modernisation. By 1991 signalling will be fully computerised and monitored from the Line Control Room at Baker Street. At the present time, the Bakerloo Line Control Room houses the Line Controller, who coordinates the day to day running of the railway and the Divisional Information Assistant (DIA) whose responsibilities include providing information to passengers through a public address (PA) system and communicating with station managers. Figure 1 shows the general layout of the Control Room.

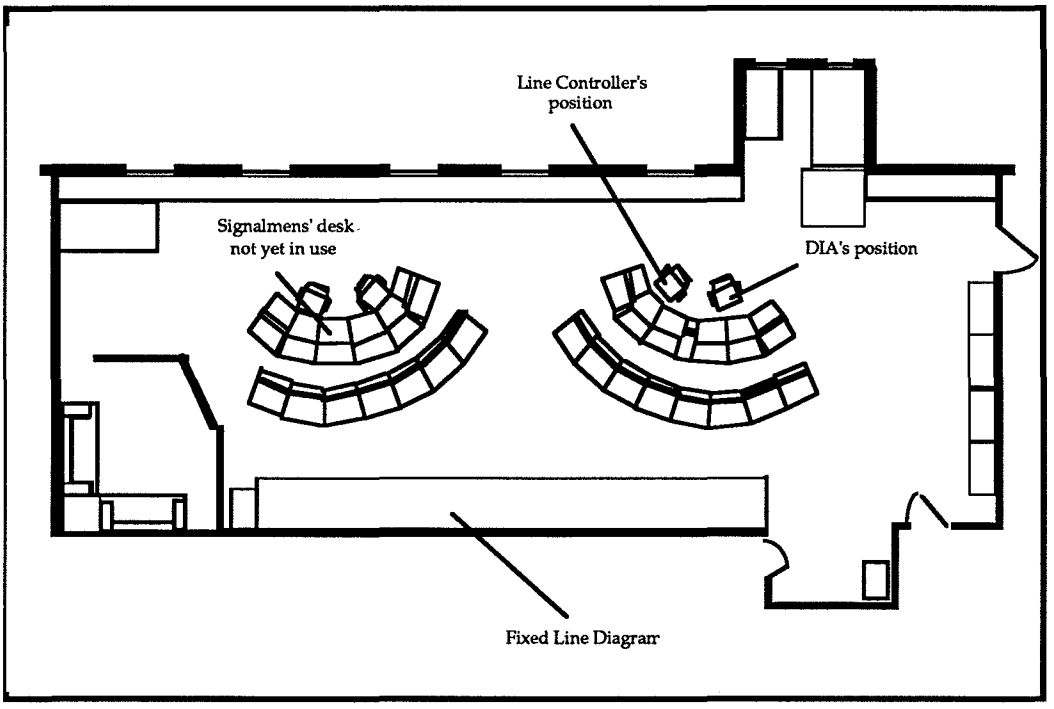

Fig. 1. The Bakerloo Line Control Room

The Controller and DIA sit together at a semicircular console which faces a tiled, real time, hard line display which runs nearly the entire length of the room and shows traffic movement along the Bakerloo Line (from the Elephant and Castle to Queens Park). The console includes touch screen telephones, a radio system for contact with drivers, the PA control keys, and close circuit television (CCTV) monitors and controls for viewing platforms (see Figure 2). Occasionally a trainee DIAs (tDIA) or a second controller will sit at this console. In the near future, two or three signal assistants will sit at a similar console next to the Controller and DIA (see Figure 1) and personnel will also have access to monitors showing real time

graphic display of the line. Therefore, the Controller and DIA use a range of devices similar to the technologies being developed in CSCW; they use audio and video channels of communication, a shared display, various keypads and monitors. Revealing some of the practices of the personnel as they utilise these tools, should inform both the further development of technology in the control room and have implications for the design of similar technology elsewhere.

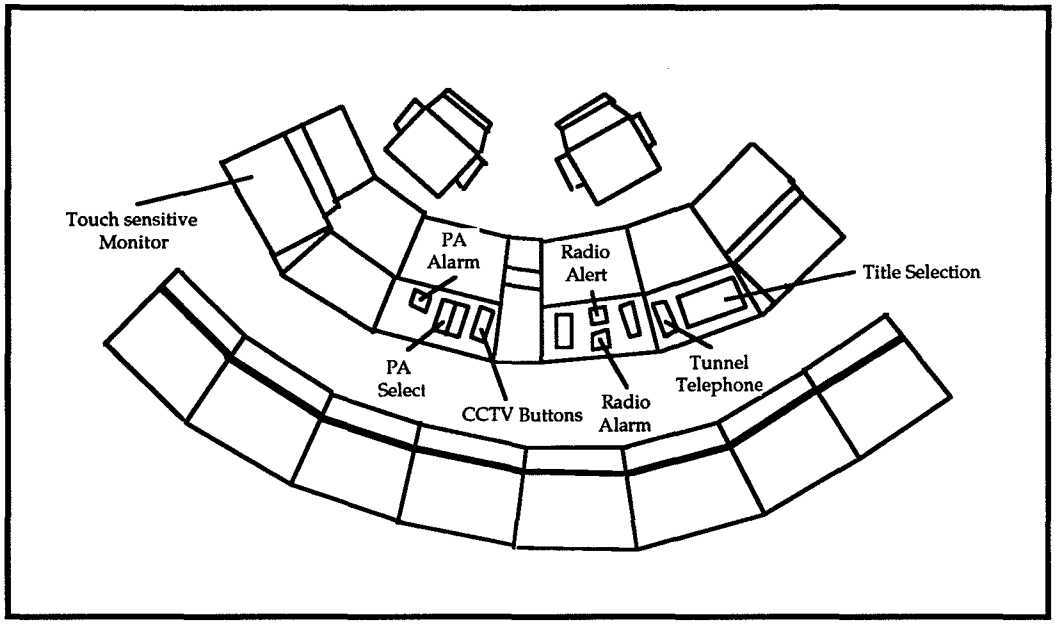

Fig. 2. Line Controller's and DIA's Desk

The Underground service is coordinated through a paper timetable which specifies; the number, running time and route of trains, crew allocation and shift arrangements, information concerning staff travel facilities, stock transfers, vehicle storage and maintenance etc. Each underground line has a particular timetable, though in some cases the timing of trains will be closely tied to the service on a related line. The timetable is not simply an abstract description of the operation of the service, but is used by various personnel including the Controller, DIA, Signalmen, Duty Crew Managers, to coordinate traffic flow and passenger movement. Both Controller and DIA use the timetable in conjunction with their understanding of the current operation of the service to determine the adequacy of the service and if necessary initiate remedial action. Indeed, a significant part of the responsibility of the Controller is to serve as a 'guardian of the timetable' and even if he is unable to shape the service according to its specific details, he should, as far as possible, attempt to achieve its underlying principle; a regular service of trains with relatively brief intervening gaps.

The timetable is not only a resource for identifying difficulties within the operation of the service but also for their management. For example the Controller

will make small adjustments to the running times of a particular train to cure a gap which is emerging within the running of the service. More severe problems such as absentees, vehicle breakdowns or difficulties with the electric current, which can lead to severe disruption of the service, are often successfully managed by reforming the service. These adjustments are marked in felt pen on a polythene coated timetable both by the Controller and communicated to Operators (Drivers), Signalmen, the Duty Crew Managers and others when necessary. It is critical that the DIA and others receive the information and make the relevant changes to their timetable otherwise their understanding of the service and their consequent decisions will be incorrect.

Despite important differences in the formal specification of the responsibilities of the Controller and DIA, the various tasks they undertake rely upon extremely close collaboration. Indeed, control room personnel have developed a subtle and complex body of practices for monitoring each other's conduct and coordinating varied collection of tasks and activities. These practices appear to stand independently of particular personnel, and it is not unusual to witness individuals who have no previous experience working together, informally, yet systematically coordinating their conduct. One element of this extraordinary interweaving of often simultaneous responsibilities and tasks is an emergent and flexible division of labour which allows the personnel to manage difficulties and crises.

Public announcements : coordinating passenger movement

The DIA makes public announcements when problems emerge within the 'normal' operation of the service. In particular, they provide information and advice in circumstances in which they envisage that certain passengers may experience difficulties in using the service. So for example, unlike others forms of transport, urban railway systems such as the Underground do not provide a timetable to the public, rather passengers organise their travel arrangement on the assumption that trains will pass through particular stations every few minutes. When such expectations may be broken, or travellers are unable to change at certain stations, or have to leave a train because the line is blocked, then the DIA should provide information and advice. The nature of the announcement varies with the circumstances, though they do tend to some recurrent characteristics. Consider the following instance.

Fragment 1 (Abbreviated and simplified)

DIA: Hello and good afternoon Ladies an Gentlemen. Bakerloo Line Information.

DIA: We have a slight gap in our south bound Bakerloo Line service^ towards the Elephant an Castle. Your next south bound train, should depart from this station in about another three minutes.

DIA: The next south bound train, should depart from this station in about another three minutes.

.....a related announcement follows a couple of minutes later.....

Even though it is a public announcement, apparently addressed to a generalised audience, it achieves its performative force, its relevance, by virtue of its design for a specific category of passenger; its 'recipient design' (cf. Sacks 1966, Sacks, Schegloff and Jefferson 1974). In the case at hand, the information is only delivered to passengers who are are waiting on a particular station and who potentially suffer a slight delay before the next train arrives. The announcement 'fits" with their potential experience of the service at this moment in time and gains its relevance by virtue of that experience. To produce timely and relevant information for passengers, the DIA systematically monitors the service and the actions of his colleagues and transforms these bits and pieces into announcements for passengers using the service at particular moments in time.

Surreptitious monitoring and interrelating tasks

In the space provided it will be impossible to describe in any detail the interaction between Controller and DIA the foundation to passengers receiving timely information concerning the operation of the service. However, we will try to provide a flavour of the complex skills which underlie their cooperative work. It is perhaps best to begin by mentioning that it is relatively unusual for either the Controller or the DIA explicitly to give information to one another. Rather they rely upon their ability to overhear each other's conversations and mutually monitor their actions even though they may be simultaneously engaged in distinct and apparently unrelated tasks. Through his subtle yet systematic monitoring of the Controller, the DIA can track the operation of the service and design information for passengers. Returning to fragment 1, we can see how the announcement(s) emerge in the light of actions undertaken by the Controller. We enter the scene as the Controller calls a driver.

Fragment 1 Transcript 2 (Abbreviated and simplified)

.....calls driver.....

C: Control to the train at Charing Cross South Bound, do you receive?

.....C. Switches monitor to the platform...

C: Control to the train at Charing Cross South Bound, do you receive?

Op: Two Four O Charing Cross South Bound

C: Yeah, Two Four O. We've got a little bit of an interval behin:nd you. Could you take a couple of minutes in the platform for me please?

Op: (( )) Over

C: Thank you very much Two Four O.
(5.2)

DIA: Hello and good afternoon Ladies an Gentlemen. Bakerloo Line Information.....

The announcements therefore emerge in the light of the DIA overhearing the Controller's conversation with the driver and assessing its implications for the passengers expectations and experience of the service. He transforms the Controllers request into a relevant announcement, by determining how and who the decision will effect, namely the passengers at Embankment, the station beyond Charing Cross whose next train is delayed as a result of the Controller's request. The subsequent announcement (not included in the above transcript) is designed for those at Charing Cross who now find their train held in the station.

The DIA does not wait until the completion of the Controller's call before preparing to take action. Indeed in some cases its critical that the announcement is delivered as adjustments are being made to the service. In the case at hand, as the call is initiated, we find the DIA progressively monitoring its production and assessing the implications of the Controller's request for his own conduct. The technology, and in particular the hard line display, provides resources through which the DIA can make sense of the Controller's actions and draw the necessary inferences for his own conduct. For example, at the onset of the call he scan's the hard line display to discern why the Controller might wish to speak to the operator. Even by the second attempt to make contact with driver, the DIA is already moving into a position where he will be able to make an announcement. At the word "couple" he is able to infer exactly what's happening and grabs the microphone to inform the passengers of the delay in the service. By the completion of the call, the DIA has set the Public Address system and is ready to make the announcement.

To enable him to provide information to passengers, the DIA monitors the actions of the Controller, using the hard line display and the station monitors to account for his colleague's interventions in the running of the service. The common availability of the same sources of information, allows the DIA and Controller to assume that they can both independently draw similar inferences concerning the operation of the service, and they can witness each other's use of the available systems.

Certain phrases or even single words addressed to an operator or signalman, implicate action for the DIA by virtue of transforming the service for certain passengers. For example, in the following instance, the DIA who is apparently engaged in making changes to his own timetable, suddenly grabs the phone to call a station manager on over hearing the word "reverse".

Fragment 2 (Abbreviated and simplified)

C: Controller to South Bound Two Three Three, do you receive

Op: Two Three Three receiving over.

C: Yeah ,Two Three Three (.) I'd like you to **reverse** at Piccadilly, and you'll also be reformed there. I'll come back to you when you get to Piccadilly. Over?

: *...call continues. Some seconds later the DIA reaches*

: *the station manager at Piccadilly Circus.....*

DIA: Two Three Three is going to reverse with with you, South to North.

Rendering tasks visible

Whilst relying on the DIA's ability to overhear his conversations and draw the necessary inferences, the Controller employs various techniques to keep his colleague informed of various changes to the operation of the service. For example, the Controller frequently 'rewrites' part of the timetable whereby he reschedules particular trains and their crews; a process known as 'reformation'. It is critical that the DIA and other organisational personnel outside the Control Room, know the precise details of any reformations which have are being undertaken. Without these details they will not only misunderstand the current operation of the service, but also in the case on the DIA. provide incorrect information to passengers and staff. The Controller needs to make relevant information available to the DIA, but often, especially during crises in the operation of the service, does not have the time to abandon his various tasks to explicitly inform the DIA of the various changes. Consequently, whilst reforming the service, it is not unusual to find the Controller talking aloud to himself; a technique which allows him to undertake quite complex changes to timetable, whilst simultaneously passing information to the DIA. Interestingly this 'self talk', not only provides the DIA with the details of reformations, but also the reasoning used by the Controller in making the particular changes. Details of which can be crucial for the DIA in deciding how to handle certain problems. Whilst the Controller's talking to himself, it is not unusual for the DIA successively glance at the hard line display and station monitors to determine exactly which trains at which locations are being reformed.

On occasions, it is necessary for the Controller to draw the DIA's attention to particular events or activities, even as they emerge within the management of a certain task or problem. For example, as he is speaking to an operator or signalman, the Controller may laugh or produce an exclamation and thereby encourage the DIA to monitor the call more carefully. Or, as he turns to his timetable or glances at the hard line display, the Controller will swear, feign momentary illness or even sing a couple of bars to a song to draw the DIA's attention to an emergent problem within the operation of the service. The various objects used by the Controller and DIA, to gain a more explicit orientation from the

other towards a particular event or activity, are carefully designed to encourage but not demand the other's attention. They allow the individual to continue with an activity with which they might be engaged, whilst simultaneously inviting them to carefully monitor a concurrent event.

In accomplishing various activities therefore, whether its undertaking a reformation or contacting signals to reschedule various changes, the Controller designs his actions so that they simultaneously address various purposes. So for example, on the one hand he will gearing his talk with his co-interactant in the signal box or on the station, whilst at same time design his talk so that its available to, and possibly, structures the participation of his colleagues in the Control Room. The production format (cf. Goffman 1981) of the activity is sensitive to multiple, simultaneous demands, coordinated with the actions of the 'primary recipient' outside the Control Room, whilst being available for and implicating action for the DIA and even a second DIA or Controller. The same activity is produced to organise participation and implicate action both in and outside the Control Room; the activity and the participation framework it generates merge, momentarily, different ecologies within the organisational milieu.

Overseeing the local environment

On occasions the Controller has to explicitly draw the DIA's attention to a particular event. In the following instance, an emergency has arisen at Baker Street and trains have not been stopping at the station. As the DIA provides information to Bakerloo Line passengers, the Controller receives a call giving the 'all clear'.

Fragment 3 (Abbreviated and simplified.)

DIA: Hello and Good Morning Ladies and Gentlemen.

....C answers the phone and begins conversation...

DIA: At Baker Street, Circle, Ham'smith and City, and Metropolitan Line trains, are not stopping at the station as the London Fire Brigade are investigating a report of emergency.

C: *.....puts receiver down, and snaps fingers....*

C: All clear

tDIA: All clear

C: Yep

DIA: Hello Ladies and Gentlemen, a correction to our last message all (..... .....) and Circle Line trains are now stopping at Baker Street Station, this follows London Fire Brigade investigating reports of emergency at that station. All trains on all lines, that includes the Bakerloo Jubilee Metropolitan, Ham'smith and City and Circle Line are now:stopping at Baker Street. Interchange facilities are now .....

Despite receiving information which contradicts the announcement, the Controller avoids interrupting the DIA. As the DIA begins to reach the first possible completion of the announcement, and before it is recycled, the Controller turns

towards his colleagues, snaps his fingers and on the possible completion of the utterance, mentions it sis 'all clear'. The trainee DIA responds, but the DIA himself maintains contact with the passengers, forestalls his earlier message, and immediately delivers a modified announcement.

Even in relatively extreme circumstances, the Controller and DIA rarely interrupt each other's activities, but provide overlaying information which will inform how they see the service and the actions they will undertake. There are of course a complex graduation of such objects; moving from the most unobtrusive, to actions which almost demand the attention of the other.

The flow of information between Controller and DIA is not simply one way. Just as the Controller assumes responsibility for keeping his colleague informed, so the DIA will monitor the operation of the service and draw the Controllers attention to any problems which might arise. Consider the following instance. The Controller finishes a conversation on the phone and the DIA attempts to draw his attention to a problem which appears to be emerging at Baker Street on the southbound. Rather than explicitly mentioning the problem to the Controller, the DIA initially successively glances at the hard line display and the station monitor attempting to delicately have his colleague notice, independently, that a problem may be emerging. His glances pass unnoticed and as the Controller begins a new activity, the DIA gently queries the signalman's conduct.

Fragment 4 (Abbreviated and simplified)

.....The Controller puts phone down.....

...DIA successively glances at the hard line display and station monitor, and as the C. returns to read the timetable utters....

DIA: Is he holding that train at Baker in the South?

.....Phone rings: Cii goes to answer: query from shunter and then takes a second call; a query from signals. Throughout the calls the DIA continues to glance at the hard line display and station monitor.....

.....37 seconds later.....

Cii: Controller calling the train Baker Street on the South Bound platform?

:

Cii: Oh I see I just wondering because we are blocking back behind you at the moment.....

:

.....Now speaking to signals....

Cii: No no no it's nothin between you an him an they're all piling up behind him. (2.8) Yeh, well let him go at Baker Street please....

((30.00))

DIA: Hello Ladies and Gentlemen Bakerloo Line Information. The next South Bound train just now leaving Ba:ker Street, an will be with you shortly.....

Before the Controller is able to deal with the potential problem, he is interrupted by a couple of phone calls. During these calls the DIA begins once more to make successive glances between the hard line display and the station monitor and shows

to the Controller that the problem has not been solved and delay is becoming increasingly severe. As soon as the second call finishes, the Controller attempts to speak to the driver at Baker Street and the DIA quietly returns the activity in which he was engaged before noticing the problem. The hard line display and monitor not only provide the DIA with the possibility of noticing the problem which is emerging within the operation of the service, but also provide for the ability to display the difficulty through his particular use of the system to his colleague. The public availability of the technology's use provides a range of resources for rendering actions visible and coordinating an individual's tasks with colleagues.

The Controller contacts the operator and finding no reason for the delay speaks to the signalman, who is mistakenly holding the train. So, the DIA monitors the operation of the service 'for' the Controller and draws his attention to a potential problem, which implicates various actions for both participants; the remedial activities of the Controller and the public announcements by the DIA rely upon close, moment by moment, cooperation.

The continual flow of information between the Controller and DIA and their ability to monitor, and if necessary correct, each others' actions, are essential features of work in the Control Room. The constant updating of information, coupled with ability and responsibility to make make it 'publicly' available within the Control Room, provides the Controller and the DIA with resources with which to make sense of the operation of the service. Without knowledge of the current circumstances, the timing and movement of vehicles on this occasion, the development of the service and any difficulties on this particular day, Controller and DIA would be liable to draw the wrong inferences from the various sources of information that they have available and risk the possibility of making incorrect decisions. The intelligibility of the scene, the possibility of coordinating tasks and activities, rests upon these communicative and socially organised practices.

An essential feature of these practices are the ways in which the accomplishment of specific tasks and responsibilities are interweaved with an interactional organisation. For example, the ways in which the DIA participates in conversations with Station Managers and the like and accomplishes various activities is not only geared to demands of the particular phone call, but also may simultaneously be designed to monitor a separate conversation between his colleague and a train driver. The accomplishment of one task being embedded within the interactional constraints of simultaneously participating in an unrelated activity. Similarly, for example, in producing an activity such as requesting a driver to 'take a couple of minutes in the station', a Controller is not only sensitive to the overt task at hand and the conduct of his 'primary' recipient, but is also simultaneously designing the activity so that in some part it is available to the DIA and perhaps other's within the Control Room. The accomplishment of specific tasks are embedded within interactional organisation and an overarching responsibility to distribute certain

information. The production format of tasks and activities is interweaved with various forms of participation framework.

The usefulness of the hard line display, the CCTV system, and the accompanying tools, relies upon a collection of informal practices through which Controller and DIA coordinate information flow and monitor each others' conduct. Without the information continually being made public and exchanged between the various personnel, the DIA or Controller's interpretation of the scenes presented by the various technologies would be wrong and thereby lead to mistakes and errors. The technology and the information it provides, does not stand independently of the various practices in and through which personnel exchange information and coordinate their actions, rather the use of the various systems is thoroughly dependant upon a current version of train movement, running times and changes to the timetable which are currently being undertaken.

The technology provides individuals with the ability to assess the state of the current operation of the service and undertake specific tasks such as remedial activities and the provision of public information. More importantly perhaps, the hard line display and the station monitors provide the foundation to collaboration between the DIA, Controller and other personnel who may be 'helping out' in the Control Room. We have noted already how the various displays may be used to make sense of a colleague's actions, such as an intervention in the particular running time of a train, or the ways in which the CCTV may be used as an 'objective' source of information concerning the presence of a particular train at a certain station. The technology does not simply provide the resources through which assessments of the state of the service are produced. Rather it provides a set of tools through which the sense of the activities of an individual and his colleagues can be unpicked, placing a single action within the framework of the overall appearance of the traffic. Moreover, the visibility of the use of the technology by a colleague within the Control Room, whether its simply glancing at a particular Station on the hard line display or looking at a platform at a certain station, provides others within the local environment of action to draw various inferences and assess their implications for their own responsibilities and obligations. The technology provides a keystone to the collaboration within the Control Room, not only a source interrelated bodies of information, but critically a medium through which particular activities become visible or publicly available within the local ecology.

Implications for design

The analysis of work practice and interpersonal communication in the Control Room has begun to generate various implications for the design of the current systems and the socio-ergonomic framework of the various interfaces and layout of the technology. More interestingly perhaps, it has begun to identify innovative tools which will support the various responsibilities of Controller, DIA and others within

the Control Room and the forms of collaboration that we have begun to discover. One such tool is a real time, screen based timetable, and we are currently exploring the possibility with London Underground of developing an intelligent system which will provide conventional timetable information and the possibility of undertaking complex changes.

In the first instance, the design of the system will be based upon detailed analysis of the conventional use of the current timetable and the type of information which is exchanges between Controller, DIA and others concerning moment by moment changes to the schedule. At the present time, Controller and DIA cover their paper timetables with cellophane sheets which allows them to mark changes and add details with a felt pen and later to remove the various arrows, figures and notes. As noted, the various changes undertaken by the Controller are rarely explicitly told to DIA or others, rather as colleagues pick up the various changes being made they sketch in the reformations and adjustments on their own timetable. By simulating these processes and providing information which is necessary to running the service, we can build a tool which will support the various tasks undertaken with the timetable and the necessary indirect communication which occurs within the Control Room.

It is envisaged that the interface will consist of a screen which presents pages of the timetable which running times alongside scheduled times. The screen will be embedded in the console at various positions so as to allow Controllers, DIA and in the future Signal Assistants direct access. The timetable can be overwritten through the use of electronic pen, and the changes represented in a similar way to that of marking a document. In undertaking reformations and making adjustments, the Controller then sends these changes to his colleagues and they appear on the screen in just the way they were drawn. Besides various other facilities, we plan build in increasing intelligence to the system, initially for example, allowing the Controller to test the consequences of candidate reformations before they are confirmed. Over time, of course, as the system builds up a substantial data base of changes and decisions made by Line Controller's, it will be possible to elicit conventional and candidate solutions from the system to specific problems faced in the operation of the service.

The provisional design of the system therefore is not simply sensitive to the conventional uses of the paper document, but the forms of collaboration undertaken by Controller, DIA and others. It supports the current forms of information exchange, and, by providing running times alongside scheduled times, allows Control Room personnel to identify problems in parallel. The system complements rather than replaces current technologies, but more particularly provides a secure foundation to current informal processes of communication and collaboration. In the long term, it is envisaged that such a tool will help merge the various organisational ecologies within the real time management of the service, communicating timetable changes and adjustments to staff at different locales. For

example, within the Control Room the system will prove invaluable to the collaboration between Signal Assistants and the Controller and outside to Duty Crew Managers involved in rearranging crews and their allocation to particular trains.

In designing collaborative tools for the Control Room which are based upon an understanding of current work practice, it should be possible to avoid some of the pitfalls which frequently arise in the introduction of 'inappropriate' systems into a real-world environment. An approach to user-centred design has been outlined that by detailed analysis of the collaborative work of people using various tools and technologies begins to imply appropriate developments to that technology. In the case at hand tools are being designed that facilitate, rather than undermine, the systematic, yet informal, process of collaboration between personnel which forms the foundation to control and passenger information and which also provide for a safe and reliable service.

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References

Bly , S. A. (1988): "A Use of Drawing Surfaces in Different Collaborative Settings", in *Proceedings of CSCW '88*, 26th-28th September, Portland, Oregon, pp. 250-256.

Cicourel, A. (1973): *Cognitive Sociology: Language and Meaning in Social Interaction.* Penguin, Harmondsworth.

Cosmos (1988): "Specification for a Configurable, Structured Message System", Cosmos Report 68.4 Ext/ALV, Queen Mary College, London.

Galegher, J. and Kraut, R. E. (1990): "Technology for Intellectual Teamwork: Perspectives on Research and Design", in J. Galagher, R.E. Kraut, and C. Egido (eds.):*Intellectual Teamwork: The Social and Technological Foundations of Cooperative Work,* Lawrence Erlbaum Associates, Hillsdale, New Jersey, pp. 1-20.

Garfinkel, H. (1967): *Studies in Ethnomethodology,* Prentice Hall, Englewood Cliffs, N.J.

Goffman, E. (1967): *Interaction Ritual.*, Doubleday, New York .

Goffman, E. (1981): *Forms of Talk,* Blackwell, Oxford.

Grudin, J., (1988): "Why CSCW Applications Fail: Problems in the Design and Evaluation of Organizational Interfaces", in *Proceedings of CSCW '88*, Portland, Oregon, 26th-28th September, pp. 85-93.

Gumperz, J. J. (1982): *Discourse Strategies,* Cambridge University Press, Cambridge.

Hutchins, E. (1989): "A cultural view of distributed cognition", Unpublished Manuscript, University of California, San Diego.

Hutchins, E. L. (1990): "The Technology of Team Navigation", in J. Galagher, R.E. Kraut, and C. Egido (eds):*Intellectual Teamwork: The Social and Technological Foundations of Cooperative Work*. 191-221. Lawrence Erlbaum Associates, Hillsdale, New Jersey.

Kendon, A. (1977): *Studies in the Behaviour of Social Interaction.*, Peter de Rider Press, Holland (second edition forthcoming with Cambridge University Press).

Lee, J. (1990): SIBYL: "A Tool for Managing Group Decision Rationale", in *Proceedings of CSCW '90*, Los Angeles, California, 7th-10th October 1991, pp. 79-92.

Linde, C. (1986): "Who's in charge here? Cooperative work and authority negotiation in police helicopter missions", in *Proceedings of CSCW '88*, Portland, Oregon, 26th-28th September, pp. 52-64.

Markus, M. L. and Connolly, T. (1990): "Why CSCW Applications Fail: Problems in the Adoption of Independent Work Tools", in *Proceedings of CSCW '90*, Los Angeles, California, 7th-10th October, pp. 371-380.

Moran, T. P. and Anderson, R. J. (1990): "The workaday world as a paradigm for CSCW design", in *Proceedings of the Conference on Computer Supported Collaborative Work.* Los Angeles, California, 7th-10th October, pp. 381-393.

Nardi, B. A. and Miller, J. R. (1990): "An ethnographic study of distributed problem solving in spreadsheet development", in *Proceedings of CSCW '90*, Los Angeles, California, 7th-10th October, pp. 197-208.

Olson, G. M. (1990) "Collaborative Work as Distributed Cognition", Unpublished Manuscript, University of Michigan

Olson, G. M. and Olson, J. S. (1991): "User-Centered Design of Collaboration Technology", *Organisational Computing*, Vol 1, No. 1, pp. 61-83.

Olson, J. S., Olson, G. M., Mack, L. A. and Wellner, P. (1990): "Concurrent editing: the group interface", in *Proceedings of Interact '90 - Third IFIP Conference on Human-Computer Interaction*, Cambridge, 27th - 30th August 27-30, pp. 835-840.

Rasmussen, J. (1989): "Coping with human errors through system design: implications for ecological interface design", *International Journal of Man Machine Studies*, Vol. 31, pp 517-534.

Rasmussen, J., Pejtersen, A. and K. Scmidt (1990): *Taxonomy for Cognitive Work Analysis*, Riso National Laboratory, Roskilde.

Sacks, H. (1966): *Unpublished Transcribed Lectures*, transcribed and indexed by Gail Jefferson. University of California at Irvine.

Sacks, H., Schegloff, E. A. and Jefferson G. (1974): "A Simplest Systematics for the Organisation of Turn Taking in Conversation", *Language*, Vol. 50, pp. 696-735.

Suchman, L. A. and Trigg, R. H. (1989): "Understanding Practice: Video as a Medium for Reflection and Design", Paper prepared for the 12th IRIS Conference, Skagen, Denmark, 13th-16th August 1989.

Winograd, T. and Flores, F. (1986): *Understanding Computers and Cognition: A New Foundation For Design*, Addison-Wesley, Norwood, NJ.