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COLLABORATION AND CONTROL:

Crisis Management and Multimedia Technology in London Underground Line Control Rooms

Christian Heath
and
Paul Luff

Department of Sociology
University of Surrey
Guildford
UK

Rank Xerox, Cambridge EuroPARC
61 Regent Street
Cambridge
UK

Abstract

Despite technical advances over the past few years in the area of systems support for cooperative work there is still 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 their relative insensitivity to ordinary work practice and situated conduct. In this paper we discuss the possibility of utilising recent developments within sociology, in particular the naturalistic analysis of organisational conduct and social interaction, as a basis for the design and development of tools and technologies to support collaborative work. Focussing on the Line Control Rooms in London Underground, a complex multimedia environment in transition, we begin to explicate the tacit work practices and procedures whereby personnel systematically communicate information to each other and coordinate a disparate collection of tasks and activities. The design implications of these empirical observations, both for Line Control Room and technologies to support cooperative work, are briefly discussed.

Keywords: **Task Coordination, Communicative Practices, Work Practices, Ethnography, CSCW**

1. Introduction

In recent years there have been significant developments in technologies to support cooperative work between multiple users in organisational environments. These tools range from shared text editors and drawing tools (for example, Olson, Olson, Mack and Wellner 1990; Bly 1988) through to systems which support group meetings and decision making (Winograd and Flores 1986, Cosmos 1988, Lee 1990), and include systems to support physically dispersed personnel (Moran and Anderson 1990). These technological developments incorporate innovations in computer architectures, computer networks, and audio-visual communications, and yet despite this enormous scientific investment, it is often found that the actual applications of the technologies fail (Grudin 1988, Markus and Connolly 1990). In their introduction to a book on computer supported cooperative work (CSCW), Galegher and Kraut (1990) suggest that the relative failure of the systems derive from their insensitivity to 'what we know about social interaction in groups and organisations. Galegher and Kraut continue by arguing that social scientists may well be able to make an important contribution to the design of complex systems to support cooperative work.

In this light, we are beginning to witness the emergence of a body of research concerned with the social organisation of human conduct in technologically mediated cooperative work environments. Although some of this work has tended to focus on abstract properties of group behaviour, there are also a number of detailed empirical studies of computer supported cooperative work. For example, Linde (1988) 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 in the navigation of large vessels and Nardi and Miller (1990) have shown the collaborative aspects of working with computer spreadsheets in an office environment. However, despite the important contribution of such studies to our understanding of collaborative work, their implications for the design and development of technology, either for the setting in question, or CSCW in general, appear to be difficult to draw.

In this brief paper we wish to attempt to bridge the gap between the naturalistic analysis of collaborative work in a real world setting and the design of technology to support CSCW. In common with Suchman and Triggs (1989) study of communication in an airline terminal operations room, we aim to show how a sociological and naturalistic analysis of work practice and organisational conduct can inform the design of tools for CSCW. The paper examines the social organisation of collaborative work and task coordination within a Line Control Room on London Underground; a multimedia environment *par excellence.* It explores the ways in which the participants

surreptitiously monitor each other's conduct and systematically distribute information concerning changes to, and the current operation of, the service. Drawing on these observations, we discuss their implications for the development of distributed, intelligent' systems to support current work practices, as well as consider more general implications for tools to support cooperative work and the design process.

2. Methodological considerations

The investigation of cooperative work supported by complex technologies demands a rather different conceptual and methodological orientation than is 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 a interrelated orientation towards a collection of tasks and activities (cf. Hutchins 1989, Olson 1990, Olson and Olson 1991). And yet, even this relatively radical reconceptualisation of the relationship between the individual, his or her activity and the system, does not quite 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 sociology, with its history of field work and ethnography, coupled with the growing corpus of research concerned with contextual analysis of interactional organisation provide the methodological resources through which to begin to explore the situated and social character of collaborative work. Utilising audio and video recordings of 'naturally occurring' work and collaboration, augmented by field observation and

interviews, the process of coordinating multiple activities whilst utilising various tools and technologies, can be subject to detailed and systematic analysis. Drawing on this naturalistic framework, it is hoped that we will not only begin to generate findings concerning the socio-interactional organisation of collaborative work, but, in the long term, also provide a distinctive approach to user-centered design.[1]

3. The technology in the control room

Whilst drawing on materials from a number of Line Control Rooms on London Underground, we focus in particular on the Bakerloo Line. Its Line Control Room is currently undergoing extensive modernisation. For example, at the time of data collection, signalling was in the process of being computerised so that it could be monitored from the Line Control Room at Baker Street. 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. It is not unusual however to find a trainee DIA or Controller in the Control Room and a relief Controller when problems and crises emerge. Figure 1 shows the general layout of the Control Room.

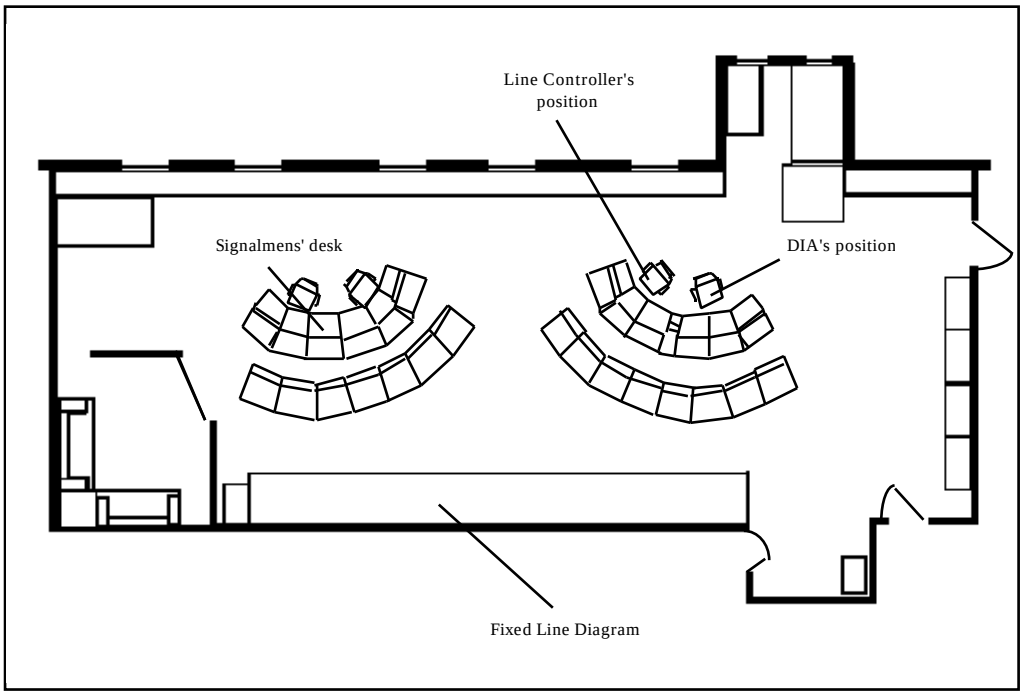

Figure 1: The Bakerloo Line Control Room

The Controller and DIA sit together at a semicircular console which faces a tiled, real time, *fixed line diagram* 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). On occasions a trainee DIA (tDIA) or a second Controller (Cii) 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 displays of the line. The Controller and DIA therefore use a range of tools not unlike the technologies being developed in CSCW, including: audio and video channels of communication, shared information displays, and various keypads and monitors.

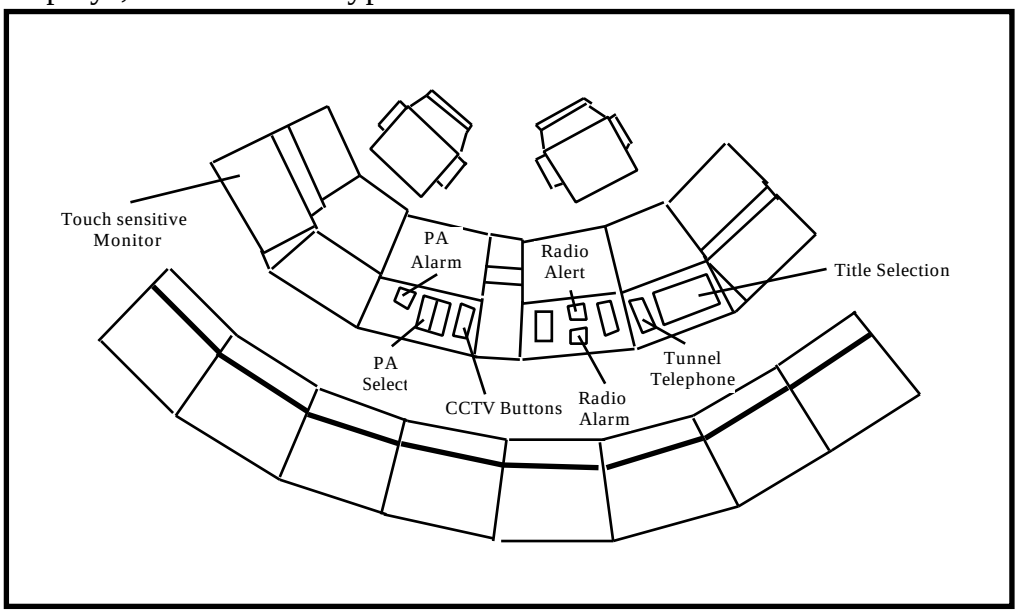

Figure 2: Line Controllers and DIAs Desk

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 various trains to cure gaps which are emerging between a number of trains during the operation of the service. More severe problems such as absentees, vehicle breakdowns or the discovery of 'suspect packages' on trains or platforms, 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 the relevant cellophane coated pages of the timetable both by the Controller and the DIA, and communicated to Operators (Drivers), Signalmen, Duty Crew Managers and others when necessary. It is critical that the DIA and others receive information concerning changes to the timetable, otherwise they will not only misunderstand the current operation of the service, but take the wrong courses of action.

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 a 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, implicitly, yet systematically coordinating their conduct. One element of this extraordinary interweaving of sequential and simultaneous responsibilities and tasks is an emergent and flexible division of labour which allows the personnel to lend support to the accomplishment of each others' tasks and activities and thereby manage difficulties and crises.

4. Surreptitious monitoring and interrelating tasks

It is relatively unusual for the Controller or the DIA to tell each other what tasks they are undertaking or explicitly to provide information concerning: the changes they have made to the service, the instructions they have provided to other personnel, or the announcements they have made to passengers. Indeed, given the demands on the Controller(s) and the DIA, especially when dealing with emergencies or difficulties, it would be impossible to abandon the tasks in which they were engaged explicitly to provide information to each other as to what they were doing and why. And yet it is essential that both Controller and DIA remain sensitive to each others conduct, not only to allow them to coordinate specific tasks and activities, but also enable them to gather the appropriate information to grasp the details of the current operation of the service.

Consider for example the work of the DIA**.** When problems emerge within the 'normal' operation of the service, the DIA presents

information to passengers and, if necessary, coordinates their travel arrangements with the schedule of particular trains. For example, on occasions a Controller will have to turn a train around before it has reached its anticipated destination. The DIA needs to provide information to passengers so that they leave the train at a particular station to enable the train to be reversed or stabled. More generally, unlike others forms of transport, rapid urban transport systems do not provide a timetable to the public. Instead, passengers organise their travel arrangements on the assumption that trains will pass through particular stations every few minutes. When such expectations are broken, or travellers are unable to change at certain stations, or have to leave a train because the line is blocked, then the DIA needs to provide information and advice. The nature of such announcements varies with the circumstances of, and reasons for their production. However, these public announcements do reveal 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 Southbound 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 the announcement is addressed to the general public, it achieves its performative force, its relevance, by virtue of its design for a specific category of passengers. In the case at hand, the information is only delivered to passengers who are waiting on a particular station and who will suffer a slight delay before the next train leaves the station. 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 carefully tailored announcements for particular categories of passengers who are using the service at some moment in time.

Returning to fragment 1, we enter the scene a little earlier as the Controller calls a driver.

Fragment 1 Transcript 2 (Abbreviated and simplified)

...Controller (C) calls Driver (D)...

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?

D: Two Four O Charing Cross South Bound

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

D: (( )) Over

C: Thank you very much Two Four O.

(5.2)

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

The announcement emerges in the light of the DIA overhearing the Controller's conversation with the driver and assessing its implications for the expectations and experience of travellers using the service. He transforms the Controllers request into a relevant announcement by determining who the decision will effect and its consequences. In this case, this is particularly the passengers at Charing Cross whose train is delayed as a consequence of a problem emerging on the Southbound service. The DIA, a little later, produces a second announcement (not included in the above transcript) to warn passengers who have more recently arrived on the platform that their train is being delayed.

The DIA does not wait until the completion of the Controller's call before preparing to take action. Indeed, in many cases, it is critical that announcements are delivered to passengers as Controllers are making adjustments 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 fixed line diagram, provides resources through which the DIA can make sense of the Controller's actions and draw the necessary inferences. At the onset of the call he scans the fixed line diagram to search for an explanation, or provide an account for, why the Controller is contacting a driver and potentially intervening in the running of the service. By the Controllers second attempt to contact the driver, the DIA is moving into a position at the console where he will be able to reach the operating panel for the Public Address system and if necessary make an announcement. On the word "couple", at which point he can infer the potential delay that passengers might incur, he grabs the microphone and headset in preparation for the announcement. In consequence, even before the Controller's call to the driver is brought to completion, the DIA has set the Public Address system to speak to the passengers on a particular platform and is ready to deliver the announcement.


The fixed line diagram and the station monitors, provide an invaluable resource for the DIA in producing an account for his colleagues interventions in the running of the service. In particular, the common availability of various sources of information in the Line Control Room, allows the DIA to assume, that the current problems in the operation of the service noticed by the Controller are similarly available to the DIA if he scans the various displays. The DIA's *looking* is motivated and driven by virtue of the Controller's attempt to call a driver, and the DIA scans the fixed line diagram in order to provide an account for the upcoming intervention. Moreover, the DIA, is not only able to overhear the Controller, and assume that they have mutual access to the same information displays, but is also able to discern, through peripherally monitoring the actions of his colleague, where the Controller might be looking and what he might have seen. The various information displays, and their use by particular individuals, is publicly visible and can be used as a resource in determining courses of action and for the mutual coordination of conduct.

Despite the necessity to monitor closely the conduct of the Controller, the DIA maintains a certain 'social distance' providing his colleague with what Hughes (1956) characterises as the 'elbow room with which to fulfil his particular responsibilities'. More precisely, as the DIA begins to track the call to the driver and prepare to make an announcement, he neither looks at the Controller nor watches the activity of his colleague. Moreover, as he changes positions and moves closer to the Controller, he avoids making his own activity visible or noticeable to his colleague; rather the actions appear to be accomplished independently of the call to the driver, as if the DIA is engaged in some unrelated business. Through his bodily comportment and the ways in which he warily accomplishes his actions, the DIA preserves a careful balance of involvement, overhearing the Controller and monitoring his colleague's actions on the periphery of the visual field, whilst avoiding overt attention to the Controller's conduct.

Certain phrases or even single words addressed by the Controller to a driver or signalman on the telephone are often enough for the

DIA to draw particular inferences and undertake relevant action. For example in fragment 1, the request to "take a couple of minutes" allows the DIA to infer that the Controller is attempting to reduce an interval in the Southbound service, a problem that he is unlikely to have noticed until the Controller called the driver. The DIA overhears the call, develops an account for intervention and assesses its implications for his own conduct. In the following instance, the DIA, who is apparently engrossed in updating his own timetable, suddenly grabs the phone and calls the Station Manager at Piccadilly Circus on hearing the word reverse.

Fragment 2 (Abbreviated and simplified)

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

D: 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?

...the call continues. 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.

...roughly 3 minutes later following a discussion with the Station Manager.

DIA: Good morning Ladies and Gentlemen, (.) Bakerloo Line Information, (1.0) this train is for Piccadilly Circus only. (1.2) This train for Piccadilly Circus only.

Even before the Controller has finished speaking to the Driver, the DIA has called the Station Manager at Piccadilly and warned him that the 233 is to be 'detrained'. On completing the call, the DIA then produces a series of public announcements on each southbound platform before Piccadilly. As the 233 arrives he warns the passengers that this train is for Piccadilly only. By surreptitiously monitoring the conduct of the Controller, whilst engaged in unrelated and independent action, the DIA is able to discriminate the local environment of activity and assess the implications of certain activities for his own conduct. In the case at hand, by overhearing the word "reverse" and gathering the relevant details, the DIA coordinates the action of station staff and passengers with the moment by moment changes made by the Controller to the timetabled service.

It is not simply that DIAs happen to remain attentive to the local environment of activity and are able to draw the necessary inferences from the actions of their colleagues. Rather, personnel within the Control Room organise their conduct so that whilst engaged in one activity, they simultaneously monitor the conduct of others. This double-edged element of performing tasks, is an essential feature of collaborative work within the Line Control Rooms, demanding that

participants design their activities so that whilst undertaking one task they remain sensitive to the relatively independent actions of their colleague(s). Producing an activity whilst simultaneously participating in the activities of another, has implications for the ways in which personnel utilise the various tools and technologies within the Line Control Room. So, for example, the DIA may switch his CCTV monitor to a particular platform to enable him to read a number from the front of a train to tell the Controller, even though he is engaged in delivering a public announcement and happened to overhear that problems concerning the the identity of particular trains are emerging. Or, as another example, it is not unusual to find the Controller or DIA switching the telephone handset to the other ear, to enable them to overhear a conversation concerning a new problem emerging in the service. DIAs are provided with headsets with which to make announcements, but it is relatively unusual to see them used 'properly'. Rather, DIAs hold one side of the headset to one ear, allowing them to simultaneously monitor the actions of their colleagues, while delivering announcements to passengers. Almost all tasks within the Line Control Room are produced as the DIA or Controller simultaneously participates, in a variety of different ways, in the concurrent activities of his colleague(s). The various tools and technologies which are provided to support these tasks, are shaped, corrupted, even abandoned, to enable Control Room personnel to engage simultaneously in activities whilst monitoring the conduct of their colleagues.

It is widely recognised amongst Line Management on London Underground that many of the skills used by Controllers and DIAs cannot be formally taught, and that working as an apprentice within the Control Room itself, is an essential part of training. The Control Room serves as a testbed for new recruits, with a large percentage of trainees failing to make the grade. Whilst a whole array of factors undoubtedly contribute to the relative difficulty that new recruits find in working in the Control Rooms, it is apparent that learning to perform complex individual tasks, whilst simultaneously participating in, and overseeing, the activities of colleagues, proves particularly difficult for the uninitiated. Indeed, it is interesting to observe how the more senior Controllers and DIAs who act as trainers, place great emphasis on the importance of not simply working with colleagues as a team, but coordinating the production of tasks with colleagues both within and outside the Control Room (cf. BBC1 1991). Trainees, whether DIA or Controller do, of course, have to learn a complex configuration of formal rules, procedures and practices before entering the Control Room, but these are widely regarded as the 'tip of the iceberg'; it is the tacit, unexplicated body of indigenous skills and practices which are part and parcel of working as a Controller or DIA. In the early days of an apprenticeship, the trainer will repeatedly try and encourage a trainee to monitor continually the surrounding

domain of action. Consider the following example where the trainee is asked by the DIA whether he overheard an incoming call to the Controller concerning a fire on the track.

Fragment 3 (Abbreviated and simplified)

...Driver (D) calls the Controller (C) ...

C: Two Three Three pass your message

D: (There's) smouldering on the track on the Southbound

...As C elicits the details, DIA turns to the Trainee DIA (tDIA) and asks...

DIA: Do you hear that? Do you get that?

tDIA: What was it?

.....they go on to discuss the incident the way its managed by the Controller and how the DIA might assist...

5. Rendering activities visible

Whilst relying on each other mutually to monitor their conduct and to draw the 'relevant' inferences, even when they are engaged in a distinct activity, the DIA and Controller employ various devices to keep each other informed of changes to the operation of the service. Activities such as telephone conversations with personnel outside the room, tracking a particular train with the CCTV, or discussions with Line Management concerning the state of the service, are, at least in part, publicly visible within the local milieu, and ordinarily the bits and pieces available can be used to draw the relevant inferences. Other sorts of activities, such as reading the timetable or entering the details of incidents on the various logs are less visible, the details of the activity may not be available to a co-participant who is even seated to one side. Perhaps the most critical activity within the Line Control Room which is not necessarily available to the DIA or relief Controller, is rewriting the timetable; a process known as 'reforming' the service. Almost all problems which arise in the operation of the service necessitate 'reformations', where the Controller, actually within the developing course of an event, reschedules particular trains, their crews, and even their destination, so as to maintain, for the practical purposes at hand, a relatively even distribution of traffic along the line. It is essential that both colleagues within the Line Control Room, and personnel outside such as Duty Crew Managers, drivers and even Station Managers, are aware of these changes. Otherwise, these staff will not only fail to enact a range of necessary tasks, but will misunderstand the state of the service and make the wrong decisions. Reforming the service however, is an extremely complex task, which is often undertaken during emergencies, and it is not unusual for the Controller to have little time explicitly to keep his relevant colleagues informed.

One solution to this potential difficulty is to render features of their individual reasoning and actions 'publicly' visible by talking though the reformations whilst they are being accomplished. The Controllers talk 'out loud', but this talk is not specifically directed towards a colleague within the Control Room. Rather, by continuing to look at, and sketch changes on the timetable, whilst producing talk which is often addressed to oneself, the Controller precludes establishing a 'recipient' and the interactional consequences it would entail. Talking through the timetable, whilst rendering 'private' activities publicly visible, avoids establishing mutual engagement with colleagues which would undermine the ongoing accomplishment of the task in question. Consider the following fragment in which the Controller finishes one reformation and then begins another.

Fragment 4 (Abbreviated and simplified)

*...C **reads** his timetable...*

C: It's ten seventeen to ( ) hhhhhhh

(4.3)

C: Right (.) that's that one done.

C: hhh hhh (.) hhh

C: Two O Six (.) Forty Six

(0.7)

C: Two Two Five

...the DIA begins to tap on his chair and he and the trainee begin a separate conversation. As they begin to talk C ceases talking out loud...

Whilst looking at the timetable, the Controller announces the completion of one reformation and begins another. The Controller talks numbers, train numbers, and lists the various changes that he could make to the 206 to deal with the problems he is facing, namely reform the train to 246 or to 225. As the Controller mentions the second possibility, the DIA begins to tap the side of his chair, and a moment or so later, discusses the current problems and their possible solutions with a trainee DIA who is sitting by the DIAs side. As soon as the DIA begins to tap his chair and display, perhaps, that he is no longer attentive to his colleague's actions, the Controller, whilst continuing to sketch possible changes on the timetable, ceases to talk out loud. Despite therefore, the Controllers apparent sole commitment to dealing with specific changes to the service, he is sensitive to the conduct of his colleague, designing the activity so that, at least initially, it is available to the DIA and then transforming the way the task is being accomplished so that it ceases to be 'publicly' accessible.

Whilst 'self talk' may primarily be concerned with providing co-present colleagues with the necessary details of changes made by the Controller to the running order of the service, it is interesting to observe that a great deal more information is made available in this way than simply the actual reformations. As in fragment 4, talking to oneself whilst engaged in a potentially 'private' activity, seems designed to accomplish more than simply providing the facts of the matter. Rather, the Controller renders visible to his colleagues the course of reasoning involved in making particular changes. The natural history of a decision, the Controller's reasoning through various alternative courses of action, are rendered visible within the local milieu, and provides colleagues with the resources through which they can assess the grounds for and consequences of 'this particular decision' in the light of possible alternatives. While the Controller is talking out loud, it is not unusual to find the the DIA following the course of reasoning by looking at his own timetable, and where necessary sketching in the various changes which are made. In this way, DIA and Controller, and if present, trainees and reliefs, assemble the resources for comprehending and managing the service, and preserve a mutually compatible orientation to the 'here and now', and the operation of the service on some particular day. The information provided through the various tools and technologies, including the CCTV monitors, the fixed line diagram, and information displays, is intelligible and reliable by virtue of this collaborative activity.

On occasions, it may be 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 fixed line diagram, the Controller will swear, feign momentary illness or even sing a couple of bars of 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(s) towards a particular event or activity, are carefully designed to encourage a particular form of co-participation from a colleague, but rarely demand the other's attention. They allow the individual to continue with an activity in which they might be engaged, whilst simultaneously inviting them to carefully monitor a concurrent event. Or, even where it is necessary to gain the explicit attention of the other, the various objects are rarely designed to interrupt the tasks in which he might be engaged. For example, in the following fragment, the Controller puts down the receiver and utters "Shit".

Fragment 5 (Abbreviated and simplified)

...Ci receives a call from the Duty Crew Manager...

Ci: Okay ta.

...finishes call and replaces receiver...

Ci: Shit

...the DIA turns towards the Controller...

Ci: How the hell did I miss that one.

DIA: What the car was (examined)?

Ci: no (.) Two O Seven

(2.3)

DIA: Two O Seven (.) (I can't find it)

Ci: I wrote it there, that's 'cos I turned over the page.

...the relief Controller (Cii) enters the room...

Cii: Have I walked in at the wrong time?

Ci: No no there's no problem.

....the Controllers go on to discuss the difficulty and its consequences...

The Controller's exclamation is directed towards his timetable; it serves to encourage rather than demand the DIA's attention, and indeed, finding the DIA slowly looking up, the Controller produces a complaint to himself. Only then, does the DIA elicit some further information and engage the participants to look for and discuss the train that has been omitted during a previous spate of reformations. The Controller not only draws the DIA and subsequently the Relief Controller into a discussion about the problem, but also implicitly draws their attention to the unforeseen consequences of earlier changes to the timetable.

The materials at hand cast some light on the ways in which we might begin to reconsider the organisation of individual work tasks and their relationship to the actions of others. Within the Line Control Room different personnel have particular responsibilities and tasks to perform, which though interrelated, involve a specific individual utilising a body of skills to accomplish a specialised activity, such as reformation. However, it is clear that whilst certain activities are primarily accomplished by specific categories of individuals, the *in situ* accomplishment of these tasks is sensitive to, and coordinated with, the actions and responsibilities of colleagues within the immediate environment. The competent production of a range of specialised individual tasks within the Control Room is thoroughly embedded in, and inseparable from, a range socio-interactional demands. Indeed, even the production of potentially private activities such as reading

and writing are systematically tailored with respect to the current and potentially relevant actions of colleagues.

One way of conceptualising the socio-interactional organisation of task based activities is to draw on Goffman's (1981) discussion of participation framework. Goffman suggests that any activity is dependant upon a particular production format which establishes, or attempts to establish, the ways in which 'those within the perceptual range' will participate in an event. In the materials at hand, we begin to discern how the design of particular activities may be simultaneously sensitive to the potential demands of different 'recipients' both within and beyond the local physical environment. So, for example, whilst speaking to a signalman on the telephone to ask whether he has corrected the running order of a couple of 'out of turn' trains, the Controller not only coordinates his talk with his co-conversationalist, but simultaneously emphasises, by volume and repetition of certain elements, details to the DIA. The Controllers actions are designed simultaneously to implicate different forms of co-participation from specific colleagues; one or more who is co-present and one, the 'primary recipient' who is on the other end of the telephone. In Goffman's terms, the production format of the activity is sensitive to multiple, simultaneous demands on the Controller, and implicates different forms of co-participation from all those who are within perceptual range of the event. The same activity is produced to organise a form of participation from co-present and physically distributed colleagues; the activity and the participation framework it generates, merge, momentarily, different ecologies within the organisational milieu.

6. Overseeing the local environment of events and activities

The Controller and the DIA have very distinct responsibilities in the overall management of the service and in the provision of information to staff and passengers. Despite their distinct obligations and skills, the Controller and DIA not only monitor each other's activities to gather relevant information with which to coordinate their own conduct, but keep a 'lookout' for their colleagues, monitoring the environment for actions and events which may have passed unnoticed but be relevant to the conduct of the other. This may require of course, that the Controller or DIA explicitly draw his colleagues attention to the event. For example, we join the following fragment during an emergency at Baker Street Station, where passengers have been evacuated and drivers told not to stop. As the DIA provides information to passengers at various stations on the Bakerloo Line, the Controller receives a call from the Station Manager giving the 'all clear'.

Fragment 6 (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 Hammersmith an City and Circle Line and Metropolitan 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 ...

Whilst the DIA is warning passengers that the trains are not stopping at Baker Street the Controller receives information which contradicts the announcement. The Controller does not interrupt the DIA within the delivery of the announcement, but as the DIA completes the first delivery of the information, the Controller snaps his fingers and warns his colleagues of the 'all clear'. The trainee DIA responds and calls the Station Managers at other locations along the Bakerloo Line to inform them of the news. The DIA, whilst appearing insensitive to the 'all clear', restarts the announcement to inform passengers that trains are now stopping at Baker Street. Even here however, where we find the Controller explicitly informing the DIA of changes within the provision of the service which are of immediate relevance to the activity at hand, there is evidence to suggest that the DIA is aware of Baker Street reopening before it is announced. Inspection of the first part of the announcement reveals that the Bakerloo Line, which is the main responsibility for the DIA, is omitted. It appears that as the Controller answers the call the DIA infers what is happening and redesigns the announcement within the course of its articulation.

The flow of information and the responsibility to oversee the environment for the other is not simply one-way. Just as the Controller assumes responsibility for keeping his colleague informed of events which may otherwise pass unnoticed, so the DIA will monitor the operation of the service and draw his colleagues attention to any events or problems which may have been missed. Consider the following instance. The Controller finishes a conversation on the telephone, and as he replaces the receiver, the DIA successively glances

in the direction of Baker Street Station on the fixed line diagram and the Southbound platform of the station on the CCTV monitor. The successive glances between the two domains, appear to be designed to have the Controller discover, independently of being told by the DIA, that something is amiss at Baker Street. The DIA's visual conduct passes unnoticed, and the Controller turns and reads the timetable on the console in front of him. As the Controller, begins to read the timetable, the DIA, realising that the Controller has failed to notice the potential problem, delicately draws his attention to it.

Fragment 7 (Abbreviated and simplified)

...The Controller (C) puts phone down...

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

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

...The telephone rings, C 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...

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

...C finds that the driver is not waiting for a relief but remaining in the station due to a red signal...

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

...C finishes the call and rings the signalman at Piccadilly to find out why the signal is being held...

C: No no no it's nothing 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 is just now leaving Baker 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 telephone calls unrelated to the difficulty that the DIA has noticed. During these calls the DIA begins, once again, successively to glance between Baker Street on the fixed line diagram and the platform on the CCTV monitor. The DIA's actions appear to be designed to display to the Controller, as he is dealing with the incoming calls, that the difficulty at Baker Street continues to require his immediate attention. In fact, the traffic is already beginning to build back up the line as a train, for some yet to be discovered reason, sits in the platform. As soon as the Controller finishes the second conversation and begins to call the driver, the DIA abandons

his almost theatrical attempts to display the increasing urgency of the problem and returns to the activity in which he was engaged before he noticed the difficulty with the Southbound service.

The personnel within the Control Room therefore not only design their conduct so that, if necessary, elements are publicly visible within the local milieu, but systematically monitor each other's actions and the operation of the service, so that they can inform their colleagues of any relevant, but potentially unnoticed, problems. The DIA and the Controller not only 'oversee' each other's actions, but monitor various events both for themselves and for the other(s); drawing, where necessary a colleague's attention to some 'matter at hand'. In mutually monitoring each others conduct and the operation of the service, and initiating remedial action, it is interesting to note how the personnel orientate to, and preserve, a division of labour and certain asymmetries in their relationship. For example, in fragment 7, whilst the DIA has undoubtedly noticed a problem of growing severity at Baker Street, he does not ask the Controller to deal with it or even explicitly point out the problem. Rather, the DIA organises his conduct so as to encourage the Controller to notice the problem for himself, and in some way manage the difficulties at hand. In part, the delicacy of the DIA's conduct may be sensitive to pointing out to the Controller something he should have noticed and be dealing with; of rendering the Controller's conduct accountable simply by virtue of informing him of a particular difficulty. Despite therefore, the very close collaboration between personnel within the Control Room, and their commitment to preserving a mutually compatible orientation to, and sense of, the current service and their own actions and activities, Controller and DIA, even under quite difficult circumstances, systematically preserve the occupational and territorial rights and responsibilities of their colleagues.

7. Shaping tasks and coordinating activities

The continual flow of information between the Controller and DIA and their ability to monitor, and if necessary correct, each others' actions, are an essential feature of work in the Control Room. The constant updating of information, coupled with the ability and responsibility to make it publicly available within the local milieu, provides the Controller and the DIA with resources with which to make sense of the operation of the service. Without knowledge of the current 'state of play', the timing and movement of vehicles at this moment at time, the development of the service and any difficulties on this particular day, the Controller and DIA would be liable to draw the wrong inferences from the various sources of data available to them. There would be a risk that the wrong decisions would be taken and misleading information would be provided to both staff and passengers. The intelligibility of the scene, the possibility of

coordinating tasks and activities, rests upon these socially organised and communicative practices.

An important feature of these practices are the ways in which the accomplishment of specific tasks and responsibilities, even those which appear individual and private, are interactionally organised. Indeed, the framework of collaboration between personnel within the Control Room enables an exploration of issues of growing importance within research on human-computer interaction, namely the ways in which the accomplishment of individual work is embedded within social interaction. Earlier, it was suggested that the production of various tasks within the Control Room, by either Controller or DIA, are not only informed by 'occupational' procedures, but at the same time are designed to display aspects of the gist of the activity for others who may be co-present. The task is not simply interactionally organised and coordinated with a client or colleague, almost all occupational activities are; rather, the task involves fulfilling simultaneous, but distinct, obligations to differentially positioned colleagues or 'recipients'. To put it another way, the Controller or the DIA is not simply obliged to fulfil the tasks, but rather to make them visibly available to others who are not directly involved. In consequence, the articulation of even the most apparently 'private' activities within the Control Room are sensitive to the responsibilities and conduct of colleagues.

Collaborative activity within the Line Control Room also rests upon the ways in which personnel shape their participation with, and are encouraged to participate in, the activities of their colleagues. Practices which successfully 'divide their attention' and provide information to each other, are not simply small additions to the formal procedures which underlie their various occupational tasks. Rather, they are an essential feature of work in the Control Room and the 'occupational culture', without which personnel would be unable to accomplish their individual responsibilities and tasks, or coordinate their activities with each other. The fulfilment of the complex configuration of tasks and activities within the Line Control Room rests upon, and is inseparable from, a socio-interactional organisation which provides for their systematic and situational accomplishment.

The usefulness of the hard line display, the CCTV system, and the accompanying tools, relies upon a collection of tacit practices and procedures 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 information presented by the various technologies would be mistaken. 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 movements, running times and changes to the timetable.

For example, the fixed line diagram displays the position of trains on the Bakerloo Line between Queens Park and the Elephant and Castle. Each train appears as a strip of between two and six lights depending on how many sections of track the train is covering at a particular moment. At any time between 6.30 am and 10.00 pm there are likely to be between 15 and 25 trains indicated on the board. The diagram provides staff within the Control Room and of course visitors, such as management, with the ability to make, at a glance, an initial assessment of the current operation of the service. An even distribution of trains (lights) along the board, with relatively few gaps between the vehicles, both South and North, tends to indicate that the service is running according to plan, i.e. the timetable. Yet, as any Controller knows, such an even distribution of vehicles along the line can conceal important problems which may later lead to difficulties, whether in a few minutes or even a few hours. The fixed line diagram does not tell which particular train is where, or whether the trains are in or out of turn. Neither does not provide information concerning an upcoming shortage of drivers, vehicles which are causing difficulties, stations which are closed 'due to a London Fire Brigade investigation' nor reveal any of the complex body of reformations which may have already been undertaken and which may lead to difficulties later in the day. In short, the fixed line diagram and the information it provides is a critical resource in control and crisis management, but only in the light of the natural history of the operation of the service on any particular day. Without knowledge of reformations, out of turns, vehicle problems, station closures, that is the incidents which have occurred and the ways in which they were managed, the technology is largely redundant. The socio-interactional organisation of individual tasks and activities within the Line Control Room, and the ways in which information is continually distributed between personnel, provides for the very possibility of using the tools and technologies at hand.

In the light of the practices which provide for the continual updating and exchange of information regarding the current state of the service, the technology provides the Controller and DIA with the ability to assess the current operation of traffic, and undertake, if necessary, remedial action or provide information to staff and passengers. The 'public' availability of the technology within the Control Room, whether it is a fixed line diagram, a CCTV screen, a screen-based line diagram or an information display, and the visibility of its use, provide critical resources in the collaboration between Controller and DIA. For example, the DIA and Controller are able to assume that they have equivalent access to the different technological sources of information and that, in principle, observations concerning the current operation of the service are mutually available. More

importantly perhaps, the DIA and Controller can use the common sources of information as a reliable means of accounting for a broad range of actions and tasks undertaken by the other. So, for example, in fragment 1 we noted how the DIA turned to the fixed line diagram as a potential source of explanation for the Controller's intervention. Moreover, their use of the fixed line diagram and the surrounding monitors of the console is publicly visible, and can be used to determine a particular activity in which the DIA or Controller is engaged, or, as in fragment 7, to display a potential problem which is emerging within the operation of the service. The mutual availability of the various information displays, and the visibility of their use, are important resources for making sense of the actions of a colleague and developing a coordinated response to a particular incident or problem. The technology provides a keystone to the collaboration within the Control Room, not only as a source of interrelated bodies of information, but critically as a medium through which particular activities become visible or publicly available within the local ecology.

In exploring the organisation of a work environment such as the Line Control Room, it becomes increasingly difficult to delineate the 'individual' and the 'collaborative'. The different personnel within the Control Room clearly have distinct responsibilities, areas of jurisdiction, and specialised tasks which are strictly not undertaken by members of the other occupational categories. Some of these tasks, such as reformations or public announcements involve highly specialised skills and competences and are undertaken by a single individual producing successive interrelated actions. It is also clear that these individual tasks are coordinated with the activities of others. Indeed, a critical feature of the indigenous organisation of conduct within the Control Room is the participants' orientation to sequential relationships between individual activities. So, for example in fragment 1, it is possible to see the way in which the Controllers intervention engendered a public announcement by the DIA. An announcement, if it is was not forthcoming, might well have been treated as 'noticeably' absent by the Controller. Whilst these indigenous sequential relationships between particular activities undertaken by different personnel reveal the ways in which particular actions are coordinated, they still preserve a sense of the individual and the collaborative.

Turning to the ways in which individual tasks are accomplished within the Line Control Room, the border between the individual and the collaborative becomes increasingly unclear. The Controller and the DIA produce particular activities, even relatively complex tasks, with respect to the responsibilities and concurrent conduct of their colleague(s), tailoring their actions so that they preserve a mutually coordinated response to particular incidents and events. Moreover,

whilst engaged in one activity, we find the Controller and DIA monitoring each other's conduct and able to discriminate the local environment with regard to contingencies which may be relevant to either their own conduct or the actions of their colleagues. Work within the Line Control Room does not simply necessitate that the participants distribute information and maintain a compatible orientation to the current scene. Rather, it requires that even the most apparently individual tasks are 'ongoingly' accomplished, moment by moment, with regard to the conduct and responsibilities of the co-participants. This may involve mutually focussed interaction between Control Room personnel, but in large part it requires Controller and DIA to engage in distinct tasks and activities, whilst simultaneously participating, if only by overhearing, the conduct of their colleague(s). The activities of personnel within the Line Control Room continually flow between the private and the public, between the individual and the collaborative, so that distinctions which demarcate particular forms of cooperative work become increasingly problematic.

8. The design of tools to support collaborative work

The analysis of work practice and collaboration within the Line Control Room raises a number of implications for the design and redesign of current technologies within the setting, but also it suggests some wider issues. Indeed, as suggested elsewhere, for example in Rasmussen (1989) and Rasmussen et al. (1990), we can see the ways in which field work and ethnography could provide a useful methodological framework for generating observations concerning work practice and technological support.

One straightforward way in which the above observations can inform design is in assessing the usefulness of proposed modifications to the technologies in the Control Rooms of London Underground. For example, it has been suggested that in the redesign of another Control Room, personnel should have individual graphic displays of the line rather than a large fixed line diagram. From the observations above, such a modification would appear to undermine the co-participation of staff in a range of activities which are currently a critical part of crisis management. For instance, with such systems, individuals may have difficulties ascertaining the orientation of colleagues to particular activities and events.[2]

Analysis of the details of the work practices in the Control Room could also inform the design of systems that would be sensitive to those practices. It was noted earlier that the timetable is critical resource for identifying problems and maintaining the service on the line. In part, the organisational culture in the Control Room is designed to render visible changes made to the timetable, undertaken individually by the Line Controller to colleagues both inside and outside the immediate setting. DIAs, Signal Assistants, Duty Crew

Managers and other personnel, will often sketch in the alterations to their own timetables when they learn about changes made by the Controller. However, despite the apparent robustness of the practices that Control Room personnel rely upon to support this continual distribution of information amongst colleagues, it is possible to observe certain difficulties emerging in the setting. For example, with the introduction of Signal Assistants, further pressure is placed on mutual, informal monitoring. As the number of personnel within the Control Room has increased, the problem of informing colleagues of changes to the timetable becomes more severe.

Drawing on observations made by the study of Control Rooms, a system has being proposed, in collaboration with staff at the London Underground, that aims to facilitate the distribution of information about changes to the timetable. The initial 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 exchanged between Controller, DIA and others concerning the moment by moment changes to the schedule. As noted earlier, the various changes undertaken by the Controller are rarely told explicitly to the DIA, or to others, rather colleagues pick up the changes being made. They then sketch in these adjustments and reformations onto their own timetables. The systems design is intended to support both the tasks related to the timetable and the necessary indirect communication which occurs within the Control Room.

One approach to the design of the interface to the system would be to implement the system utilising screens and electronic pens. The system would consist of a screen which presents pages of the timetable with running times alongside scheduled times. Changing the timetable would be done in a similar way to marking a document. However, as with other distributed CSCW systems these changes could immediately be made available to colleagues in the Control Room in just the way in which they were drawn. This provisional design of the system therefore, is not only sensitive to the conventional uses of the paper document, but also to 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.

Later extensions to the system would allow for further distribution of information outside the Control Room, communicating timetable changes, in appropriate forms, to staff such as Duty Crew Managers in different locales. From the changes and decisions made by Line Controllers, it may also be possible to elicit a set of conventional and candidate solutions to specific problems faced in the operation of the service. These may then be utilised so that the system could be developed to allow Controllers to test the consequences of candidate

reformations before they are confirmed. It is important that these later extensions to the system would still be informed by detailed analysis of the work practices. The aim of the system is not simply to provide support for complex changes to the timetable, but more to support the systematic, yet informal practices, through which information is exchanged between staff.

The examination of work practices and task coordination in the Line Control Room may also suggest some more general considerations for designers of CSCW systems. For distributed systems that allow users to have both individual and shared work areas, one problem faced by designers is how to allow users to move easily between the two types of work, how to make the transition from individual work to collaborative work appear seamless (Ishii 1990). The study of work in the Line Control Room suggests that this problem may be more complex. Unlike the timetables, the fixed line display could be considered as a shared resource. In order for a DIA to oversee the Controllers look at the fixed line diagram, the diagram has to be available to both participants. More importantly however, the Controllers activity in relation to the diagram has to be available to a co-participant, the activity has to be public. Thus, to facilitate individuals mutually to monitor their co-participants, technologies would have to support a seamlessness between public and private activities.

The public nature of the uses of artifacts and technology may not be peculiar to London Underground Control Rooms. Harper and Hughes (forthcoming) mention how controllers and other individuals can see the state of the skies from a glance at the air flight strips, and Goodwin and Goodwin (forthcoming) reveal the ways that looking at monitors is embedded in the organisational environment in the control room of an airport.[3] Thus, technologies to support collaborative work may have to be designed in relation to the public, as well as the shared nature of activities. For example, it may be possible to enhance certain aspects of the private work on a conventional computer system to provide public resources for other individuals in the environment.[4] However, a more radical development may be possible, utilising technological developments that move away from the dependency on screen-based systems to support computational activities.

Such technological developments are being undertaken at Xerox PARC, Rank Xerox EuroPARC and other research laboratories, developments that have been collectively termed ubiquitous computing (Weiser 1991). They include systems which allow users to manipulate both screen objects and paper documents on work surfaces. These systems integrate video projections of screen displays, camera views of desks and locational information generated by digital tablets (Tang and Minneman 1991, Wellner 1991, Newman and

Wellner 1992, Ishii and Kobayashi 1992). For example, DigitalDesk (Wellner 1991, Newman and Wellner 1992), enables users to place paper documents on a desk from which a camera can read items. Meanwhile a projector displays a screen image back onto the table. On such a system it is possible to engage in work on documents and screen objects, preserving the advantages of each. Thus, alternatives could be envisaged to systems utilising the screens and electronic pens mentioned above. In addition, by allowing for the use of paper documents such systems are the beginnings of a technology that allow for both private and public work as well as flexible movement between the two. These systems enable users to monitor the orientations of their co-participants in relation to the activity at hand and thus they provide a resource for supporting the 'public nature' of activities. By providing large flat working surfaces digital desks could be utilised to support co-present, collaborative work. Related developments are also underway that may facilitate distributed working (Tang and Minneman 1991, Ishii and Kobayashi 1992).

Studies of technologically mediated collaboration in the work place may reveal other generic issues relating to CSCW system design. For example, revealing the social and interactive nature of what has been traditionally considered as individual tasks such as reading, writing or typing has implications for the design of systems to support collaborative work.[5]

If detailed analysis of collaborative work and the use of various tools and technologies can provide insights for system design, then it may be possible to consider methodological frameworks to facilitate this process. As yet the character of such a methodology is unclear. However, it may be in the form of a collection of practices, including the repeated analysis of fragments of materials of recorded activities in their work setting: a so-called ‘structured ethnography’. The sequential relationships of activities may provide the foundation for such a distinctive approach to user-centered design, an approach that emphasises the tacit practices utilised by personnel to accomplish particular actions and activities and to coordinate their work with others.

Indeed, given the socio-organisational foundations to work and situated practice, and the strong commitment to field work and case analysis in the discipline, it would only seem appropriate that sociology should become increasingly involved in the design and development of tools and technologies. It appears that recent developments in the social sciences may be relevant for the evaluation of prototypes and current systems or for identifying tools to support tasks and interaction for more innovative technologies. In designing collaborative tools based upon an understanding of current work practices, it may be possible to avoid some of the pitfalls which

frequently arise in the introduction of 'inappropriate' systems into real-world environments.

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Notes

[1] The investigation of the Line Control Rooms on London Underground is one a number of interrelated case studies concerned with Work, Interaction and Technology currently being undertaken by the authors and David Greatbatch in close collaboration with Cambridge EuroPARC.

[2] Preliminary observations of a control room with individualised line displays suggest that the work of the equivalents of Controllers and DIAs has become more localised (Luff and Heath 1991).

[3] Obviously, there are public aspects to the uses of technology in domains other than control rooms. For preliminary observations on work and interactional practices in medical consultations and in an architecture practice, see Greatbatch et al. (1992) see Luff and Heath (forthcoming) respectively.

[4] For example, Gaver (1986, 1991) suggests the uses of sounds to support both individual and collaborative work.

[5] See Luff et al. (1992) for some related issues deriving from studies of interactional and work practices.