Codifying Distributed Cognition:
A Case Study of Emergency Medical Dispatch

Dominic John Furniss

Project report submitted in part fulfilment of the requirements for the degree of Masters of Science (Human-Computer Interaction with Ergonomics) in the Faculty of Life Sciences, University College London, 2004.

Acknowledgements

Special thanks go to my supervisor, Dr Ann Blandford, who has provided me with valuable guidance and advice throughout my project and who was instrumental in providing me with access to the data used in the project: both in using video recordings she had previously made and in contacting the London Ambulance Service.

Special thanks also go to Avril Hardy and Steve Sale for allowing me the opportunity to visit and study the London Ambulance Service Central Ambulance Control Room first hand. The staff that I met during my visits were always forthcoming, friendly and helpful despite the busy and stressful nature of the work, which made my visits productive and more enjoyable than I had envisaged they would be.

Abstract

The theory of distributed cognition is recognised as being relevant to system analysis and design but it has lacked visibility for practice. In this paper I develop a codified method of analysis based on distributed cognition which provides both structure and guidance in the use of the theory. The method developed comprises a systematic exploration and description of three functional levels of a system, namely, the information flow model, physical model, and artefact model. These levels are analytically separate but integrate in modelling the propagation and transformation of information within a system. The approach to developing this method has been exploratory and iterative: developing the understanding of distributed cognition and contextual study literature, with practical application to the London Ambulance Service Central Ambulance Control room context. The application of the method to this context reveals a number of design issues and concerns lending support to its use in these situations. Furthermore, this paper introduces a conception of how distributed cognition can be used to deliberate about potential design scenarios, which is a use of distributed cognition that has been alluded to but has not been explained elsewhere. This paper makes progress in narrowing the gap between distributed cognition theory and practice by adding guidance through a structured codified methodology. The method provides an accessible, practical approach to analysing team based systems using distributed cognition.

Table of Contents

Table of Tables

Table of Figures

General Introduction

The aim of this paper is to develop a codified approach for the application of distributed cognition (DC) theory to analyse a multi-agent environment. The context that is being used to develop this application is the London Ambulance Service (LAS) Central Ambulance Control (CAC) room. It is important to have a suitable context to aid the development of the method so that the requirements of such an analysis can be practically evaluated. As a consequence of this approach this paper contributes to the understanding of Emergency Medical Dispatch (EMD) as well as the application of DC.

DC is a theoretical area that is relatively new in the cognitive science tradition. It differs in its approach to traditional cognitive science as it does not limit information processing to internal mental activities; instead it claims that external artefacts and structures are intimately involved in cognition. Because of this emphasis on external structures and artefacts DC theory brings HCI closer to influencing the psychology of human behaviour and action; in this sense the artefacts are not just designed to be used easily but play an intrinsic role in structuring people's thought. Despite the benefits of DC theory to HCI it remains underused, I hypothesise that a contributing factor to this is the gap between the established theory and a structured method to aid its application. This paper aims to develop an accessible and practical DC method to close this gap, bringing HCI researchers and practitioners closer to the benefits of applying DC theory.

EMD involves the allocation of emergency medical resources to incidents that require their attention. This allocation process is often centralised; emergency calls are collated, incidents prioritised, and the available emergency medical resources allocated according to need. This complex process is time critical and involves the coordination of information between different individuals and different artefacts. Due to the complexity of the interactions that support the performance of the process, in the actual setting, the current literature on EMD has employed a number of methodologies that aim to grapple with these issues. It is this richness of interaction between agents and external artefacts that make it suitable for a DC analysis. In this sense, the analysis aims to contribute to the understanding of the complex processes involved EMD and more specifically provide recommendations for further development, where applicable, for the LAS CAC.

Introduction to Emergency Medical Dispatch (EMD)

Emergency Medical Dispatch (EMD) provides the context of the current study for three clearly identifiable reasons. Firstly, it provides a rich area for human-computer interaction (HCI) analysis and intervention as this important activity seeks to take advantage of new technologies. Secondly, it is a worthy cause for attention as any improvements in reliability and speed can ultimately affect people's health, lives and wellbeing. Lastly, it follows a line of research undertaken by my supervisor, Ann Blandford, and her colleagues, which has allowed access to knowledge and resources for the duration of this research project.

The data collected for this study was conducted at the London Ambulance Service (LAS) Central Ambulance Control Room (CAC). A brief overview and history of the LAS CAC has been included below to set the context of this work. This is followed by a discussion of the different theoretical approaches used to explore EMD and the various challenges that have been uncovered in this area.

London Ambulance Service (LAS) Central Ambulance Control Room (CAC)

An Overview

The LAS CAC is amongst the largest of its kind in the world. It receives over 3000 calls every day, and is operated 24 hours a day all year round. The room is physically divided into two areas on two different levels. The lower is the call takers' area where all incoming calls are taken and prioritised. The higher of the two is the allocating area where decisions are made concerning which ambulances should go where and when. The allocating area is divided into seven sector desks which each has the responsibility of allocating ambulances to a specific area of London. Each sector desk manages approximately 35 ambulances and comprises three roles to perform the task: the allocator, who is the most senior person on the desk making the allocating decisions; the telephone dispatcher, who calls ambulance stations and liaises with other external parties via the phone; and the radio operator, who maintains contact with the ambulance crews once they are mobile or 'on the road'.

The allocating process provides a challenging time-critical environment where multiple sources of information have to be assimilated and fast decisions made. Decisions prioritising limited resources have to be made with the highest intention of preserving life, and so ambulance crews may be allocated, and even reallocated before reaching their original destination, to incidents where their assistance is most crucial. *In EMD, for example, every delay of one minute can reduce the chances of survival for a person with Sudden Cardiac Arrest by 10% (National Center for Early Defibrillation, 2002).* The central endeavour of this activity is to respond quickly and reliably to medical emergency demands using a robust system.

A Brief History

The LAS CAC is an evolving entity which has developed and continues to develop with the introduction of supporting technology to make its service more efficient. To understand the context of where the service is now it is useful to note where it has been, which can be particularly useful for tracking changes and identifying trends. To this end I include a précis of the history recorded by Blandford et al. (2002), and supplement this with additional changes that have been made since that report was written:

Since 1992, the LAS have taken a more cautious approach to automating their services after receiving a torrent of negative publicity when an attempt at computerisation failed. In reaction to this the LAS reverted back to its manual (paper based) system until 1996, when it developed a new approach using a small in-house development team. The new system allowed call takers to type in the details of calls which would simultaneously appear on the screens of the correct sector desks (the incident location would be matched to the correct sector area). Further management of the incidents was developed using printed incident cards in combination with a tray system that contained slots representing each different ambulance in that sector. This allowed notes to be made and information to be physically tracked and passed around, and it created a visible display of what ambulances were allocated to each incident by placing cards in slots. The developments up to 2001 included: incident details being printed at the station rather than being verbally reported to station staff; a computer aid for the call takers prioritising the calls; and the introduction of a Automatic Vehicle Location System (AVLS) allowing the vehicles to show their distance, 'as the crow flies,' from an emergency incident and hence aiding the allocation of the nearest vehicle. Further changes that have been incorporated into the current system include Mobile Data Transfer (MDT) units for each vehicle allowing incident details to be sent into the vehicle even whilst they are on the move; and satellite tracking/navigation of vehicles that gives directions to the incident for the crew, and allows the CAC to visually see where the vehicles are located on a map display. The increasing computerisation and the incorporation of new technology has led to a perceived diminishment of the importance of the paper based system, but the two systems are still used conjointly.

Theoretical Approaches and Challenges in EMD

It should not be surprising that the area of EMD has been the subject of past HCI research. It is an area that faces challenges in managing numerous sources of information; in empowering its users with tools and representations to make effective decisions; and in coordinating a variety of communication channels from external callers, through internal control processes, to the crews working on the street. These challenges, and the system's own time-critical and reliability requirements, appear to be a 'textbook case' for technological intervention and hence its interest for HCI research.

Like other rich contextual environments, to think that a computer program could adequately replace the complex interactions of the individuals, teams, tools and artefacts that currently support EMD processes would be to neglect the intricate factors involved. Due to this, research in this area has mainly involved exploring those context based methodologies and theories to engage with the complexities of this multifaceted system. Wong and Blandford (2003) make the point well when they recognise that the coordination of decisions and actions by multiple individuals implies that they need to share an understanding of the situation, which raises issues of distributed cognition, team decision making, situation awareness, non-formal information flows and naturalistic decisions making (NDM).

A variety of research techniques (qualitative and quantitative) have been used to investigate the area e.g. Workload Analysis, Observation and Contextual Inquiry, (Wong & Blandford, forthcoming); Video Protocol Analysis and a technique based on Situation Awareness Global Assessment Technique (Wong & Blandford, 2003); Critical Decision Method and Emergent Themes Analysis (Wong & Blandford, 2002);

Ontological Sketch Modelling (OSM) (Blandford et al., 2002); and Grounded Theory (Wong & Blandford, 2001). Not only does this selection give an indication of the rich variety of data to be considered in the EMD context, but it also gives an indication of how trials of new methods aim to meet the new contextually based challenges that HCI research needs to become adapted to (e.g. Wong & Blandford, 2002; and Blandford et al., 2002).

The contextual orientation of this area of research has also led to the exploration of theories that come away from rigorous task and device centric methods such as GOMS (e.g. Gray et al. 1992) and towards understanding the intricacies of how people operate in their environment e.g. situated action and NDM. These theories have contributed to noticing subtle information handling strategies of people in their real context, which actually provide important functions for making the whole system perform smoothly. One such example is the use of paper incident cards in planning action by piling them on the desk, in comparing incident details by laying cards side-by-side, in using them as a shared information space with others, and configuring cards back-to-back to suggest that one vehicle will proceed from one incident to the next (Wong & Blandford, forthcoming). Another example of what might be considered a ‘soft’ or informal feature of a system is the observation that people will start planning or initiating appropriate actions before they are instructed to do so: *“…you can hear things going on around you and you start to do it without even being asked to do it”* (Wong & Blandford, 2001). In these two examples we have important observations which highlight ways that people interact with their physical and social environment to structure their own actions. In analysing such a system it is important to attempt to understand these intricacies otherwise any design recommendation might have a negative impact on a subtle but important part of the system, and hence fail overall. The idea of broadening the traditional HCI focus to studying the real context and the potential impact of technological change on that context is not new (e.g. Checkland & Howell, 1998; Brown and Duguid, 2000). It appears that understanding many aspects of EMD systems will call on theories that offer a broader approach to the role of context; theories which are still establishing their place in the HCI paradigm (Kaptelinin et al., 2003).

Introduction to Distributed Cognition

Distributed Cognition (DC) is recognised as having obvious relevance to HCI theory and design, but despite this fact its ideas have lacked visibility in the HCI community (Wright et al., 2000). This chapter will introduce DC from its contrasting approach to disembodied cognitive science; outline the key concepts of DC theory; and summarise literature that is trying to advance DC theory in HCI. This literature, some of which is motivated in making DC theory more accessible to the HCI community, will provide the motivation and context for the current paper.

Background

The Heritage of a Disembodied Cognitive Science for HCI

The pervasiveness of the disembodied approach to the study of mind and behaviour in mainstream Western thought is part of our cultural heritage, influenced by years of thought and research that has gone before. Culturally pervasive ideas of this sort are often taken for granted, particularly when one is immersed within them and has no contrasting experience (Hutchins, 1995). By drawing attention to two influential roots of this approach I will help substantiate it as a 'belief' or a 'view'. By doing this it becomes a clearer object of thought, and so it is subsequently easier to have reflective thoughts about (Clark, 1997).

The rich heritage for mainstream psychology and HCI that I have referred to has a deep history. The disembodied tradition of cognitive science has philosophical roots as far back as Descartes, around the mid-sixteenth century, who proceeded to detach thought from all he perceived, which he thought could be a source of doubt and deception in his discovery for truth. His argument that detaches mind from body (Cottingham, 1986) is best known for its famous Latin phrase: '*cogito ergo sum*' meaning 'I think therefore I am' which was a truth he believed did not rely on external perception.

In more recent times, the disembodied approach has been championed by the computer metaphor of mind, which was most ambitiously expressed in the *Physical Symbol System Hypothesis* (Newell & Simon, 1976). Simply put, this claimed that any machine capable of calculation using abstract symbols could exhibit general intelligence. Winograd and Flores (1986) have summarised the computational assumptions behind this hypothesis as follows:

- All cognitive systems are symbol systems. They achieve their intelligence by symbolising external and internal situations and events, and by manipulating those symbols.
- All cognitive systems share a basic underlying set of symbol manipulating processes.
- A theory of cognition can be couched as a program in an appropriate symbolic formalism such that the program when run in the appropriate environment will produce the observed behaviour.

This gave an image of cognition that all perceptions were internally coded in symbols for calculation and manipulation, which meant that the external world merely provided sensation to be coded and modelled. The real heart of cognition was therefore inside the programs that processed these symbols, programs that were deep inside heads, and inside machines. In this formulation the analytic knife had surgically separated the world and cognition. This formed the basis of the traditional Artificial Intelligence (AI) program that aimed to produce intelligent machines.

For psychology and HCI, the disembodied mind leaves a detached and impoverished image of the true mechanisms that form our cognition. The view of mind we are left with is highly centralised, has a high workload in creating internal representations to act upon, and is decoupled from the external world. For HCI this means trying to create a better fit between the artefact and the user, which are two quite separate systems. These separate systems interact at a psychological level by the user building a mental model of the system, which hopefully reflects the actual model of the system, so it can be used efficiently i.e. so the user does not think a function does one thing when it does something else. Norman (1986) has described this cognitive interaction in detail and suggests that usable systems should aim to reduce the gulfs of execution and evaluation in the users' mental models of interaction with a system. The work on mental models, particularly the discrepancies between the user's mental model compared to that of the actual model of the system, has provided a useful analytic approach to looking at the usability of systems (e.g. Blandford et al., 2003). I do not aim to criticise the usefulness of these approaches, on the contrary Newman and Lamming (1995) illustrate how the concept of the mental model is useful for design; however, I do criticise the rigid analytic boundaries that these concepts are built upon. I support the view that these boundaries should be softened to allow for explanations better suited to understand and cope with contextual interactions, where people and artefacts are observed to form integrated working units (Hutchins, 1995; and Clark, 1997).

Criticisms of Disembodied Cognitive Science

The disembodied approach to cognition has been the focus of much debate and criticism, which include two main themes: neglecting the influence of the physical environment and social interaction on our behaviour and understanding.

The effect of the environment on our actions is one that is familiar in HCI, most well known in the ideas of *affordance* applied to design (Norman, 1988). The idea of affordance, originating from the work of Gibson, is a bottom-up concept in which the visual environment provides enough information for action (Gross, 1996). Winograd and Flores (1986) argue the same point from different origins. They quote the work of Maturana in finding biological evidence in frogs that perceptions and actions are not as neurologically distinct as we might have thought. Through this they build the idea of *direct-coupling* to the environment, in which our actions are directly influenced by perception in Gibson's sense. This contrasts with the disembodied top-down approach that first has to construct an internal mental representation, which is then used in performing internal calculations before any possible actions can be selected and implemented (e.g. Norman's Action Cycle (Norman, 1988)).

The disembodied view has a centralised view of processing. Within this there is a central control of action, which has goals that form the basis of plans which are a precondition for action. Suchman (1987) argues strongly against this conception of action. In her criticism, and the conception of *situated action* that she puts forward, she tries to put action at the heart of behaviour rather than plans: *Rather than attempting to abstract action away from its circumstances and represent it as a rational plan, the approach is to study how people use their circumstances to achieve intelligent action. Rather than build a theory of action out of a theory of plans the aim is to investigate how people produce and find evidence for plans in the course of situated action. More generally, rather than subsume the details of action under the study of plans, plans are subsumed by the larger problem of situated action (Suchman, 1987).* Her argument provides a convincing case for viewing the constraining executive processes of goals and actions as part of the environment that we may choose to act upon to achieve intelligent action.

The disembodied approach has also been strongly criticised as being asocial and lacking in its ability to account for ‘meaning’. This line of argument is developed by Winograd and Flores (1986) who quote Heidegger in situating meaning in our social interactions or hermeneutic circles. Hermeneutic circles are those social circles where people interact and share meaning; people in different hermeneutic circles will share different meanings and concepts. The idea of ‘meaning’ being situated in hermeneutic circles means that ‘meaning’ is situated in social interaction and activity, rather than in dictionary definitions and symbolism (Wenger, 1998). We might not be able to define a word clearly and distinctly but we might feel confident in its use. This is particularly poignant in ‘stimulus-neutral’ cases where the concept has no definable physical characteristic e.g. game, bargain and leadership (Gauld & Shotter, 1977). This directly conflicts with the physical symbol system hypothesis underlying the traditional AI program. If meaning cannot be symbolised then it will be impossible for a machine to understand, the idea of hermeneutic circles makes the claim that interaction and action are necessary for meaning and understanding. Winograd and Flores (1987) develop these arguments and emphasise the importance of communicating meaning and negotiating work in activity, where conversations constitute the social process. They believe this is an important consideration in the design of computer supported work which can be addressed through the conception of the language/action perspective (Kaptelinin et al., 2003), something beyond the boundaries of explanation for the individualistic disembodied perspective.

The idea of participation being a key factor in performance and understanding is not just one that resides in the ‘social’ elements of cognition, but is also recognised in the acquisition of skill. In both instances we participate effectively in an interaction or activity but when interrogated about specific details of our performance they may be inaccessible to us i.e. we may not be able to define a word we have used or explain the way we have done something. Michael Polanyi is attributed with first conceiving of the distinction between explicit and tacit knowledge (Jha, 2002). The former we can articulate but the latter we cannot: *we know more than we can tell* (Jha, 2002). The acquisition of tacit knowledge is associated with observation and practice over an extended period of time, either through training or an apprenticeship; because this knowledge cannot be articulated it cannot be transferred by explanation and instruction alone. Everyday activities of a tacit nature may include tying shoe laces, swimming and riding a bicycle. An excellent example used by Dreyfus and Dreyfus (1986) is the practice of chicken sexing, which greatly strengthened the American poultry industry at a vulnerable time. This inexplicable skill was practiced in Japan and brought over to America through training and apprenticeships. Those that adopted and practiced the technique extensively could accurately and immediately identify the sex of a day old chick. This remained beyond the ability of people that had not been through the apprenticeships; even those accustomed to chicks with extensive investigation could not tell the sex of a day old chick. This form of knowledge creates two problems for the disembodied approach: firstly, its implicit nature means that it cannot be symbolised; and secondly, its acquisition through practice suggests a closer integration between the mind and actions of the body than the theory allows.

In this section we have seen a number of limitations of the explanatory power of the disembodied approach to cognition. This has included: the influence of the environment on our actions in the idea of affordance; the weakening of the internal control on behaviour in the ideas of situated action; the importance of social participation in developing meaning and understanding; and the acquisition of tacit knowledge through observation and practice. An alternative view closely related to the DC tradition is the extended mind which addresses some of these limitations by re-embodying the mind and re-emphasising the influences of the social and physical world we are situated in.

A Conception of the Extended Mind

Like Humpty Dumpty, brain, body, and world are going to take a whole lot of putting back together again. But it's worth persevering because until these parts click into place we will never see ourselves aright or appreciate the complex conspiracy that is adaptive success (Clark, 1997, pp 222).

Andy Clark (1997) takes a multidisciplinary approach in bringing in evidence to support the case for an extended mind, some of which I will try to highlight in this section. A strength of this work is that it goes beyond philosophical arguments and conjecture and presents empirical work to support his case.

With reference to work in robotics, particularly that of Rodney Brooks, Clark begins to lay the foundations of a dispersed, environmentally driven, and emergent view of cognition. The new approach to robotics has left the old AI tradition of representation and problem solving behind. For years AI researchers struggled to get robots to successfully navigate physical environments as the perceptual and commanding processes were so intensive (involving extensive modelling, strategy planning and decision making). Brooks has taken a different approach by building robots as a collection of subsystems that communicate and compete to govern collective action e.g. each leg on a six legged robot may sense and suggest a reaction to their local stimuli, these inputs are coordinated via parallel circuitry and follow a few simple rules (e.g. object avoidance and locomotion routines). It is important to note that the communication between subsystems is not symbolic encoding but signal interaction: they are able to encourage, interrupt, or override the activity of another. Here, successful environmental interaction takes place without central control but dispersed interactive subsystems; without modelling the world but using its input directly; and without complex calculations and planning but by collective subsystem communication and simple rule following behaviour. Clark (1997) argues that this dispersed approach to AI is also a plausible model for human cognition.

It is well accepted that overtly complex group behaviour in many relatively simple organisms actually emerge from simple individualistic rule following in response to multiple local factors e.g. fish swimming in a shoal and birds flying in a 'V'. It is now suggested that similar properties may underlie human behaviour: *Some recent studies of infant development suggest that it, too, may be best understood in terms of the interactions of multiple local factors – factors that include, as equal partners, bodily growth, environmental factors, brain maturation, and learning (Clark, 1997, pp 40)*. In this example the multiple factors go to form the potentials of behaviour for a developing child rather than outward group behaviour but the point is still well taken; that the outward phenomena we perceive is often an emergent consequence of a multitude of local factors and influences, dispelling the idea of a central internal control.

Once we begin to appreciate the idea that behaviour is influenced by different internal and external factors, some driven by our local environment, then we can begin to speculate how this happens, when it happens and how it helps us. Clark (1997) provides a number of illustrative examples which capture some of the idiosyncrasies of the extended mind:

- Completing a jigsaw puzzle is rarely done by pure thought and deliberation alone. Instead physical actions rotate pieces and enable experimentation with fit and position. Pieces can also be grouped by physical characteristics. These physical actions are triggered from internal deliberation which in turn change or simplify the problem confronting the same deliberative processes. This is what Clark (1997) calls an action loop.
- When asked to do a long multiplication e.g. 7222 X 9422 most people would use a pen and paper to help them if they didn't have a calculator. The paper provides an external medium so the problem can be broken down into simpler problems e.g. 2 X 2, so these smaller solutions can be externally stored and integrated. The external resource of paper allows the problem to be broken down and simplified, allowing our cognitive apparatus to tackle problems more amenable to its capabilities. This common strategy for long multiplication tells a story of the intricate interplay between physical and mental resources which form a coherent performing system.
- Scrabble playing strategies also involve the external manipulation of tiles to prompt internal possibilities and combinations (Kirsh, 1995a). As Clark (1997, pp 64) states: *The fact that we find external manipulations so useful suggests that our on-board (in-the-head) computational resources do not themselves provide easily for such manipulations*.

Clark (1997) also cites the important work of Kirsh and Maglio (1994) in this area for distinguishing pragmatic and epistemic action, and conceiving of a physico-informational space. Pragmatic action is the action we perform to alter the world get closer to achieving a goal, compared to epistemic action whose primary purpose is to aid our cognising processes (Clark, 1997). Kirsh and Maglio also suggest that our brain works so closely with local environmental supports that the current perception of treating the two as separate is false. They suggest that the independent constructs need to be unified to share a informational space (the physico-informational space); much like Einstein replaced the separate notions of space and time with the unified construct of space-time (Clark, 1997).

The changing vision of intelligent action and the slow integration of environmental involvement can be traced from Piaget to Wason (1977) to Zhang and Norman (1994). Piaget was a developmental psychologist who conceived of four major stages of cognitive development in children, which could be approximately mapped to ages. The most advanced of these was the formal operational stage whereby a child could reason with ideas, arguments and verbal statements alone, without regard to content (Gross, 1996). This theory was dealt a fatal blow by Wason (1977) in conceiving of his well known four card problem. This was a sound logical problem without content, hence ideal for formal operational thought, but tests showed that human cognition was not amenable to this problem. *In summary our results suggest that reasoning is radically affected by content in a systematic way, and this is incompatible with Piaget's view that in formal operational thought the content of a problem has at last been subordinated to the form of relations in it (Wason, 1977, pp 132).* The idea that the content of a problem influences its solution is taken further by Zhang and Norman (1994). By varying the traditional Tower of Hanoi problem (where rings of different sizes have to be moved across three pegs with certain rule constraints) they were able to show that the environment can implicitly hold logically constraints which aid the user, improving performance. For example, rather than explicitly saying that a larger ring cannot be placed on a smaller one the logical rules can be maintained with filled soup bowls, whereby a smaller soup bowl could not physically be placed on a larger one without spillage (whether the constraint prohibits larger on smaller, or vice versa, the importance is in the fact that the logical structure of the problem can be maintained). This shows that the same logical representation of a problem can vary immensely depending on the actual representation and content of the problem. Far from the intellectual heights of formal operational thought we have the suggestion that intelligent behaviour closely depends on the content it is working with, coupled with the action loops and epistemic action that we have already discussed it does not seem far fetched to consider intelligent behaviour as being an output of the interplay between mind, body and world.

In summarising some of the ideas of the embodied and extended mind I have adapted a table from Clark (1997, pp 83) which represents how ideas have changed since the classical conception of mind (see Table 1). The connectionist view that we have not discussed in this paper concerns a different method of internal circuitry involving parallel distributed processing. This involves an interconnected network of nodes that enhance and inhibit activation levels depending on the inputs to the system which is very different from explicit symbol manipulation. Key properties of connectionist networks are that they allow for pattern recognition, adaption and a decentralised control which is very different from the logical, central commanding strengths of the classical view.

Table 1: The Transition of Ideas between Three Different Conceptions of Human Cognition (adapted from Clark (1997) pp 83)

Classical Cognitive Science	**Connectionism**	**Extended Mind**
Memory as retrieval from stored symbolic base	Memory as pattern recreation	Memory as pattern recreation
Problem solving as logical inference	Problem solving as pattern completion and pattern transformation	Problem solving as pattern completion and pattern transformation
Cognition as centralised	Cognition as increasingly decentralised	Cognition as increasingly decentralised
The environment as (just) a problem domain	The environment as (just) a problem domain	The environment as an active resource whose intrinsic dynamics play an important problem-solving role
The body as input device	The body as input device	The body as part of the computational loop

In reflection on the classical view, people that support the notion of an extended mind believe that the classical view mistook the intricate subtle interplay between the brain, body and world to be the just what happened inside the head (e.g. Clark , 1997; Hutchins, 1995). Norman (1995) calls the centralised view of cognition the ‘personal view’ where environmental support changes the task performed by the individual; and calls the extended point of view the ‘system view’ where environmental support makes the whole system smarter. Here we see the crux of the difference between the two perspectives: where and how to bound the computational loop of cognition. The arguments of this chapter have tried to demonstrate that our cognition goes beyond our brain, in the intricate interplay between internal and external resources, and so the computational loop should be extended outside of the head.

Describing the Distributed Cognition Perspective

This section will focus on describing the DC perspective. As the main arguments and motivations for this approach have been presented in previous sections I will concentrate on outlining the main principles of DC that define it and distinguish it from other post-cognitivist approaches.

Core Tenets and Concepts

The seminal work on DC is Hutchins' (1995) *Cognition in the Wild*. In it he describes how DC theory can be used to explain how the navigation team of a large vessel operates to perform their task of navigating effectively. This involves explaining how information is transformed and propagated around the system of the navigation team. The DC approach that is applied can be distinguished from other theoretical methods by its commitment to two related principles (Hollan et al., 2000, pp 175):

1. The unit of analysis is expanded so the *cognitive process is delimited by the functional relationships among the elements that participate in it, rather than by the spatial collocation of the elements.*
2. The analysis looks for a range of mechanisms that can partake in the cognitive system rather than restricting itself to symbol manipulation and computation. *For example, an examination of memory processes in an airline cockpit shows that memory involves a rich interaction between internal processes, the manipulation of objects, and the traffic in the representations of the pilots.*

Hutchins believes that much of the concepts and vocabulary familiar to classical information processing cognitive science can be retained but that the unit of analysis needs to be expanded from the individual to the wider system. In this he proposes to apply three levels of Marr's (1982) cognitive description outside of the head, as shown in Table 2.

Table 2: Three Levels of Marr's (1982) Cognitive Description (adapted from Hutchins (1995) pp 50)

Level	Summary	Description
1	System processing purpose	What the system does and why it does it
2	Representation	How the information going into and out of the system is encoded, and the details of transformation which take place
3	Realisation	How the information is actually realised and transformed in the world

This implies that there are different levels of description in a DC system that interact with one another but it gives no indication of the diversity of phenomena that need to be observed in contributing to a DC process. Hollan et al. (2000, pp 176) suggest three ways that cognition may be distributed:

1. *Cognitive processes may be distributed across the members of a social group.*
2. *Cognitive processes may involve coordination between internal and external (material or environmental) structure.*
3. *Processes may be distributed through time in such a way that the products of earlier events can transform the nature of later events.*

This gives some indication of the sorts of observations and phenomena that a DC analysis might highlight but these will not become fully realisable for the DC novice until some concrete practical examples are encountered.

Important elements of Hutchins' (1995) observation include how artefacts and representations aid the individual using them, group communication and coordination, physical layout and accessibilities, and the historical cultural heritage that has shaped the system. Readers should resort to Hutchins' (1995) work for a full explanation which is too rich to summarise here. However, I will try to abstract a selection of elements useful in demonstrating the diverse concerns of DC theory and supplement this with observations and insights from other studies.

Table 3: Abstracted DC Concepts, Ideas and Insights
(where sources are quoted they indicate where I retrieved this information; I do not claim that these ideas originally originated at these sources, or that they are the only sources with these ideas. Only that they serve my purpose in explaining DC theory.)

1	Creating Scaffolding	Hollan et al. (2000) pp 192
The environment is one's partner or cognitive ally in the struggle to control activity. Although most of us are unaware of it, we constantly create external scaffolding to simplify our cognitive tasks (Hollan et al., 2000, pp 192).		

2	Mediating Artefacts	Hutchins (1995) pp 290
Mediating artefacts include any artefacts that are brought into coordination in the completion of the task. The full range of mediating structures cannot be listed because they are too numerous but examples include: language, writing, counting, maps, signposts, computer programs, mental models and diaries.		

3	Representation – Goal Parity	Wright et al. (2000)
In Hutchin's (1995b) example of cockpit speeds it is necessary to notice when the declining speed reaches the target speed, at which point the flap setting for the plane should be increased. *One of the coordination processes that is carried out is therefore to make a comparison between a target or goal state (the target speed) and the current state (i.e. the current speed). In order to do this, the goal and current state resources must be brought into co-ordination, and precisely how this happens is highly dependent on the way the resources are represented (Wright et al., 2000).* The closer the representation can be to the cognitive need or goal of the user the more powerful that representation will be (it will be more efficient in addressing the need).		

4	Perceptual Principle	Norman (1995) pp 72
Perceptual and spatial representations are more natural and therefore to be preferred over non-perceptual, non-spatial representations, but only if the mapping between the representation and what it stands for is natural – analogous to the real perceptual and spatial environment (Norman, 1995, pp 72).		

5	Naturalness Principle	Norman (1995) pp 72
Cognition in relation to a representation is aided when the form of the representation matches the properties of what it represents; in these cases what is experienced is closer to the actual thing, so the necessary mental transformations to make use of the representation are reduced.		

6	Information Transformation	Hutchins (1995)
Information can be represented in different forms; transformations occur when the representation of information changes. This can happen through artefacts and communications between people. For example, a table of numbers could be represented as a chart or graph; and the strength of a person’s opinion might be recorded on a numerical scale.		

7	Information Movement	Hutchins (1995)
Information moves around the system. This can be achieved in a number of different ways which have different functional consequences on information processing. These ways differ in their representation and their physical realisation, for example these differing factors may include: passing physical artefacts; text; graphical representation; verbal; facial expression; telephone; electronic mail; shouting; and alarms. Even inaction might communicate information.		

8	Expert Coupling	Hollan et al. (2000) pp 186
The more interaction and experience a user has with a system the better they perform in it as they become tightly coupled with the environment. Here the processing loops in the functional cognitive system become tight, fast and spontaneous.		

9	Coordination of Resources	Wright et al. (2000)
Resources are described as abstract information structures that can be internally and externally coordinated to aid action and cognition by Wright et al. (2000). The six resources that they describe in their Resource Model are: plans, goals, affordance, history, action-effect, and current state. A good example of the coordination of resources is a shopping list which contains a list of goals; if the products are in the order they will be picked up the list will constitute a plan; and if the items on the list are crossed off then the list will show the current state. Without this external coordination of resources the individual will have to internally coordinate the activity, which will become more demanding with the increasing complexity of the activity.		

10	Space and Cognition	Hollan et al. (2000) pp 190-191

Space is a resource that must be managed, much like time, memory, and energy. Accordingly we predicted that when space is used well it reduces the time and memory demands of our task, and increases the reliability of execution and the number of jobs we can handle at once.
In Kirsh (1995b) we classified the functions of space into three main categories: spatial arrangements that simplify choice, spatial arrangements that simplify perception, and spatial dynamics that simplify internal computation.
... For instance, we saw them covering things, such as garbage disposal units or hot handles, thereby hiding certain affordances or signalling a warning and so constraining what would be seen as feasible. At other times they would highlight affordances by putting items needing immediate attention near to them, or creating piles that had to be dealt with (Hollan et al., 2000, pp 190-191)

11	Subtle Bodily Supports	Hutchins (1995) pp 236

In interacting with the environment we may use our body to support our cognitive processes e.g. pointing at a place in a book we are reading whilst responding to an interruption is part of the retrieval mechanism of remembering where we are.

12	Situation Awareness	Norman (1995) pp 142-143

One of the key things in shared tasks is to keep people informed of what is going on, what has happened and what is planned. This can be influenced by how accessible the work of the team is. Where there are large controls the work of individuals is more accessible e.g. large power plant control rooms sometimes involved people walking to different areas that had different displays and pulling large levers.

This can also be influenced by the proximity of the person, involving both observation and overhearing conversation.

13	Horizon of Observation	Hutchins (1995) pp 268

The horizon of observation is what can be seen or heard by a person. This will differ for each person in an environment depending on their physical location, the activities they are close to, what they can see, and the manner in which activities take place. The horizon of observation of a person will play a large role in influencing their situation awareness.

14	Information Hubs	Blandford & Wong (forthcoming)

Information hubs can be considered as a central focus of where different information channels meet and where different information sources are processed together e.g. where decisions are made on various sources of information. Busy information hubs can be accompanied by buffers to control the information to the hub, which can keep it working effectively.

15	Buffering	Hutchins (1995) pp 195

As information propagates around a system there may be times when the arrival of new information may interfere with important ongoing activity creating conflict and increasing the chances of an error occurring by losing or distorting the new information or the message, or making a mistake with the ongoing activity. Buffering allows the new information to be held up until an appropriate time, when it can be introduced. In the case of the ship there is a phone talker on the bridge who can decide when to report information that he receives over the phone; this will depend upon the activity on the bridge and the urgency of the message received.

16	Arrangement of Equipment	Hutchins (1995) pp 197

In the DC approach the physical layout of equipment is not just an issue for non-cognitive ergonomists. The physical layout affects access to information and hence the possibilities for computation. As well as physical representations and artefacts this would also hold for the different levels of access to people, their conversations and their work.

17	Communication Bandwidth	Hutchins (1995) pp 232

Communication between persons who are copresent in a shared physical environment differs in many ways from communication across a restricted bandwidth (Hutchins, 1995, pp 232) e.g. computer mediated communication, radio and telephone will not share the same richness as face-to-face communication.

18	Informal and Formal Communication	Hutchins (1995)

Informal and formal communications play important functional roles in the system. This can include the propagation of important information about the state of the system, and the transference of knowledge through stories, which can have important consequences for learning how the system behaves.

19	Cultural Heritage	Hutchins (1995) pp 169

Hutchins extends Simon's (1981) parable of an ant's movements scouring a beach. In this we are asked to envisage a whole history of ants searching for food. After a time the seemingly random behaviour becomes more focused and directed as the later ants can go straight to the food source. In refraining from attributing a greater intelligence to the later ants the changes that we have actually been observing to influence behaviour has been the changing landscape as chemical trails have been left on the beach. In the same way as ants we haven't changed but have been left with an enriched landscape to support our behaviour. In the case of ship navigation the team has adopted maps, tools, strategies and lessons all developed and laid down by previous generations. This forms part of our cultural heritage.

20	Behavioural Trigger Factors	Hutchins (1995)

It is possible for a group of individuals to operate without an overall plan as each member only needs to know what to do in response to certain local factors. These can be dubbed 'trigger factors' because of their property to trigger behaviour.

21	Social Structure and Goal Structure	Hutchins (1995) pp 203

The social structure can be superimposed with a goal structure such that a subordinate can only stop when their superior determines that their goals have been met. In this manner the goals filter down through a hierarchy with overlapping responsibility. This creates robustness in the system through group monitoring and job sharing, if necessary, to get the work done. It also means that the system can work through individuals whose main concerns are their local goals.

Figure 1: Goal Hierarchy and Distribution of Responsibility (reproduced from Hutchins (1995) pp 203)

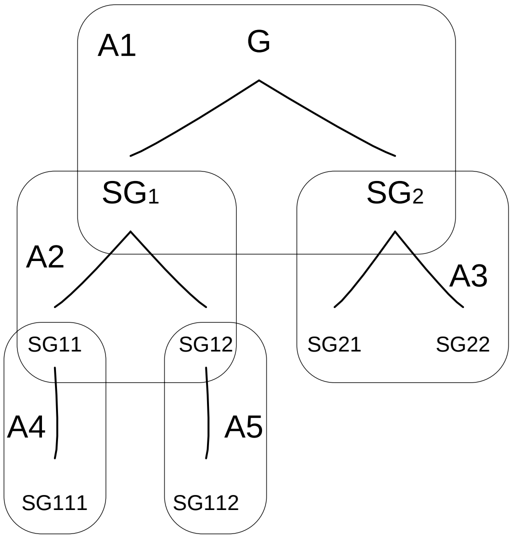


Figure 1 shows a goal structure represented by goals and sub-goals (e.g. G, SG1, SG12) and the area of responsibility of agents (e.g. A1, A2, A3). In this representation the agent A1 has overall responsibility of the goal but does not explicitly share the sub-goals performed by A4 and A5. In these cases each agent is aware of their local responsibilities and goals, it is the social structure and the overlap in responsibility that maintains the goal hierarchy. Intermediary agents (in this case A2 and A3) provide the link between the accomplishment of sub-goals (performed by subordinates) to contribute to the overall goal (responsibility of superiors).

22	Socially Distributed Properties of Cognition	Hutchins (1995) pp 262

The performance of cognitive tasks that exceed individual abilities is always shaped by a social organisation of distributed cognition. Doing without a social organisation of distributed cognition is not an option. The social organisation that is actually used may be appropriate to the task or not. It may produce desirable properties or pathologies. It may be well defined and stable, or may change moment by moment; but there will be one wherever cognitive labour is distributed, and whatever one there is will play a role in determining the cognitive properties of the system that performs the task (Hutchins, 1995, pp 262).

Two ways that social distribution can be organised to produce some cognitive effect include: 1) lots of overlap and the sharing of responsibilities for error checking, and 2) separating communication channels to make sure that decisions are robust in checking that multiple independent sources agree.

The theory of DC covers a diverse range of complex factors: those factors that have a functional role to play in cognition. This involves the interplay of internal resources, bodily action, the use of artefacts, the structure of representations, social organisation and communication, and culture. As the theory of DC is highly contextualised each situation of study has the potential to offer different methods of functional organisation and the opportunity for new insight. *In distributed cognition, one expects to find a system that can dynamically configure itself to bring subsystems into coordination to accomplish various functions (Hollan et al., 2000, pp 176).* The coordination of these subsystems can change with context, task, and in reaction to changes, which makes their study situation dependent. However, patterns can be recognised in and across systems. *Cognitive processes involve trajectories of information (transmission and transformation), so the patterns of these information trajectories, if stable, reflect some underlying cognitive architecture (Hollan et al. 2000, pp 177).* The more abstractly these persisting patterns can be represented the better the chance that they may have application in other cognitive systems. In grasping the theory of DC it is important to understand its motivation, and core tenets and concepts; its methodology remains rather unspecified and is reliant on the analyst's skill in a variety of ethnographic approaches and mastery of DC theory.

The Development of Distributed Cognition in HCI

DC is not the only theory that has been developed that has been perceived as a reaction to the limitations of classical cognitive theory. Nardi (1996a) and Kaptelinin et al. (2003) discuss DC with other approaches, including: activity theory, language/action theory, and situated action, which all share similar concerns in focusing on more 'contextual' HCI. These theories are in different stages of development and are trying to establish themselves as legitimate HCI approaches to contextual research e.g. Nardi (1996b, pp 9) claims that a major American journal of HCI rejected a set of papers on activity theory because the application of the theory had not yet been established or accepted as a beneficial approach by the HCI community.

At the heart of the motivation of this current paper is the premise that DC should not only be developed at the higher end of theory development, moving forward what is already in existence, but also in the lower end in encouraging uptake and the wider use of the theory. The wider understanding and use of the theory is likely to lead to more research that can feed the theory-growth cycle from the bottom up: application of current theory to case studies, establishment of theory, development of theory, and back round again. Wright et al. (2000) have commented that despite the relevancy of DC to HCI it has lacked visibility in the HCI community; and Rogers and Scaife (1997) recognise that a problem with the DC approach is that *it is a not a methodology that one can readily pick off the shelf and apply to a design problem*. The answer to both of these problems could be to try to develop a more structured and useable approach to applying DC to a context and design problem, which I will explore and develop in this paper.

Hollan et al. (2000) are working at the higher end of theory development in taking DC theory and method forward by describing their view of an integrated research framework that bases its approach in research loops that feed into one another e.g. ethnographic observation, to experimentation, to theory development; and ethnographic observation, to abstract insight, to theory development. They recognise that their framework is ambitious in scope and in the skills demanded, but outline practical steps that have been taken in establishing a new laboratory and training programs for the research skills and knowledge required. The picture of a self sustaining DC research framework that Hollan et al. (2000) describe sets a high level goal for the area; but I think more could be done in addressing lower level problems for the wider HCI community i.e. making DC more visible and accessible for researchers, students and practitioners.

Wright et al. (2000) are working at the lower end of theory development in making DC more visible and accessible to the HCI community, a problem recognised in their paper. They outline the Resource Model which looks at clarifying how abstract resource structures can be coordinated in strategies to produce behaviour. The idea of abstract cognitive structures is related to Suchman's (1987) argument about plans; where plans become a resource for activity rather than a precondition of activity, so all our actions are not planned but we can use plans to shape and support our activity. In a similar vein Wright et al. (2000) recognise five other abstract resources: goals, affordance, history, action-effect, and current state. These resources can be realised internally or externally; and depending on the coordination of these resources the activity can be more or less supported. For example, an unordered internal shopping list might just be considered a series of goals; whereas an ordered external shopping list that I tick off as I retrieve items involves a plan, goals, a history and easy access to my current state within the total activity. Wright et al. (2000) demonstrate that this model is a useful framework in considering designs. This work does not just have value in contributing to DC theory but gives an added structure to its application, a lack of which could be a contributing factor to its problems of visibility in the HCI community.

Wright et al. (2000) intentionally address a single user single system operation to show how DC can be applicable to more traditional areas of HCI software design. However, they do realise that this is a potential limitation of their paper as a multi-agent system has the possibility to involve a far richer array of cognitive subsystems and strategies. Fields et al. (1998) apply DC to an air traffic control (ATC) room to look at the representations present and their distribution, manipulation and propagation through the ATC system. They recognise that a potential criticism of their paper is the lack of method that takes them from analysis to design, but despite this they have sound DC insights into ATC work. It is the development of such a method that I aim to explore in this paper.

In reviewing the development of DC theory I have interpreted that it is being progressed at two levels. At the higher level DC theory is progressing and leading the field forward which will exhibit back propagation, depending on its success, by attracting further research to the area. At the lower level the current DC theory is trying to be made more visible so it can be more readily used by HCI experts in the field (problem referred to by Wright et al. (2000); and Rogers & Scaife (1997)). These two levels do overlap but their subtle distinction is important in developing and expanding theory. As an analogy we can choose to improve the mechanics of the car so that it has improved performance even though it may be demanding to learn to drive (high level), or improve the access, usability and comfort of the car so more people are able to get in and use it (low level). Of course, the more usable the car the better it performs so the two are not exclusive. The mileage in the theory depends on both, which will affect its use, insights and future development.

The aim of this paper is to address the need to develop a method for a DC analysis in a multi-agent context, which itself has a number of sub-objectives:

- With the addition of some structure and guidance in a DC analysis of a team environment those unfamiliar to implementing a DC analysis may have the confidence to try it, expanding the theory's user base and aiding its development.
- By adding structure in a method the area will gain a higher level of transparency so it can be evaluated, criticised and developed in the usual scientific/academic cycle.
- And not least importantly, depending on the usefulness of the method developed it may also serve as a resource to structure DC analyses in the future for those with varying levels of experience.

Method

The aim of this paper involves codifying a method for a DC analysis. This section describes the exploratory approach that I undertook in developing the codified DC method. The exploratory process involved an iterative cycle of reviewing literature, collecting data, and conceiving of an approach that would be suitable for the LAS CAC context. The results section includes the final abstracted description of the codified DC method that has been developed through this work.

Materials and Practical Constraints

The duration of the study was for 3 months from data collection to write-up, which meant that aspects of it, such as access to the LAS CAC, were agreed and set early. Two 3 hour visits were arranged to visit the LAS CAC, split by a duration of approximately one month, the first in the morning and the second in the afternoon. The first was planned to function primarily as an exploratory and familiarisation visit, and the second was to tie up loose ends and get answers to outstanding queries.

Access was also available to four 1 hour and 30 minute audiovisual clips that were recorded by Dr A. Blandford and her colleague, Dr W. Wong, in 2000 and 2001 as part of their work on EMD (see various Wong & Blandford papers in bibliography). Dr A. Blandford was also a source of advice and explanation of the processes that occurred within the LAS CAC. Processes in the LAS CAC had changed since the previous research and since the video footage was recorded, which was accounted for in the analysis.

Literary Support

The process of analysing a rich and complex contextual environment that is unfamiliar and novel to the analyst can be a daunting task: *When faced with the study of complex systems involving teams of workers with multiple information systems, the possible approaches to data collection and analysis can be overwhelming (Wong & Blandford, 2003)*. The task of developing a practical codified approach to a DC analysis would involve the exploration of the literature on contextual analysis, the literature on DC, and the exploration of the field that was to be analysed and represented. In developing a greater understanding in each of these areas the requirements and structure of a DC method emerged, gaining greater clarity with each step of this exploratory approach.

Studying work and behaviour in context is now well recognised as having benefits for design and understanding (e.g. Bodker et al. 1991; Suchman & Trigg, 1991; and Luff et al. 2000). However, with the benefits in context come added complexities, which are alluded to when Thomas and Kellogg (1989) discuss ‘ecological gaps’ caused by bringing studies into the lab. To cope and be productive within this complexity I have extracted a number of guiding suggestions from the current literature on contextual study:

- Designers should take a practical approach toward analysing a work setting rather than rigorously following a certain methodology (Wynn, 1991). Responding to the needs of the situation, rather than the rules of a method, may also lead to the development of a new methodological approach suited to those needs (Fisher & Sanderson, 1996).
- Different researchers will view research activity differently. Requirements engineers will aim to produce a partial description of a system to explore the effects of a proposed design change, unlike a sociologist or anthropologist who may be careful

about being much more complete (Jirotka and Wallen, 2000). This also implies that we do not have to take everything into account all of the time.

- Often the researcher will only know what to look for in a study after they have made some preliminary observations of the area (Jirotka and Wallen, 2000).
- Often the researcher will only know what methods might be suitable to capture the available data after they have made some preliminary observations of the area (Fisher & Sanderson, 1996).
- Different representations which form part of an analysis are used for different purposes; one of these purposes might be to communicate issues to stakeholders which will require a representation that only needs minimal training for interpretation (Sumner, 1995).
- The analyst should not prematurely commit to any methodological scheme as it may not be an effective way to proceed (Fisher & Sanderson, 1996).
- Data is often much easier to collect than it is to analyse, particularly with modern techniques such as video capture. Just because this data can be collected doesn't mean that it should and doesn't mean that it should all be analysed (Fisher & Sanderson, 1996).

The lessons above try to emphasise the practical considerations in collecting and analysing data from contextual studies. It is obvious that there is a wealth of data 'out there' but it is the analyst's job to use their available time and resources effectively to find out as much as they want to know. To this end I agree with Bannon (2000, pp 232) that a methodology should *have the flexibility, coverage and ease of use necessary to make it a really useful instrument for designers*. Flexibility, in not being too prescriptive; coverage, in adequately capturing relevant data; and ease of use, in not being too time consuming to learn.

Sanderson and Fisher (1994a) introduce and draw together research interest in the growing and complex area of observational methods for HCI. Despite its growing importance and use they state that there is little support in choosing, applying and evaluating the results from the many techniques that have been developed. To help focus work on the area they name it 'Exploratory Sequential Data Analysis' (ESDA). Their definition of ESDA gives a more formal outline of what a DC analysis would be part of: *ESDA is any empirical undertaking seeking to analyse systems, environmental, and/or behavioural data (usually recorded) in which the sequential integrity of events has been preserved. The analysis of such data (a) represents a quest for their meaning in relation to some research or design question, (b) is guided methodologically by one or more traditions of practice, and (c) is approached (at least at the outset) in an exploratory mode (Sanderson & Fisher, 1994b, pp 255)*. Further structure for a novel approach, in the form of clarifying central questions of an ESDA methodology, can be added by referring to their research in categorising methodological traditions of ESDA practice. I have applied these clarifying questions to DC theory which helps provide a greater clarity and focus in what needs to be achieved (refer to Table 4).

Table 4: Generic ESDA Questions and Dimensions Applied to DC (based on Sanderson and Fisher, 1994b)

ESDA Question	ESDA Dimension	DC Perspective
What's the issue at hand?	Investigative approach	Model cognitive processes in a cognitive functional system over time, potentially including multiple agents and artefacts.
What should be observed?	Setting	Field setting.
	Sampling	Identify functional roles of artefacts, communications, physical layout, and social structure.
	Focus of analysis	Cognitive functional influences in the propagation and transformation of information through the system.
What operations should be done?	Coding and description	Interpret and describe the cognitive functional role of the components in the extended environment.
	Means of analysis	Descriptive: emphasis on insight and interpretation of how things 'really' contribute to system performance.
What's an acceptable type of answer	Sources of rigour	Adequacy of description compared to the actual (extended) cognitive system.

In terms of actually observing and recording data Suchman and Trigg (1991) offer some sound suggestions concerning where to focus attention and how the development of familiarity can influence understanding. When confronting a novel environment to observe it may not be obvious where to focus the analyst's attention as the analyst does not know where to look, does not know the meaning of the unfamiliar activity, and cannot observe all the overlapping activities of several people in detail (Jordan et al., In prep.). Suchman and Trigg (1991) offer four possible recording perspectives that allow the analyst guidance on what to observe:

1. Setting orientated records: records taken of a view or an area e.g. a desk.
2. Person orientated records: records taken of a particular person e.g. secretary.
3. Object orientated records: the tracking of a particular artefact or technology e.g. a patient's medical records.
4. Task orientated records: may require multiple recordings of different individuals working toward a common goal e.g. landing a commercial passenger plane.

Suchman and Trigg (1991) state that analysis is like an iterative design process where meaning is built through observation which is constantly re-evaluated through re-observation. This cycle builds understanding and affords insights as familiarisation develops. I agree with this view but in focusing on familiarisation I do not think Suchman and Trigg (1991) do justice to the special place that analysts find themselves at the beginning of a study. When everything is unfamiliar we notice the details of those things that do not make sense to us and hence we are full of questions before familiarity glosses over details; Winograd and Flores (1986) might say that an unfamiliar situation is rich in 'breakdowns' before the details of activities are assimilated into our understanding. I would argue that analysts should take advantage of the truly unfamiliar nature of novel situations to notice the details, and record questions and observations before familiarity has a chance to develop.

One of Clark's (1997) concerns for a science based on the conception of the extended mind (see 'Introduction to DC') is *isolating appropriate large scale systems to study and motivating some decomposition of such systems into interacting component parts and processes (Clark, 1997, pp 84)*. The full force of this concern includes taking account of those elements that are internal, external, physical and social that have an influence in the wider cognitive functional system. With this, and a recognition that it is impractical to expect to study everything in a complex contextual domain (a theme that had emerged through the literature of contextual study) we must expect to divide and split the context into manageable portions and focuses. With this in mind and with regard to those elements of a context that DC is interested in studying, the ideas of Contextual Design seem very amenable to the DC cause (Beyer & Holtzblatt, 1998). Contextual Design involves studying a context and building up models to describe that context. There are five models outlined by Beyer and Holtzblatt (1998) that overlap to describe different elements in a contextual study:

1. Flow Model: Focuses on communication.
2. Sequence Model: Focuses on the order of events.
3. Artefact Model: Focuses on the reasons for the design and structure.
4. Cultural Model: Focuses on the role sand relationships of different individuals.
5. Physical Model: Focuses on the layout of the physical environment.

The idea of building a description of the system through developing overlapping models of this nature seemed suited to the aims of a DC analysis. Of course, the analysis would have to be focused on those questions most pertinent to the DC theory.

The data collection method of Contextual Inquiry (Beyer & Holtzblatt, 1998) also seemed like a useful tool to utilise given the context of my analysis. This involves observing work as it happens and finding opportune moments to ask questions of the actors involved, combining observation and interview within the context of study.

Stages of Analysis Undertaken

This section aims to provide an outline of the main stages that I undertook in my analysis; these stages have been taken from a diary that was kept through the process:

1. A video log was recorded. This provided a general log of the content of the videos and provided an opportunity to generate questions in this unfamiliar area.
2. I planned for the first visit which included recognising my overall objective, which was to develop my understanding enough to start to begin a description of the

system; and specific objectives, which included what I wanted to observe, who I wanted to talk to and where my focus of analysis should be.

3. In carrying out the first visit I created a map of the room, retrieved an incident card (a paper artefact used at the LAS CAC) and took a number of photos of the different screens that were used. I took extensive field notes in what was an exploratory visit aimed to familiarise myself with the context, processes and activities.
4. In light of my visit I returned to the videos that were now much more meaningful. These were useful in identifying the processes, communication and artefacts that all played a part in the wider cognitive system.
5. Based on my first visit I started to build a description of the system. This generated more questions that needed to be answered and representations that could be taken along and annotated at the next visit e.g. a map of the room and diagram of the desk layout.
6. The second visit was planned which directly aimed to provide material to fill the gaps in my description that were not covered in the first visit. The exploratory approach in the first visit was not taken, as I now knew what I needed to find out and where I was going to find the information.
7. On the visit I completed the questionnaire that I had created for myself to recall all the questions that needed to be asked. I also checked and annotated those diagrams that I had already done the first drafts of. Despite this added structure I still maintained the Contextual Inquiry approach of observing and fulfilling my inquiry needs at opportunistic moments; this included those pre-prepared questions and new questions that naturally arose from the context and activity.
8. The data gathered in the second visit was used to complete the description of the system. However, I returned to the video data to carry out a more detailed artefact observation by tracking how the incident card and tray system was used (this was more meaningful to me after the data I had collected on the second visit and it became apparent that this would be a useful area to focus on in my analysis – due to its large role and the prospect of it being ‘phased-out’ in place of a fully computerised system).

Analysis of London Ambulance Service (LAS) Central Ambulance Control Room (CAC)

This section includes the analysis of the LAS CAC that was undertaken whilst developing the codified DC methodology. It provides a practical example of how the codified DC method can be used to analyse a system.

Overview of the Analysis

The core of the analysis involved building three separate overlapping models that were informed by Contextual Design (Beyer & Holtzblatt, 1998). Within each model there is a hierarchical description which aids the analyst in being able to drill down and add detail as they progress in building the description. Each model also recognises specific issues that arise within it; this is important because even though they overlap they each have their own issues in contributing positively and negatively to the performance of the system.

Information Flow Model
This section of the analysis provides a description of the flow of information in the system. More specifically this turns the focus of the analysis to the communication between the participating members, what their roles are and the sequence of events, which provide the mechanics of the system.

Physical Model
This level of analysis aims to describe those factors that influence the performance of the system, and performance of components of the system, at a physical level. This level of description is important from a distributed cognition perspective as those things that can be physically heard, seen and accessed by individuals will have a direct impact on their cognitive space and hence will shape, empower and limit the calculations that individuals perform.

Artefact Model
The influence of artefacts on the performance of system components and hence the system as a whole is very important for an analysis using distributed cognition. According to distributed cognition our cognition extends outside the skull into the world. This means that the environment that we inhabit plays an intrinsic part in the types of cognition we are involved in; bringing artefacts, representations, and environmental affordances centre stage in a cognitive analysis.

Information Flow Model

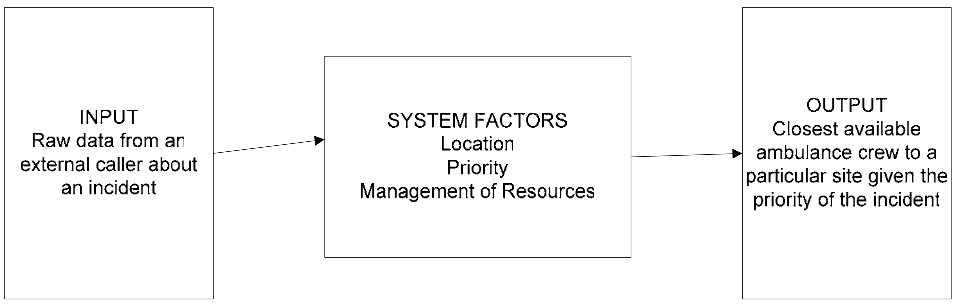
To provide a coherent description of this level of analysis of the system I have thought it best to present the information in a hierarchical manner. Starting with a high level input-output diagram of the system which summarises what raw information goes into the system, the main system factors, and what the main target output is. There are many other factors that affect system performance (e.g. the effect of staff training) and outlying tasks (e.g. paramedic advice to low priority incidents) which we need to consider whether to include in this analysis. When modelling a system we necessarily provide a limited representation of the real system; successful modelling should strive to be made more powerful by focusing on those elements most potent to the analysis. To this end the high level representation helps provide a reference frame for the focus of the analysis.

This high level representation can be decomposed to look at the system in more detail. This means looking at how the component parts are organised and integrate to form a coherent whole. These component parts generally include the actors, the tools the actors use, and how they integrate to achieve their goals. In keeping with the hierarchical structure I have developed two flow diagrams: the first concentrates on describing the individual branches of the communication channels in the system; and the second emphasises the key information flow properties of the system. This detail is broken down into a summary, detail, further notes and issues. This structure allows for a development of the model in increasingly further detail and allows the analyst to flag potential system issues as the representation is developed. The representation of the model should not only allow for a clear representation but also afford an effective learning experience for the analyst that is developing the model.

Overview: High Level Input-Output Diagram

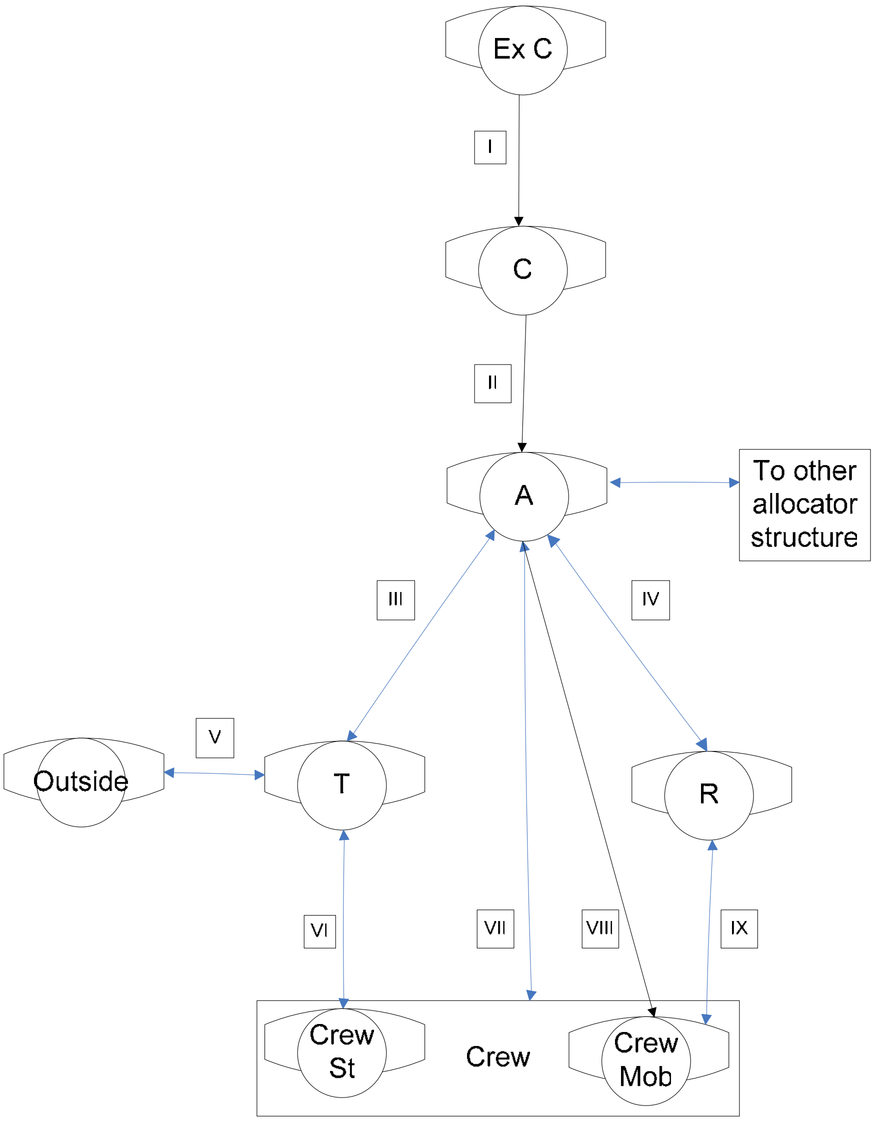
This diagram shows the main input and output factors of the part of the system that I am concerned with in this analysis. We are interested in seeing what information propagates through the system in the task of allocating ambulance crews to incidents.

Figure 2: Input-Output Diagram of the Allocating Process



Flow of Information: Looking at communication channels

Figure 3: Flow of Information by Communication Channels



Key

Letter	**Actor**	**Role**
Ex C	External Caller	People who make the incoming emergency 999 calls.
C	Call Taker	Takes the details of the incoming calls and enters it into the computer system.
A	Allocator	Person who decides which ambulances should go where and when.
R	Radio Operator	Speaks to ambulance crews via the radio.
T	Telephone Dispatcher	Speaks to ambulance crews via the telephone.
Crew St	Ambulance Crew	Ambulance crews based at the station.
Crew Mob	Ambulance Crew	Ambulance crews which are mobile.
Outside	Outside contacts	Anyone that needs to be contacted via phone e.g. calling external callers or other emergency services

Table 5: Description of the Individual Communication Branches in Figure 3

<table>
<tr><th>Process</th><th>Comment</th></tr>
<tr><td>I</td><td>

<u>External Caller to Call Taker</u>

SUMMARY
The call taker receives a call. The external caller is greeted and taken through a set procedure to verify their contact information and location, and to categorise the call according to its medical priority.

DETAIL
In terms of the efficient operation of the whole system this stage is very important. It distils the raw information from the external caller into a form where the rest of the system can act upon it in a fast and effective manner. The call taker uses the ProQA 3 system, which is a computerised version of the APMDS (Advanced Medical Priority Dispatch System), to interview the external caller. This system operates much like a computer 'wizard' – extracting information through a structured dialogue. This system allows the incident to be classified in terms of its medical urgency and advises the external caller on any action they might wish to take e.g. it was reported that a call taker who had only been using the ProQA 3 system for two weeks successfully talked an external caller through delivering a baby. The ProQA 3 system structures the dialogue in the following manner:

- External caller is greeted
- Questioning procedure commences
    - Verify telephone number
    - Location
    - Chief Complaint
    - Further Support and Advice
    - Close the call e.g. "Go to meet the ambulance."

It is worth noting that the most essential three pieces of information are found out first (contact number, location, and incident priority). As soon as the location is determined the relevant sector desk will receive the 'live' file which is updated on their system as the call taker inputs further information. This allows the sector desk to act on the information at the very earliest opportunity.

FURTHER NOTES

- The call takers are aware that about 10% of calls are audited and marked out of 100. Marks are deducted for deviating from the script e.g. leaving out closing information. It was reported that this mainly happens when external callers are being awkward or are particularly hard to communicate with.
- The call takers are aware that they should be collectively trying to reach the government set ORCON targets. This means that 999 calls should be answered within a certain period of time. An ongoing status of the percentage of calls reaching the ORCON targets, the number of calls waiting and the number of call takers available is displayed on boards around the room so all are aware of the current situation.
- It was noted that the ProQA 3 system was an indispensable support for the call takers. This meant that the dialogue was structured, and that the call takers could deal competently with medical emergencies

</td></tr>
</table>

	and even offer relevant medical advice with minimal medical training. A card version of the ProQA 3 system was available as a back up. This replicated the wizard using laminate sheets, tabs and indexes. • The call takers have two screens: one to take them through the ProQA 3 system and enter the information, and the second displays a map so that the location of incidents can be viewed. Once an incident is located it is shown as a red triangle on the map. Unlike the sector desk screens ambulances are not shown on the map. The map provides a representation that helps the call takers visualise the location and narrow down the area e.g. if a long street is identified the call takers will ask for more detail. • There are many abbreviations and shortcuts that can be entered by the call takers, that are familiar with the other members of staff and recognised by the computer system e.g. CVA (cardio vascular accident or stroke), RD (Road), ST (street), DIB (difficulty in breathing), and RTA (Road Traffic Accident). A '71 YOM' would be a 71 year old male. • Registered BT landlines show the address of the caller. It was hoped that this would also be extended to cable customers soon, although there did not appear to be a firm timescale. The general location of mobile phone callers could be viewed on the map as a green shaded area. This showed the area of their nearest transmission mast that the incoming mobile phone call is connected to. • Doctors should ring a separate number for hospital transfers. The call taker then negotiates a time in which the hospital transfer should be completed. This negotiation can be important for giving the system some added flexibility to effectively deploy resources. • The quality of people's English can vary quite substantially around the capital. In the most severe instances the call is transferred to a separate service where translators provide assistance. • Sometimes the call takers can be very busy and struggle to keep on top of taking calls; this can be made worse if an accident happens in a busy street and many people call about the same incident. If callers hang-up then they have to be called back by a call taker to make sure that they did not require an ambulance. ISSUES • One of the chief complaint questions involves asking the external caller whether the person is experiencing chest pains. People sometimes intentionally answer this question incorrectly so that they gain an advantage in getting a higher priority call when really it is not warranted. • Doctors sometimes call 999 rather than their separate number to get through faster because they know that their call will be given a higher priority. • If a call comes in from a previous caller the system does not recognise and recall what was previously said so the person is in a position where they have to explain everything again. These instances are likely to be time consuming and frustrating for all involved.

II	**<u>Call Taker to Allocator</u>**
	
	SUMMARY
	Once the call taker has established the external caller's location the 'live' file is automatically linked to the relevant sector desk via the computer system. The sector desk can then view the information of the call as it is updated. The allocator's actions then depend upon the priority of the incident and the nearest available crew. The allocator roughly goes through the following process:
	• A new incident is received showing first the location. This then updates when the incident priority is known.
	• The incident details are viewed to get an overview of what has happened.
	• The nearest vehicle screen is viewed to see which crews are the shortest distance away.
	• The process for allocating the nearest available vehicle is begun which may need the support of the:
	    o Radio operator (for mobile vehicles)
	    o Telephone dispatcher (for vehicles at station)
	• The vehicle is selected, sent an MDT (Mobile Data Transfer) and should accept the call. However, if the vehicle is at a station it will need to be called prior to this happening.
	
	DETAIL
	As the call taker updates information from the call it is immediately shown at the relevant sector desk (provided enough information has been gathered to identify the correct sector desk).
	
	The location and priority are both essential pieces of information in dealing with an incident. The location allows the computer to transfer the call to the relevant sector desk, allows the sector desk to establish which crews are most appropriate to attend in their sector, and lets the crews know where to go. The priority gives the urgency of the incident – whether it is immediately life threatening (red call), a serious emergency (amber call), or whether it is less severe (green call).
	
	The information that is transferred between these two individuals is generally done automatically by the computer – reducing direct contact. The rest of the system works on the distilled information collected through the AMPDS system. In the rarity that extra information is needed the external caller can be called using their contact details. Due to this the call takers do not need to be closely situated with the sector desks and can concentrate solely on their task of receiving calls and logging information.
	
	Once the location and priority have been identified a crew can be dispatched. This can often happen before the call has been finished thanks to the linked computer system and the order that the information is gathered. In these cases, where the call is unfinished, the crews may only be given the location and chief complaint. The crews automatically receive an updated MDT file once the call has been completed.

	FURTHER NOTES • The allocators want to manage their resources as best they can and this is primarily achieved by working on the call location and priority. However, other factors do bear an influence e.g. if a resuscitation is likely then two crews might be sent to relieve each other, there may be multiple patients, not all crews have a trained paramedic, etc. • The call priority affects the Government set ORCON targets and governs the urgency that the call is allocated i.e. a red call will be dealt with above an amber call. A red call has to be reached within 8 minutes and an amber call has to be reached within 14 minutes. This time starts from when the priority code is established through the AMPDS system. • Unlike sector desks which work on all the calls in their area, the FRU (Fast Response Unit) desk operates as a support for the most serious calls (red calls) across all sectors. This operates as an add-on because normal ambulances have to be sent regardless of the FRU attendance. Unlike the sector desks the FRU desk only receives red priority calls, they are not area based. ISSUES • If an allocator identifies an ambulance belonging to another sector suitable to attend an incident in their area, they have to wait until the call taker has completed the call before the call can be transferred to the relevant sector desk to be allocated. Sector desks can only transfer MDTs to their own crews. Due to this there can be a significant delay if the call takes a long time e.g. if an interpreter is needed, or worse still if the person is in labour the call taker cannot finish the call until the crew arrives providing an obstacle for MDT transfer. • Whilst a call is active the allocator can receive Police updates on the incident. This happens by the printer giving the CAD (Computer Aided Dispatch) number and an indication that they have received a Police update. The allocator then checks this via the computer, decides whether the crew need to be notified about it and gives it to the radio operator to verbally notify the crew. Given the allocator can already send text via their MDT system these messages could be forwarded.
III	**<u>Allocator to Telephone Dispatcher</u>** SUMMARY The telephone dispatcher supports the allocator by dealing with incoming telephone calls, contacting the ambulance stations and dealing with queries that either arise internally or externally. In allocating crews the telephone dispatcher's normal role is to contact a station identified by the allocator to find out which particular crew will attend an incident. This information is relayed to the allocator so the correct crew is allocated the call. This can be done by passing the incident card to each other without talking, purely by talking or a combination of the two.

	DETAIL Since the introduction of the MDT system the activity of the telephone dispatcher has reduced as their primary role was to call the crews situated at the stations and read the details of the call to them, which was noted by the crew before they left. Now this information is automatically transferred to the vehicle once it has been allocated so the telephone dispatcher's primary role is now to identify the correct crew at the station. However, there is still a lot to do and the telephone dispatcher is a valuable member of the team for support. Allocators cannot allocate crews at a station until they know which vehicle to send the MDT to and know that a crew is on its way to the vehicle to accept it. If a crew is away from the vehicle they have no way of knowing that an MDT has arrived. The telephone dispatcher liaises with the crews whilst they are at the station and away from their vehicles. The telephone dispatcher might also need to contact the station to find out the status of crews and check what vehicles are in use by crews – this can provide valuable synchronisation information between what the sector desk believes is going on and what is actually going on, on the ground. FURTHER NOTES • The telephone dispatchers cannot contact crews via their mobile phones. The crews do have mobile phones but only senior members of staff have their numbers for emergency use. The phones are mainly for the crew's use in an emergency. This is unlike the FRU where mobiles are used more freely and extensively in normal operation. • The telephone dispatcher can also provide a supportive role by answering queries from the crews if they ring (this can act as a buffer for the allocator), liaising with the Police and other parties that can be reached by phone. ISSUES • There could be a more efficient transition from an allocator wanting to allocate a crew at a station rather than liaising with the telephone dispatcher who in turn liaises with the station. Could crew members be automatically notified if an MDT is sent to their vehicle? Is there a lot of time lost phoning the station talking to the crew and them getting to their vehicles? Could they have a pre-set crew ready to respond rather than deciding when a call comes in?
IV	**<u>Allocator to Radio Operator</u>** SUMMARY The radio operator supports the allocator by dealing with incoming queries from the crews via the radio, informing crews of details and circumstances whilst they are on the move and checking that the correct statuses for all crews are maintained (this is primarily so that the crew statuses, that the allocator is working on, are up-to-date and reliable). When allocating crews the radio operator's role is to contact any crews that

	are mobile that have not accepted their MDT within a specified time (approximately a minute). The radio operator also gives Police updates to the crews as they are passed over by the allocator. DETAIL The radio operator provides a similar supportive role as the telephone dispatcher but they work more closely with the crews that are mobile over the radio. They are perceived as the allocator's deputy. If the crews are on the move and have not replied to an MDT incident then they might be prompted to accept it via the radio operator. Also, if a crew's status needs to be checked, if they need to be updated on further information, or if they are changed to a different incident then this will be done over the radio. FURTHER NOTES • The allocator and radio operator work in close coordination. They are sat either side of the tray which organises how the incident cards are allocated between the different ambulances. Each incident card refers to an incident, and each slot represents a different ambulance, so a card in a slot shows which ambulance has been allocated a particular incident. Communication between the allocator and radio operator is achieved through direct speech, passing cards to each other and more implicitly by overhearing the other's conversations. ISSUES • It was mentioned that the incident cards and the tray would be phased out once confidence in a solely computerised system had grown. How would this effect how the allocator and radio operator work together successfully? What affordances are available with the card system which might be compromised when using a solely computer based system?
V	**<u>Telephone Dispatcher to Outside</u>** SUMMARY The telephone dispatcher will contact people via the telephone in relation to any incident. DETAIL The telephone dispatcher may be called upon to make calls to people in relation to an incident that an ambulance crew is attending. This may involve liaising with other emergency services or re-contacting the person that reported the incident to gain further information for the crew. FURTHER NOTES • Although this route is the primary outlet of external calls the allocator and radio operator also have phones where they can make calls, which they do if the telephone dispatcher is unavailable (either through a high workload or absence) or if the transfer of the task will lead to an undue delay of the action e.g. it was observed that an allocator called the crew themselves as the incident involved a

	choking baby and so they did not want any delay. ISSUES • There could be an issue when the crew is mobile and they need to contact someone from the outside which they don't do directly. The current communication structure indicates that the crew contact the radio operator, who has to pass the message through the allocator to the telephone dispatcher to whoever the external party is. Two instances where this may occur are: when a crew want a hospital notified of a blue call so they have an emergency team waiting for their arrival and when directions are needed to an incident from an outside party.
VI	**<u>Telephone Dispatcher to Ambulance Crew at Station</u>** SUMMARY When telephone dispatchers contact the crews it might be to check the status of vehicles at that time or to identify which crew will respond to an awaiting call before the MDT can be sent to their particular vehicle. DETAIL The telephone dispatcher contacts the crews and other ambulance staff when they are situated at the station. The main reason this is done when allocating crews is to find out which crew will attend an incident from a specific station. From the allocator's point of view each ambulance is just as close to the incident, and from the station's point of view there may be a crew suited for a certain type of call (e.g. not all crews have paramedics) or they may have agreed an order locally, between the crews on duty at the station. The telephone dispatcher might also be called upon to help in contacting hospitals, other emergency services, and finding out the statuses of crews at the station. FURTHER NOTES • The telephone dispatcher's role has diminished since the introduction of the MDT system. Prior to the implementation of the MDT system the telephone dispatcher was required to repeat the details of the call but now these are transmitted electronically. • The telephone dispatcher acts as a buffer between the allocator and incoming calls. They can take messages and relay information leaving the allocator free to advise and carry on their main duties. The allocator may also give them tasks to complete leaving themselves available to respond to other events. ISSUES • The FRU desk has a much more flexible system for contacting their crews. They are able to ring the crew's mobile phone, the phone in the vehicle, the personal radio and the vehicle radio. The normal sector crews can only be contacted via the station telephone and the vehicle radio. Apparently personal radios proved unsuccessful for sector crews and it was believed that their use diminished as they were not looked after well enough because they were assigned to

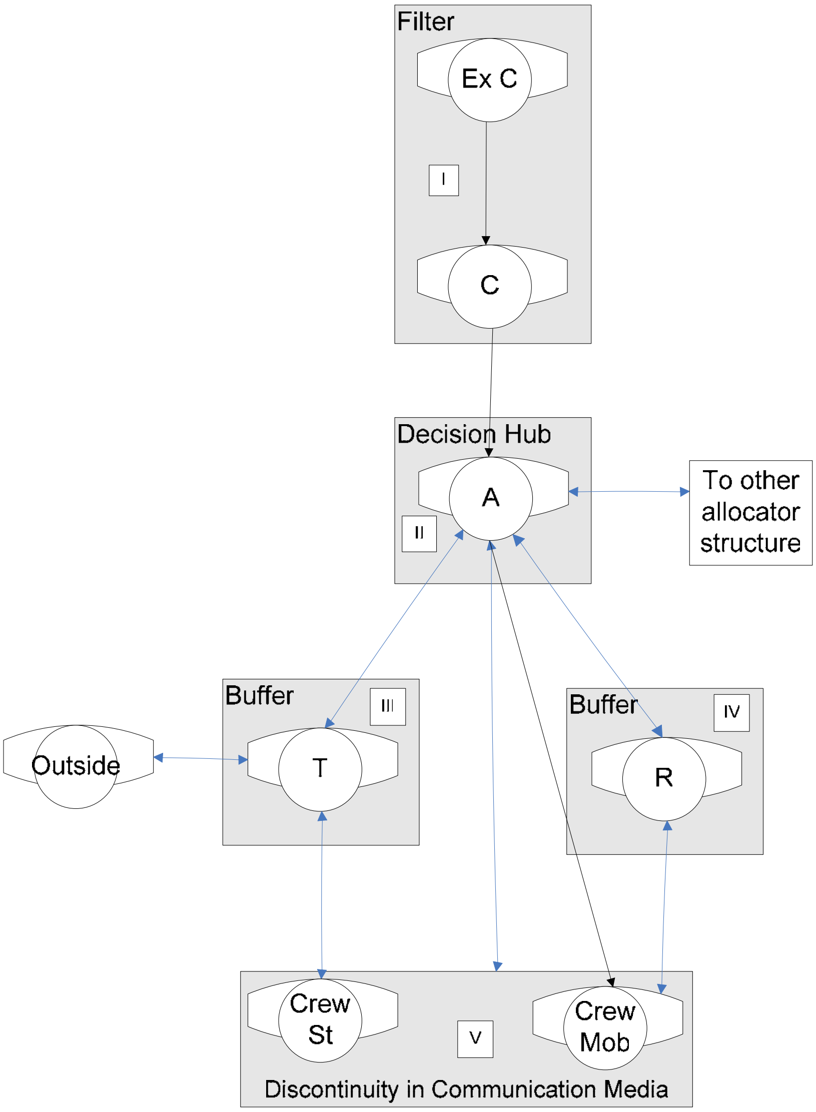
	vehicles rather than individuals.
VII	**<u>Allocator to Ambulance Crew (via computer system)</u>** SUMMARY Allocators use information provided to them via the computer system extensively to make decisions in managing their resources. This includes the status of the ambulance crews and their location. DETAIL The computer system provides constant feedback to the allocators of the ambulances' statuses (e.g. whether they are available or on their way to an incident) and their location. The location of the ambulances is maintained through satellite tracking technology whereas the statuses of the ambulances is updated by the crew when they accept a new call, when they arrive at a scene, when they are on their way to a hospital and when they are available. When they are allocating a call they are presented with a visualisation that lists all the closest ambulances to that incident in order. This representation, calculated by the computer, offloads much of the calculation from the allocator, transforming two-dimensional spatial coordinates to a single ordinal figure. The allocator then can work down the list taking into account the priority of the call and the current statuses of the ambulances close to the incident. In their 'neutral' position (i.e. when the allocator is not taking any action) the allocator will typically be viewing a screen that shows incoming calls in the order they are received. Once a call comes through the allocator will check the details, and then see where the nearest vehicle is to it. By pressing a button they can go from the call summary screen to a screen showing the nearest vehicles in order of distance. The allocator would then typically pick the nearest available vehicle. However, this decision process can be made more complicated e.g. a vehicle on its way to an amber call can be diverted to a red call meaning that the amber call must be reassigned to a different crew. FURTHER NOTES • The allocator is the person who is at the centre of the decision of how to allocate their resources but information gathered by the computer is also available to other LAS members. Sometimes this is needed to support the allocator's role, e.g. part of the radio operator's remit is to make sure the crews have updated their status. • When allocating a call the visual representation lists the nearest ambulance as the crow flies but this might not be the closest – the allocators can check their map screens to show where the incident and ambulances are to take into account things like major roads and one-way systems. ISSUES • The system lists the closest ambulances as the crow flies but not according to the road layout, this could make considerable difference in London where one-way systems and main roads could make a lot

	of difference to the speed of response to a call. The system that calculates distances could be enhanced to make it better reflect reality.
VIII	**<u>Allocator to Mobile Ambulance Crew</u>** SUMMARY The allocator normally only communicates directly with the crews via the MDT. This is usually to send incident details related to a call that the crew should attend. However, there is a function that the allocators use which enables them to send text messages to the crews e.g. to ask them a question or to remind them to update their status. All information that requires talking to the crews should be done through the telephone dispatcher and radio operator. DETAIL Once the allocator has allocated a vehicle to an incident then the details are transferred via the MDT system. The crew receives all the information that the sector has up to that point and then receives an update once the call taker has finished the call. The allocator can also send a text message to the crew via the MDT system. This might be a prompt, but if it is something that needs a reply then the crew will have to do so via the radio operator. FURTHER NOTES • The allocator's proper role should be composed of allocating crews to incidents via the computer, and liaising with the telephone dispatcher and radio operator. The allocator should not be in a position where they contact the station or the crew because they should be free to allocate. However, sometimes they contact the crews at the stations directly because they feel it is fit to do so or there may be a shortage of staff. Where there is a shortage of staff (e.g. a telephone operator is not in attendance) then this buffer is removed and the allocator and radio operator are put under more strain – the allocator may fall behind in allocating crews due to their extra workload. ISSUES • Sometimes details cannot be transferred via the MDT system e.g. the FRU desk can sometimes offer support to crews on amber calls but the system does not have this flexibility built into it. • When the allocator receives a Police update they will receive a card from the printer notifying them of a Police update and be given the CAD, this is then checked and passed to the radio operator to tell the crew. Given the MDT has a text facility it would be good if the crew received this directly or could merely be forwarded the details. • The MDT transfer can be held up by the allocator wanting to allocate the call to a crew belonging to a different sector. The source of the delay is in the technical ability of the system rather than communicating with the other allocators.

IX	**<u>Radio Operator to Mobile Ambulance Crew</u>** SUMMARY The role of the radio operator is to be the main point of contact for crews once they are mobile. This involves updating crews with further information and dealing with their queries. DETAIL The radio operator works very closely with the allocator and the crews. They are the main point of contact for queries e.g. the property may be closed and locked, or the crew may be unable to find its location. The radio operator has a head set to talk and listen, and controls the radio via a touch screen display. When ambulances want to talk to the radio operator they join a queue, which is clearly visible on the display, which provides a structure for the radio operator to work through. The radio operator will generally contact the crews for any reason, as required, whilst they are on the move e.g. extra information update, check status, etc. FURTHER NOTES • The sector desks can only contact crews via their vehicle radio as the use of their personal radios has diminished. It was believed that this may have been caused by an increased negligence in the care of the radios due to diminished responsibility – the personal radios were assigned to vehicles and not to individuals. The FRU desk is able to contact crews via their personal radios which provides a more flexible communication system. ISSUES • A crew may contact the radio operator to report a ‘blue call’ which means that the appropriate hospital should be warned that they are coming in and should have an emergency team ready for them. This is the first step in a convoluted process. The radio operator notes down the details from the crew; then passes these to the telephone dispatcher who relays them to the hospital. It was reported that the hospital often has additional questions that the telephone dispatcher is unable to answer. On the surface it appears that it might be easier if the crews could take a more direct approach in contacting hospitals for this purpose. • The crew may need help in trying to locate a specific incident and may benefit from talking to the external caller directly in some instances, which they do not do at the moment. For example, local knowledge and details (e.g. a skip, a pub, the third lamppost on the left) might prove useful in directing the ambulance to a specific location. This might seem like extraneous detail when relayed to a remote radio operator who does not share the same access and engagement to their physical space. There is a facility for a three way call via the radio but it was reported that this is rarely used if at all.

Flow of Information: Overview of key flow properties

Figure 4: Overview of Main Information Flow Properties of System



Key

Letter	**Actor**	**Role**
Ex C	External Caller	People who make the incoming emergency 999 calls.
C	Call Taker	Takes the details of the incoming calls and enters it into the computer system.
A	Allocator	Person who decides which ambulances should go where and when.
R	Radio Operator	Speaks to ambulance crews via the radio.
T	Telephone Dispatcher	Speaks to ambulance crews via the telephone.
Crew St	Ambulance Crew	Ambulance crews based at the station.
Crew Mob	Ambulance Crew	Ambulance crews which are mobile.
Outside	Outside contacts	Anyone that needs to be contacted via phone e.g. calling external callers or other emergency services

Table 6: Description of the Main Flow Properties shown in Figure 4

Process	Comment
I	**<u>Filtering of External Caller Information</u>** SUMMARY Call takers receive calls from external callers who help in filtering out the required information so that the system can perform effectively. They will also negotiate times that hospital transfers need to be made with doctors, which also has an impact on the management of resources in the rest of the system. DETAIL The filtering of information at this stage is no trivial task and is essential for the successful operation of the rest of the system. From all the things that the external caller might wish to say to the call taker the allocator wants to know two key things: the incident priority and its location. The whole system is enhanced as these two pieces of information are amongst the first things found out by the call taker, using the structured dialogue provided by the ProQA 3 system, the rest of the system can act on this information whilst the call continues. FURTHER NOTES • In the filtering process the raw information from the external caller is transformed into a spatial fix, which is used in computer calculations, and one of a limited set of priority codes. • Further details can be found in Table 5. ISSUES • Allocators cannot transfer an incident to another sector to be dealt with until the call has finished, even though they have enough information to know that is the right decision. This can delay the allocation of ambulance crews. • In being prioritised some external callers answer the chest pains question falsely to gain an advantage in the system which stretches resources. • As there is a bottle neck in the number of external callers compared to call takers some doctors will use the emergency line rather than using their dedicated line to get through faster. • Duplicate calls can put a strain on the allocators e.g. if there is a road accident in a busy street the LAS might receive 20 calls about the same incident and these will all come through to the allocator as separate calls.
II	**<u>Allocator at the Decision Hub</u>** SUMMARY In focusing on the process of allocating ambulances to incidents the allocator can be seen as the central person that makes the decision of what ambulance should go where and when.

	DETAIL
	The allocator is the main decision maker in the allocating process and is at the hub of a number of communication channels: from information filtered by the call takers; from external information coming through the telephone dispatcher, radio operator, and the computer system; and from other sector desks (via other allocator structures).
	
	FURTHER NOTES
	• The allocator has a number of representations that aid their decision making e.g.
	    o the nearest vehicle to incident screen transforms two-dimensional spatial locations to one-dimensional ordinal values, and the fact that these are placed in order means finding the nearest vehicle to an incident is an easy perceptual calculation;
	    o the map shows roads and ambulance locations so real world structure can be incorporated into the decisions;
	    o the categorisation of calls into levels of priority makes calculations more 'rough and ready' and hence faster to respond to; and
	    o the colours that represent those call priority categories aid perception.
	• The allocator can concentrate on their main role of allocating whilst the radio operator and telephone dispatcher do the necessary communicating with the outside world.
	• Further details can be found in Table 5.
	
	ISSUES
	• The representations could be enhanced to enhance decision making capability e.g. showing nearest vehicle by road rather than as the crow flies.

III	**The Buffer of the Telephone Dispatcher** SUMMARY The telephone dispatcher supports the allocator by dealing with incoming telephone calls and contacting outside parties as required through the business of allocating. This provides an extended arm of communication for the allocator and protection against a potential barrage of incoming calls. DETAIL The telephone dispatcher contacts crews when they are at the station and liaises with external parties e.g. re-contacting external callers and other emergency services. The telephone dispatcher will also take incoming calls freeing up the allocator for their main role and leaving them in an advisory position. FURTHER NOTES • Due to the close nature of the working between the telephone dispatcher and allocator they require close contact that allows them to communicate effectively. • Further details can be found in Table 5.

	ISSUES • Restrictions on communication channels with the crew limits the telephone dispatcher's ability to contact them. • The MDT system is limited to being sent to vehicles, so whilst vehicles are at the station and the allocator doesn't know which crew is due out next there is a blind spot and a delay in finding out this information.
IV	**<u>The Buffer of the Radio Operator</u>** SUMMARY The radio operator supports the allocator by dealing with incoming radio communications from mobile crews and contacting them whilst away from the station. This provides an extended arm of communication for the allocator and protection against a potential barrage of incoming requests and queries. DETAIL The radio operator contacts crews when they are mobile and deals with incoming queries. The radio operator can be called upon to contact mobile crews to allocate, reallocate, and update them on incident information. Like the telephone dispatcher the radio operator acts as another branch of communication and resource for the allocator. FURTHER NOTES • Due to the close nature of the working between the radio operator and allocator they require close contact that allows them to communicate effectively. • Further details can be found in Table 5. ISSUES • Restrictions on communication channels with the crew limits the radio operator's ability to contact them.
V	**<u>Discontinuity in Communication Media used by the Ambulance Crews</u>** SUMMARY The ambulance crews have two mains forms of communication that they use to talk to the sector desk: they use the phone when they are at the station and away from their vehicle; and use the radio when in their vehicle. This discontinuity is amplified as the two communication channels are dealt with by different people at the LAS control room. DETAIL The main sector ambulances have two main forms of communication with the sector desk whose use depends on where they are located. If the crew is at the station they are likely to be away from their vehicle and so the station phone will be used. If the crew is mobile they are likely to be in their vehicle and so the vehicle radio is used.

	FURTHER NOTES • It was reported that sector ambulances did have personal radios at one stage but their use diminished. It was thought that this happened through neglect as the radios were not assigned to individuals but to the vehicles that they used. • It was reported that all sector crews have mobile phones for their personal emergency use but their numbers were not shared so these couldn't be used as a communication channel by the sector desks. • The FRU desk has a different set up from the main sector desks. Their vehicles are more dynamic in that they are always on the move and have a variety of communication channels that they can be contacted on; in addition to the vehicle radio they also have a personal radio, a vehicle phone and a mobile phone. • Further details can be found in Table 5. ISSUES • Due to the set up in communications there is currently a lengthy procedure if a crew need to contact an external party e.g. if a crew want to notify the hospital that an emergency team should be on standby to meet them it originates at the crew, then passes to the radio operator, through the allocator, to the telephone dispatcher, finally to the hospital. • There may be circumstances where it might seem more efficient for the crew to be able to speak to the external caller directly for directions rather than through the sector desk – this could allow for the crew and the people at the incident to come to a shared space more quickly. There is a facility for the radio operator to facilitate a three-way call but this function is rarely used if at all.

Physical Model

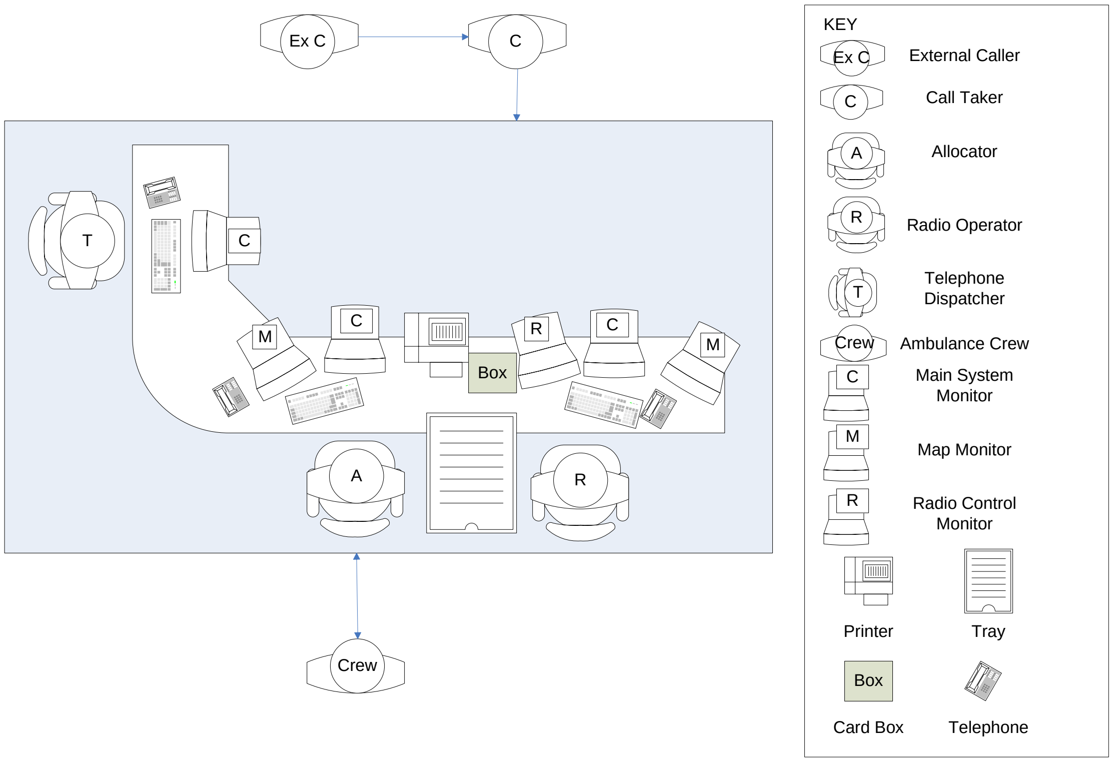
There are a number of different levels which we may choose to model but like other areas of analysis we must choose those levels that are most relevant to our focus. From a physical perspective we may take the environment of the individual, the team, wider working unit and the organisation; or from a more location based perspective we may take a desk, a room, a floor or a building. Like other areas of analysis bounding decisions have to be made in terms of the relevancy of the material under study and the potential payoff of an area of enquiry (i.e. analysis is costly in a number of ways and so payoffs in effort should be maximised). It is interesting to note that what might be considered relevant by one analyst may be different to another but this is the nature of research. Following these principles I have chosen to focus on the structure of the sector desks and the layout of the room – both of which have important properties that help structure information flow and hence affect the performance of the system.

In considering the effect of the physical layout of the system we will want to look at the component parts of the system and ask ourselves questions about the proximity of, and access to, devices and people; what can be seen in an individual's horizon of observation; and what can be heard in an individual's zone of normal hearing. These questions centre around the most influential senses of the human being, hearing and vision, both of which have to be considered differently and both of which will affect the information processing ability of an individual and consequently the information flow in the system.

Sector Desk Level

SUMMARY
There are seven sector desks in the London Ambulance Service (LAS) control room each of which has the responsibility of allocating ambulances to incidents in an area of London. The sector desk can be viewed as an information hub which receives information via computer from the call taker; and other information from the external environment via the MDT (Mobile Data Transfer) system, satellite tracking and communications via the radio and telephone with ambulance crews. This information has to be properly integrated and considered to achieve the effective management of resources. The decisions of how to manage these resources lie with the allocator, and due to their central role we can view the layout of the desk as being built up around the allocator to help support their task.

Figure 5: Sector Desk Diagram



DETAIL
Communication (Access to Actors)
The allocator is sat in close proximity and in between the radio operator and the telephone dispatcher so that s/he has easy access to them. The allocator can talk to them directly and pass artefacts to them to trigger behaviour (e.g. passing an incident card without talking is enough to trigger behaviour in either actor). All three actors are within each others zones of normal hearing so the overhearing of conversations can enhance group awareness, which impacts on group monitoring of events and tacit learning in less experienced members of staff.

Access to Artefacts
It is easy to see from the desk level diagram that the three different actors that form the component parts of the sector desk have access to different artefacts to fulfil their roles. This shows how the environment is shaped to support specific tasks. Each actor has access to a 'main system monitor' that gives them access to the LAS computer system which shows incident details and the statuses of ambulance crews. This is essential for finding out what is happening in the allocating procedure and what needs to be done. In addition to this monitor the allocator and radio operator also have a 'map monitor' which allows the actor to see where incidents are located and where ambulance crews are via satellite tracking. This is less relevant for telephone dispatchers who will only contact crews when they are located at their stations, meaning mobile crew locations are not essential to their work. The radio operator has one additional monitor, the 'radio control monitor' which provides a touch screen interface for controlling the radio.

As can be seen from Figure 5 the desk is an 'L' shape with the telephone operator positioned more remotely than the radio operator. This is because the radio operator plays a more central role in the allocating process, keeping track of incidents and crews whilst they remain active because the crews are away from the station and only contactable via their vehicle radios and MDT system. Due to this role the allocator and the radio operator have shared access to the printer, card box and tray which are essential components of the paper based incident card system (expanded upon in the artefact model). The allocator is positioned closer to the printer to take cards out and the radio operator is positioned closer to the card box to put the cards away when an incident has been completed.

FURTHER NOTES

- It is interesting to note that the different actors around the sector desk will choose different screens to monitor when they are in 'neutral' mode (not currently acting on anything) to perform their role effectively e.g. the allocator will monitor the incoming call screen whereas the radio operator will prefer the vehicle status screen. This shows that each actor will structure their environment to perform their own responsibilities as best they can, in this situation it involves focusing their attention on different screens according to their role. This also shows that when in a 'neutral' mode people will perform monitoring tasks on those aspects of a system likely to trigger further action i.e. they are not passive but prime themselves for future action.
- The allocator and the telephone dispatcher have sloping chutes between them which aid the flow of incident cards to and from each other.
- As the allocator and radio operator are side by side both of them have a peripheral awareness of what the other may be doing. Events which catch the others attention can be inquired about in more detail, and the added awareness can lead to better synchronisation e.g. the radio operator was observed contacting the ambulance crew prior to the allocator passing details across. This is of particularly benefit considering how closely these two work together.
- The current system of passing cards to one another appears to be a great support for the task. Each actor can quickly recognise their role in the process on receipt of a card, which can be seen as triggering action. Sometimes this can come with verbal instruction which enriches the process.

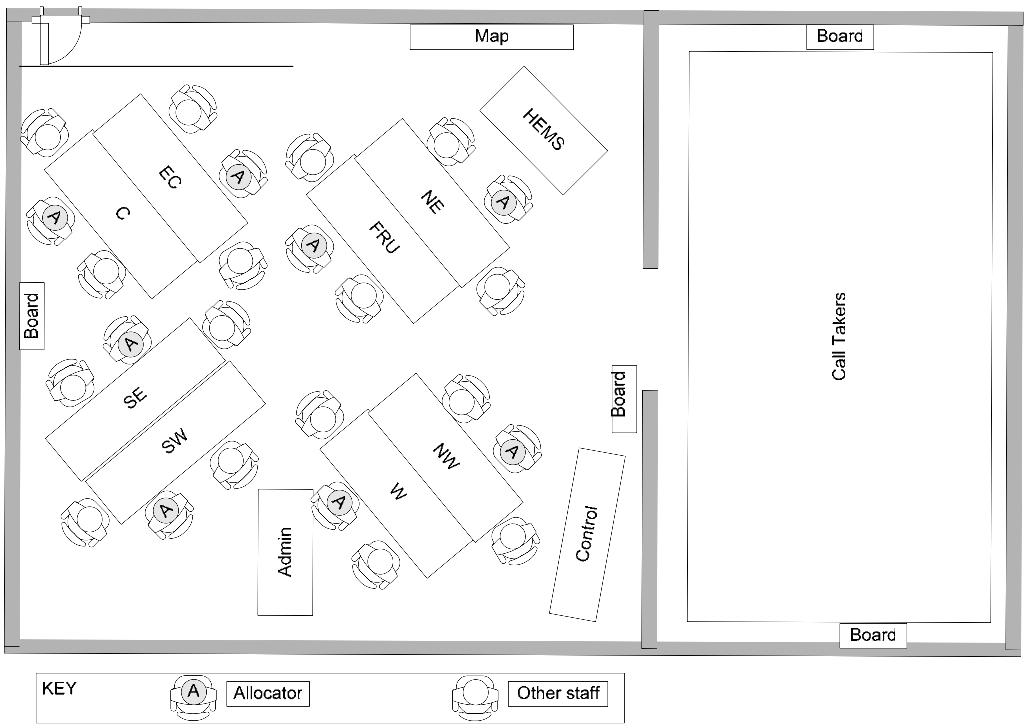
ISSUES

- The paper based system requires the printer, tray and card box which take up a considerable amount of room. Without these artefacts there would be more available space.
- On some occasions the radio operator will need to liaise with the telephone dispatcher which can cause problems due to their distance e.g. when a crew reports a ‘blue call’ meaning the appropriate hospital needs to be readied for their arrival.

Room Level

SUMMARY
There are seven sector desks in the London Ambulance Service control room each of which has the responsibility of allocating ambulances to incidents in an area of London. Although these sectors provide operational boundaries where different allocators are responsible for certain areas it is their collective responsibility to provide the best service for the whole of London and this entails cross boundary working. This is achieved by allocators communicating with each other across the room.

Figure 6: Room Level Diagram



Key

Letters	Description
C	Sector Desk: Central
EC	Sector Desk: East Central
SE	Sector Desk: South East
SW	Sector Desk: South West
NE	Sector Desk: North East
NW	Sector Desk: North West
W	Sector Desk: West
FRU	Fast Response Unit Desk
HEMS	Helicopter Emergency Medical Service Desk (also controlling bicycles)
Admin	Various support services e.g. vehicle maintenance and paramedic advice
Control	Where managers are situated
Call takers	This is a large area on a lower floor where the Call takers are situated
Map	This is a large map of London
Board	This board gives the status of incoming calls and targets being met by the call takers

DETAILS

Communication (Access to Actors)

The sector desks are roughly organised geographically, so sectors that border each other are close by for communication. This arrangement is for its functional properties rather than its aesthetic appeal. When an allocator identifies an ambulance closest to an incident it may be an ambulance from a neighbouring sector. Permission to allocate ambulances from different sectors has to take place with the allocator responsible for the ambulance. Hence the ease of communication between allocators is important for cross boundary working. Depending on where the allocators are seated in the room people will generally raise their voices to get their attention and communicate with them.

Unlike the sector desks the FRU desk does not operate on a boundary system. They only respond to red calls and will allocate their nearest vehicle to those calls, particularly where it is estimated an ambulance will take a long time to reach it. These vehicles will either be on the move or be waiting off-road at an agreed strategic position ready for a call. This desk has a central position as the fluid nature of its resources, at least compared to the bounded sectors, makes this unit a source of support which could entail increased cooperation with sector desk allocators e.g. a sector desk allocator could make a specific request if their vehicles were not nearby, if they were all occupied, or if they needed extra help due to the nature of a particular incident.

Other desks which fall outside the area of my analysis but are worth mentioning are: the HEMS desk which provides helicopter support for the most serious incidents and paramedics on bicycles in central London in the summer months; the admin desk which provides a number of supportive functions e.g. paramedics trying to negotiate whether low priority calls actually need an ambulance with external callers, and vehicle maintenance; and the control desk where supervisors oversee the operation of the whole room.

Access to Artefacts

The most prominent shared artefact, for the purposes of my analysis, are the boards which indicate the status of the amount of incoming calls, how many call takers are free and the percentage of calls that have been answered within an allocated time period (this is expanded in the artefact model). This representation is placed in a number of places, high on the wall, so it is accessible by everyone. This information gives an indication of how busy the call takers are, which will generally means that this will knock-on to the sector desks because the calls have to be allocated. The exception to this general rule is if a number of people are phoning about the same incident where lots of duplicate calls about the same incident will occur.

Another artefact, included in the diagram, which may have been made further redundant due to the introduction of the computer based maps is the large map of London behind the HEMS desk. This falls outside of the current analysis but may be used as a large scale navigation aid for those involved in liaising with the helicopter crew.

FURTHER NOTES

- Allocators on neighbouring borders are placed closer together so they can communicate more easily. Allocators may shout across the room to gain attention or may call on an internal line. However, people were observed taking advantage of environmental affordances in creative ways to perform efficiently e.g. two people were observed talking over the phone across the room but maintained eye contact thereby taking advantage of visual cues.

- Call takers are situated in a different area from the sector desks as they do not have to have direct contact with the sector desks. The floor to the call taker's area is on a lower level than the sector desk area. This adds a further degree of distinction between the two and could help prevent sound travelling.
- It is clear that the displays showing the performance of the call takers is a source of motivation for them but it is not clear what direct use this is for the sector desks. The displays could provide a shared point of reference for the whole group, and may be used to monitor sudden influxes of calls which might signify a major incident.
- The control desk where the supervisors are situated oversee the operations of the whole room and their position literally reflects this 'overseeing' role. They face the sector desks but can easily see what is going on downstairs in the call takers section behind them. This gives them a good horizon of observation for the whole room which reflects their status and role.
- The HEMS desk is placed slightly to the side as they do not have a frequent central role but are still within reach of whatever is going on. This is another desk with a monitoring role of the wider room, waiting to see if an incident might warrant their services. It was also reported that the paramedic that mans the HEMS desk will monitor serious calls and may take over from the call takers advising the external caller – this also gives them some justification in having a position that oversees the call taker area. To consolidate this point, a call taker reported that they were able to get the paramedic's attention if they thought the call warranted it.
- The sector desks take a central configuration on the upper floor as they are involved with the main hub of activity. Sector desks work as component teams which have to communicate with other allocators on occasion. Due to this they do not have an overseeing position; instead they are grouped to work together.
- The 'L' shaped sector desks provide an interlocking pattern so they can be paired and better organised collectively.

ISSUES

- The allocators are not always within easy reach of other allocators they may wish to contact. This may be of particular importance where a major incident requires multiple crews to attend from different sectors.
- The display giving the status of the call takers work load and performance does not directly impact on the allocators work load. The impact of alternative displays would have to be considered carefully as it might incite a negative reaction amongst staff and may not be of tangible benefit.

Artefact Model

In terms of looking at the artefacts that are used in the ambulance control room we want to concentrate on those artefacts and representations considered central to the performance of the system. As explained in the introduction to other models it is often unfeasible to model every aspect of the system in its entirety, and even if it were possible it may not be an efficient use of resources. Once left with the question of what to attend to we should aim to focus on those elements most central to the design or those elements where the designer predicts the greatest potential pay off; either due to a perceived problem, in light of proposed changes, or to take advantage of a new technology.

At an individual artefact level we want to ask questions about how its design impacts on shaping, structuring and empowering cognition either at a team or individual level. Through building up a model of the artefact, and the system in which it operates, we hope to understand just how it contributes to system performance. To this end we can use the Resource Model (Wright et al., 2000) to help inform how resources are internally and externally represented in the system. The better the understanding we have of how information propagates around the current system the better our chances of identifying design issues and identifying properties that should be attended to in redesigns of the system.

In developing an artefact model for the LAS control room I have attended to three areas:

1. Incident card and tray system
2. Screen representations
3. Call Taker Status Board

Incident Card and Tray System

SUMMARY

The incident card and tray system is a central feature of the sector desks both in a physical and operational sense. The cards aid the flow of information by keeping a paper based, physical record, of the incidents and the ambulance crews in attendance. They act as triggers for action when passed to people, they act as memory aids, they can provide plans through their ordering, and system status information by seeing how many cards are present and how well they are organised.

With the introduction of the MDT system those details that were once manually transferred to the crews via the telephone and radio are now 'beamed' directly to the emergency vehicles. This automation has also led to a greater reliance on the computer automatically keeping track of actions; which in turn has led to a diminished role for the card and tray on keeping track of system actions. If this system continues to be phased out it is important to understand what the consequences might be and what mechanisms need to be considered in its replacement.

DETAIL

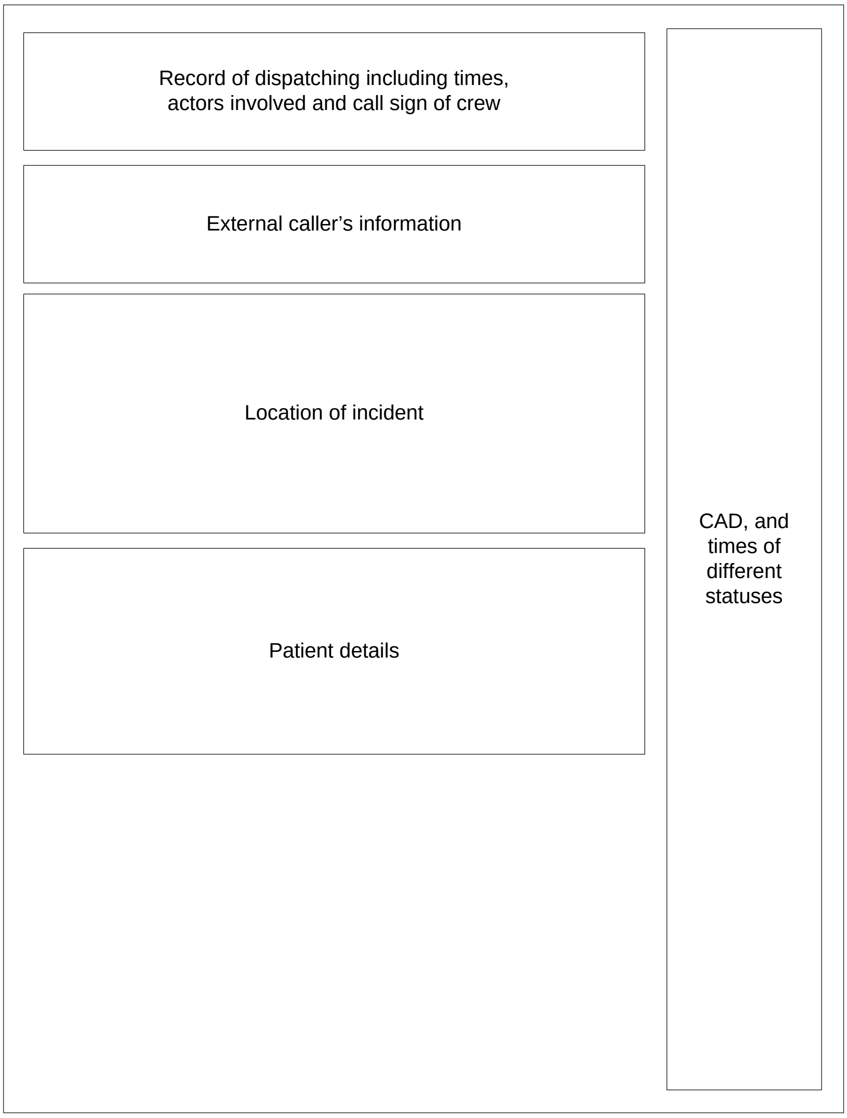
Description of the Incident Card

The incident cards are A5 in size; they have a different back and front containing many different boxes and fields that add structure and order to the card. There are different coloured cards that mean different things: red means that it for an emergency incident (which in turn can be a red, amber or green priority call); blue means that it is a hospital transfer; green means that it is to do with an unavailable vehicle; and yellow means that it is a vehicle that is doing extra time or is an addition to a particular shift. For the purposes of my analysis I will focus on the red cards and how they help structure cognition and the flow of information in the system.

The affordances of the cards have to be considered with the tray system where their design features become apparent given the context of their use. One important aspect of this is the distinction between the front and the back of the incident card, and another is that information that needs to be most accessible to sector desk staff is placed at the top of the card. The front of the card deals with task information to get the ambulance to the call, so the card is forward facing whilst the ambulance is on its way to the call and whilst it is at the scene. The back is for notes and if the patient needs to be taken to hospital after the ambulance has attended the incident. When the ambulance is going back to the station the card is back facing in the tray to show its state (as the call is finished with the details on the front are no longer necessary). The fact that the most used information is situated at the top of the card means that LAS staff can quickly flick through the tray by partially lifting cards rather than removing them completely to see the information they need. Both of these physical attributes have taken advantage of how the card and tray system fit together, enhancing the flow of information associated with them.

Front of the Incident Card

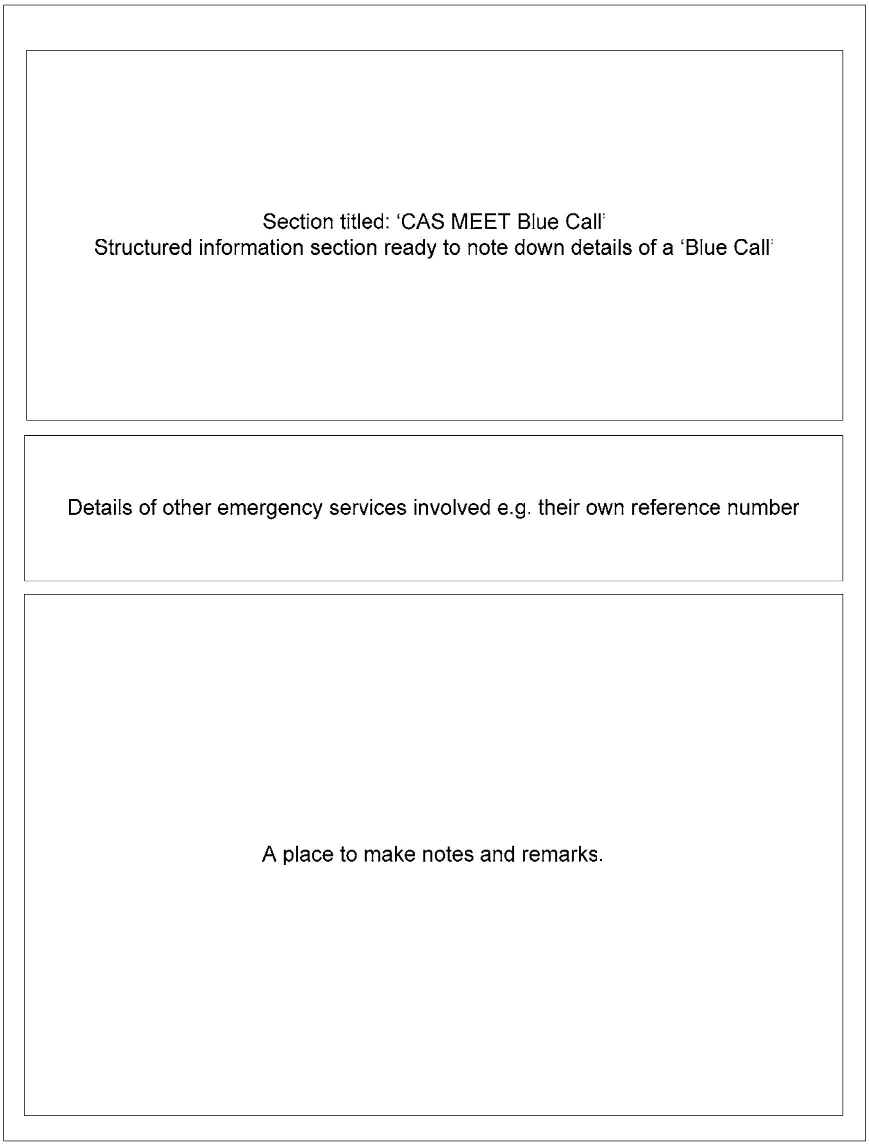
Figure 7: Diagram of the Front of the Incident Card



- The very top of the card has the allocated details. This is the sector desk's primary job, to get the ambulance on its way to the incident. The rest of the card contains details of the incident e.g. who reported it, the location of the incident and the diagnosis. The right hand column contains the CAD number and allows a space where the times of various crew statuses can be noted e.g. time mobile, red at scene, red to hospital, and green time. All of these details have specific places to be entered on the form so they are easily found by experienced staff.
- When the cards are printed they have as much detail as the computer file at that time, these details are printed in the correct sections of the card, which is done in type. As well as this normal type extra detail will be overlaid on the card in a large grey font to give a 'ghost' or 'shadow' type effect. This detail will include printing the incident priority code at the top of the card e.g. AMBER1, RED2, etc. which can be viewed without removing the card from its tray slot. A similar type will be used if the address is recognised as an aggravated address (i.e. where the crew may require Police protection). This large grey font adds an additional layer of information that can be easily recognised by sector desk staff.

Back of the Incident Card

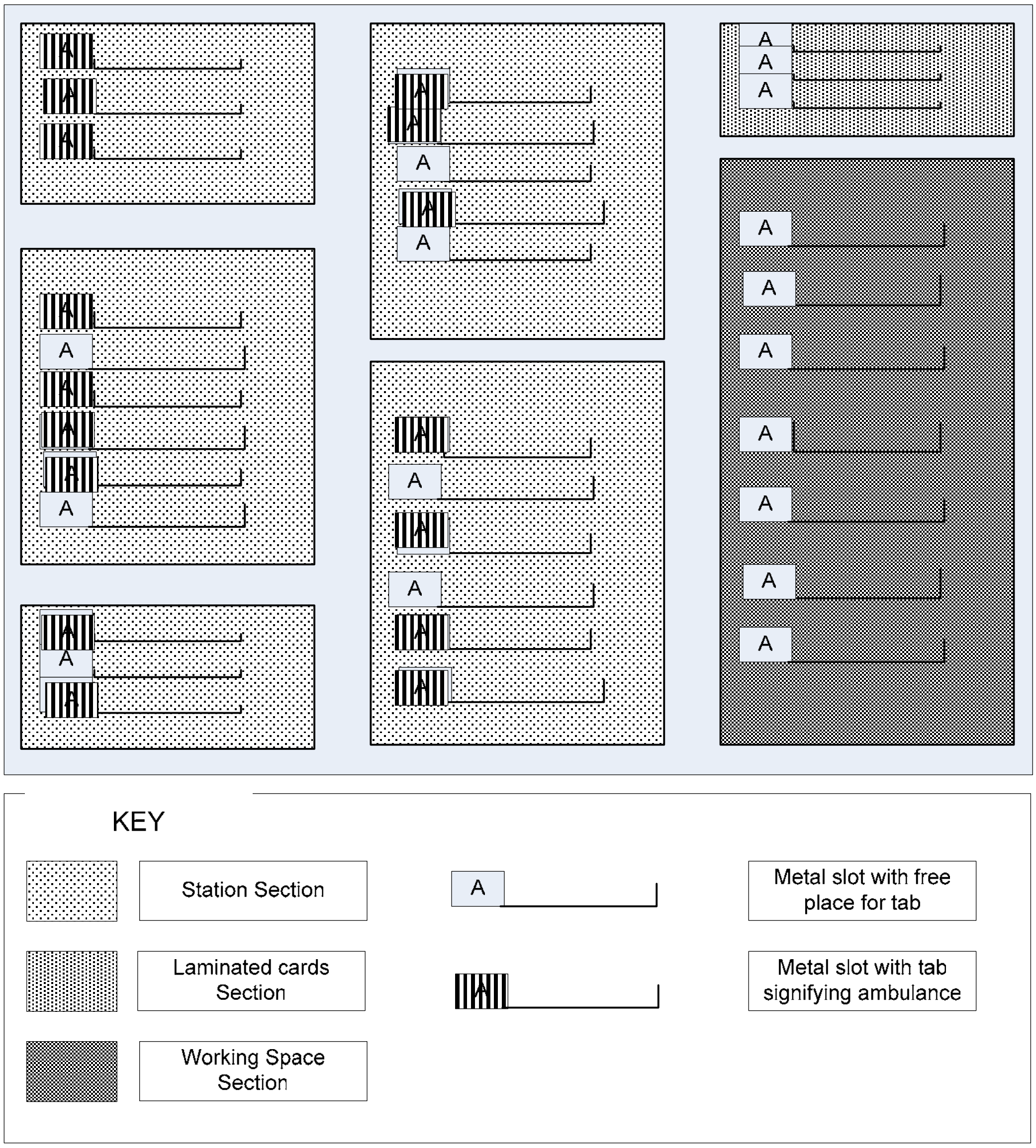
Figure 8: Diagram of the Back of the Incident Card



- The top section of this card is used to note down the details of 'blue calls' which is when the crew will notify the radio operator to have an emergency team ready at the hospital that they are going to. No doubt the structure of this section, caught in the acronym CAS MEET (Call sign, Age of patient, Sex, Mechanism of injury/illness, Eta, Examination, Treatment type), also helps structure the conversation and make sure that details are not missed when a blue call is reported
- The details of other emergency services can be essential to aid successful liaising e.g. making sure that their reference code is known so incident details can be quickly matched and established. Noting down this information will mean that the system knows but that any individual in the system may not know it alone.
- The bottom of this side allows notes to be made, including the noter's initial and the time of making the note. This allows for flexibility in the system for details that are not able to be recorded elsewhere e.g. why a call could not be immediately allocated an emergency crew.

Description of the Tray

Figure 9: Diagram of the Tray



- The tray was highly structured which helped the cognitive processing around it i.e. experienced users were able to easily find what they wanted to.
- The left and middle columns of the tray were organised into sections, each section signified a station, which contained slots for the ambulances associated with that station. There was only a gap, and no special divide, to signify where one station stopped and another started.
- The tray consisted of three columns of metal slots. Each metal slot had a tab on the left hand side. This tab allowed for a coloured thimble to be placed over it. These plastic coloured thimbles had the call sign of the ambulance and the shift that the ambulance was doing noted on it. This allowed a slot to be identified with an ambulance and told when that ambulance was working.
- Under the radio operator there was a separate tray with all the different coloured thimbles for that sector. As the shifts changed the correct thimbles would be selected and brought on to the radio operator’s desk. When the crews were due to change shift the thimbles were placed on their appropriate slots in their appropriate station

sections; however, these thimbles remained back facing until the crew had actually started working.

- Crews that were due to finish their shift were placed in the working space (refer to Figure 9). This was a temporary measure to signify that their shift was coming to an end, so they could be phased out from taking on any more calls.
- All the details for an incident were written on cards and kept in the appropriate slot for the ambulance dealing with that incident. If printed cards refer to the same incident then they are physically kept together
- When an ambulance had dealt with a call and was returning to the station the card was turned back to front. This showed the state of the ambulance in the tray in a clear, visible manner. It was observed that some allocators put the cards in the card box after the ambulance had gone green (when they had finished with an incident and become available). In these cases the computer tracking of where the ambulances were was considered sufficient to give the allocator the data they needed, hence the perceived duplicated and unnecessary steps were cut.
- When cards were out of the appropriate slot for an extended length of time they had coloured laminates put in their place. This might be for an extended enquiry. The colour of the laminate would reflect the colour of the card taken out, keeping the information that the colour signifies. This system ensures that where cards have been removed they are not mistaken for available ambulances.

Incident Card Flow

One of the most prominent tasks of the sector desks is to keep the paper based system up to date. This roughly entails printing and writing notes on incident cards, passing them to different people for action and storing them in the tray correctly. If done correctly this system maintains an accurate record of what ambulances are allocated to what incidents, the details of an incident, which ambulances are free and which ambulances are returning from an incident.

Figure 10: Diagram to show Incident Card Movement

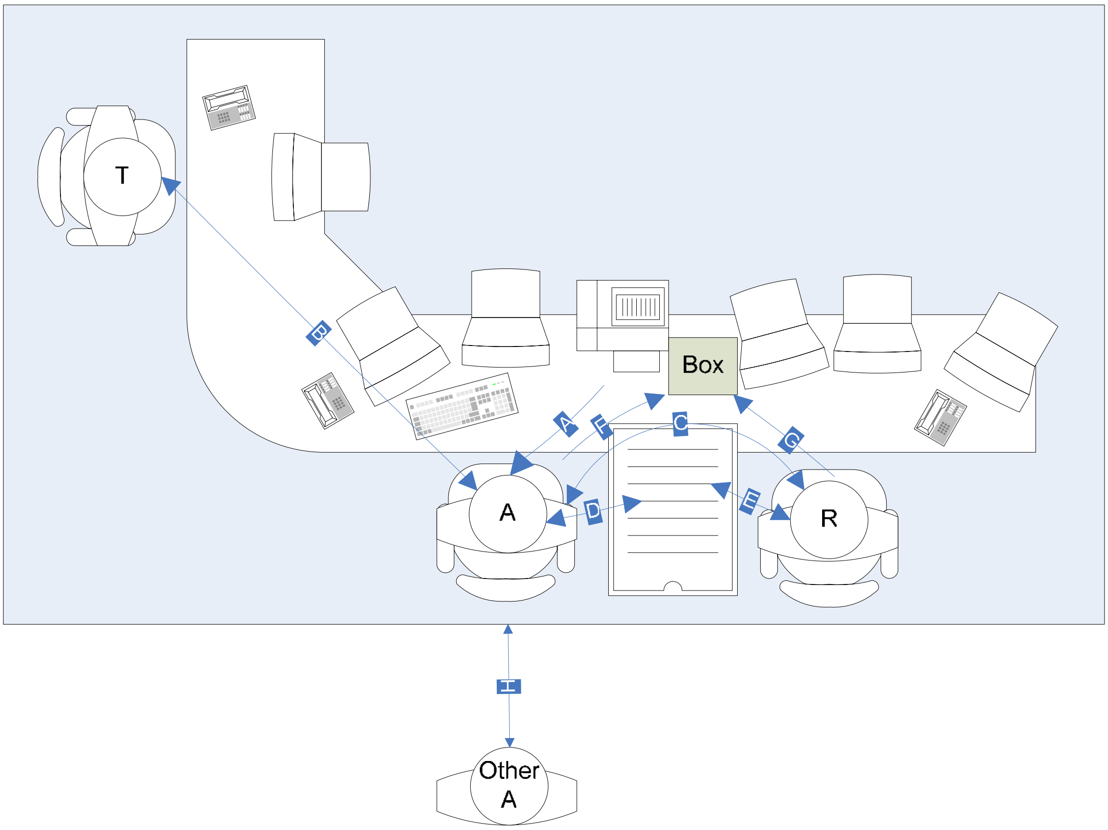


Table 7: Description of Incident Card Movement shown in Figure 10

Arrow	Description
A	At the beginning of any card cycle the allocator will retrieve it from the printer. The cards can be an incident card or a Police update on an active incident. In the case of cards about emergency calls (red coloured cards) it is likely that the allocator will have already started the allocating process by viewing the detail on screen. In these cases the cards are playing catch-up, although they can still act as sources of information when they are passed to the telephone dispatcher and radio operator. Blue cards are also printed from the printer, which are hospital transfers. These cards usually have a number of hours to be dealt with and are often kept in a pile, in order, so the allocator can maintain a plan of what is to be done. Police update cards contain the CAD of the incident that they are about and are also red in colour. In these cases the allocator will check the details on

	screen and then pass the card to the radio operator to inform the crew (arrow C).
B	If the allocator needs to contact a station to find out what crew from a particular station will attend a call then s/he can pass the card to the telephone dispatcher to find out. Whilst doing this the allocator will typically repeat the name of the station to the telephone dispatcher so they know who to ring. Alternatively the telephone dispatcher could be told the CAD and station name and will know to find out what crew will attend, this variant does not need a card. When the crew is identified the card is passed back to the allocator to send the MDT to the appropriate vehicle. Before the MDT system was introduced the telephone dispatcher would also repeat the details of the incident to the crew at the station via the phone. Sometimes the allocator will be in a position where they are merely passing a card on from the radio operator e.g. when a blue call has been reported the allocator will pass the details from the radio operator to the telephone dispatcher. Although this seems unnecessary it does keep the allocator informed as to what is going on.
C	If the allocator needs to contact a crew on the move then he will pass the card to the radio operator. This might be to allocate a crew that has not yet returned to the station or reallocate a crew to a different call. The allocator will also pass cards which are Police updates to the radio operator to update the crew over the radio. There are a variety of ways that allocators and radio operators pass cards to each other including putting the cards flat on the tray and sliding them across the desk. The radio operator will pass cards to the allocator if they need to go to the telephone dispatcher. If incidents are cancelled or reallocated they might also go back to the allocator for a decision.
D	The allocator will interrogate cards that are in the tray and the tray itself to find out details of incidents and to see that the statuses of ambulances are correct. This interrogation of the tray is often done during quiet periods and can be used as a method to build up a situation awareness of the sector ambulances. If a card is removed from the tray for an extended period then the same coloured laminate will be placed in the appropriate slot to indicate that the ambulance is not free and that a card has been temporarily removed.
E	The radio operator will interrogate cards that are in the tray and the tray itself to find out details of incidents and to see that the statuses of ambulances are correct. If a card is removed from the tray for an extended period then the same coloured laminate will be placed in the appropriate slot to indicate that the ambulance is not free and a card has been temporarily removed. Checking that the tray reflects the real world statuses of the ambulances is one of the roles of the radio operator.

F & G	Once an incident is complete at the scene the ambulance will change its status to GM (green and moving), which means they are available and returning to the station, this is indicated in the tray by turning the incident card back to front. When the ambulance reaches the station they become GS (green at station) and the card is placed in the card box for filing. The empty ambulance slot shows that the ambulance is green (available) and at the station. A shortcut to this 'official line' is to put the cards in the card box as soon as they turn green to show they are available rather than leaving the cards back to front to show they are returning from a job. The extra step can be cut out because the computer provides an accurate fix of the ambulances status and location via the MDT and satellite tracking. This is an example of how the introduction of the new computer support is affecting the amount of aid needed by other artefacts and hence impacting on the procedures that take place.
H	When an ambulance from another sector is identified as the most appropriate to attend an incident the allocator at the target desk is asked for permission to use the ambulance. If accepted the card is physically transferred to that sector desk where it can become part of their card and tray system. As in the cases of the radio operator and the telephone dispatcher the card can be preceded by the incident CAD number so the call can be dealt with quickly in the absence of the card.

FURTHER NOTES

- The tray is shared between the allocator and the radio operator which also provides a shared cognitive space. If one doesn't understand a certain action or why the tray is in a particular state the other can inquire. This leads to joint error checking and heightens a shared awareness.
- The experienced staff I observed using the tray and card system were quick to assimilate the information that the different artefacts provided and skilled at responding to them in an appropriate manner. Through experience they had become accustomed to the structure and patterns of the artefact so they were much more tightly coupled to the artefact than a novice might be. For example, staff could retrieve any card they wished from the tray with little thought and almost immediately knew what to do with a card once placed on their desk.
- On receipt of a card the recipient will generally be ready to perform an action (tasks for emergency dispatch generally do not take long). As this contact is made the allocator may say the CAD and station or call sign so that person can act immediately. In these cases the card becomes a token of work as it does not give any more information than can be found out by entering the CAD into the computer.
- Cards can be used to order and structure work in the long and short term. When any of the actors has more than one task to perform the cards can be ordered on the desk to suggest a plan. This can be achieved by piling cards on top of each other or arranging them in a pattern that makes sense to the user. The hospital transfers that are able to be completed in a few hours are sometimes ordered in a pile according to their priority by the allocator. One allocator was repeatedly observed to glance around the desk and screen once they had completed a task,

in this 'neutral' state the allocator looked to see what his structured environment afforded him – to trigger the next cycle of action.

- Cards provide a visual and physically sustained token of work. If a card is given to a person and it is not being attended to then this inaction will be visible by others sharing the environment. In this sense it provides a visual cue that the work is being attended to and done. This sort of work monitoring may only happen on the periphery of awareness but it would soon get noticed should it become an issue.
- Cards can be used as reminders of information in the long and short term. In the long term they provide a source of incident details and system actions which are easily accessible from the tray. The radio operator is often observed retrieving the card from the tray when a crew call in, then scanning the details whilst listening to the crew. In the short term cards can act as information buffers. Verbal instructions are not persistent and can decay quickly in the working memory, particularly when disturbed by other verbal processing. In these cases the cards can be considered a safety net to help recall details.
- The tray maintains a constant physical summary of the sector desk's status. It can be glanced at by the allocator, radio operator or other member of staff to gain an overview of what is happening e.g. how many slots are empty and the number of blue cards being dealt with might give an indication of how busy the sector is and has been (blue cards are generally dealt with during quieter periods).
- Cards can be placed diagonally in their slots so that they protrude above the normal level of placement in the tray. This is done intentionally by the user. It may be to aid their own recall if they are temporarily attending to something else; to have the card ready for an impending action that they are waiting for; or to get the other person's attention drawn to it (either allocator or the radio operator).
- Cards can be passed from one sector to another as a token of work and as a reminder or seal to their agreement to take an action.

ISSUES

- With the increased computerisation of the allocation system, following the introduction of MDT, some staff believe that the card and tray system does not provide enough of a central function in the allocation procedure i.e. it is not far from merely duplicating work for records and is a potential back-up in case the computer system fails. It seems as if the phasing out of the card and tray system could be part of a computerisation trend, but it is not clear what effect taking the card and tray system will have on system performance or how a computer system could be designed to replace some of the system affordances that the card and tray system gives.

Screen Representations

SUMMARY

Due to the computerisation of the allocation system much of the sector desks' work is done using the computer. Due to this the screens that can be viewed by the actors play a large role in structuring and empowering the calculations of individuals, which affects the performance of the system.

DETAILS

Description of Unallocated Jobs Screen

Figure 11: Diagram of the Unallocated Jobs Screen

- This is the main screen that the allocator will look at to see incoming calls. If the allocator is in a 'neutral' mode i.e. not taking any immediate action, then it is likely they will view this screen, waiting for the next incoming call which acts as a trigger for action.
- The Job Ref contains the CAD number which will appear in white as soon as the call taker has established the location (this allows it to be sent to the right sector desk). From this point on the allocator can view the details of the call as they are updated by the call taker. Once the call taker reaches the stage of establishing the medical priority the colour will change appropriately i.e. to red, amber or green.
- The jobs will come in by the order they have been received and the Min on the right will record the time they have been waiting to be allocated. The allocator will prioritise the calls on how long the calls have been waiting and their medical urgency (given by the category of priority the AMPDS system has given it).
- Jobs disappear from the screen when they have been accepted via the vehicle's MDT. So even after an MDT has been sent out the job will remain on the screen until the crew have accepted it. This provides the allocator with important information concerning the crew's acknowledgement of the MDT request.
- The FRU desk is different in that it does not have its own calls but responds to red calls in all the sectors. Due to the system set up the jobs will disappear from the FRU screen once a sector vehicle has accepted the MDT regardless of whether the FRU

allocator wanted to view the file and regardless of whether they might have been of tangible benefit to the call.

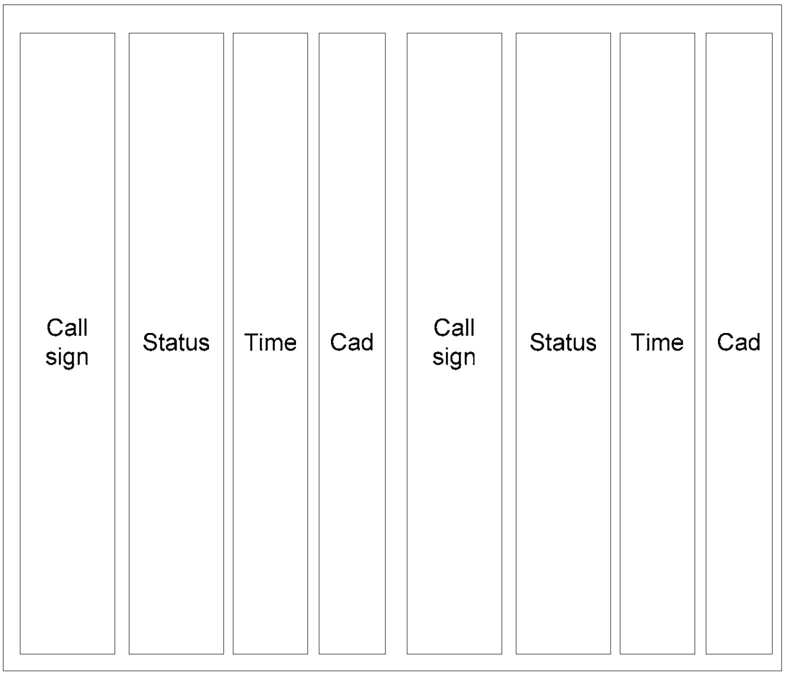
- Jobs can also be cancelled from the screen by the allocator who must give a reason for cancelling the job via a computer menu. One of the most common reasons for cancelling a call will be because it is a duplicate call and already has a vehicle on its way to it; other reasons might include being cancelled by the external caller, another LAS crew or under the instruction of another emergency service.

ISSUES

- In some instances the sector desk can receive many duplicate calls about the same incident in a short space of time. These will come up as separate incidents on the screen and quickly fill the space on the screen. In circumstances where this happens allocators can change to a screen showing more incidents but less information about each one. There is a dichotomy between making the process of identifying duplicate calls easy and fast for the allocators, and making sure that no mistakes are made. It was reported that a similar accident that happened in the same road at the same time was classified a duplicate call when it wasn't which greatly delayed emergency vehicle attendance to one of the calls.
- The jobs that disappear from the FRU desk without them seeing it could be improved. Rough heuristics could be established to aid the decision of where the FRU vehicles would be most effective to attend. For example, a red call where an available ambulance is over three miles away but an FRU is nearby might be given a high status of some sort on the screen e.g. an estimated value of how effective the attendance by an FRU vehicle may be. Effective estimates above a certain value may remain on the screen suggesting that the FRU allocator will more likely attend to those calls where a real tangible difference can be made.

Description of Resource Status Screen

Figure 12: Diagram of the Front of the Resource Status Screen



- This is the main screen that the radio operator looks at; as part of their role is to make sure that the vehicles have the correct status. This is extremely important for the effective operation of the system. It makes sure that emergency crews accept MDTs in good time and makes sure that the allocator is basing their decisions on reliable system data.
- This screen can contain information from all the sectors but it is easy to see which ones belong to the sector that you're in as they are in white and the others in grey.
- The status has different colours and initials for the different states that ambulance crews can be in (shown in Table 8).

Table 8: Table to show Initials and Colours of Different Crew Statuses

Initial	**Colour**	**Description**
GS	Green	Green at station – available for call
GM	Green	Green and mobile – available for call
AS	Amber	Amber to scene – on the way to a call
RS	Red	Red at scene – occupied at the scene
RH	Red	Red at hospital – occupied at the hospital
ZZ	White	Unavailable

These colours reflect the colours of a traffic light and can easily be perceived by the people that use the screens. The traffic light scheme does give an indication as to the availability of crews (go, caution and stop), which could be quickly interpreted by novices but might not be so important for a system used by experts.

- The time shows how long a vehicle has been on a certain status. This could indicate something in need of attention e.g. a RS for a very long time might mean that the crew have forgotten to switch modes and 'go green' after dealing with their call.
- As soon as the allocator allocates a crew to a call by sending an MDT the CAD appears on the Resource Status screen next to the appropriate vehicle call sign. Due

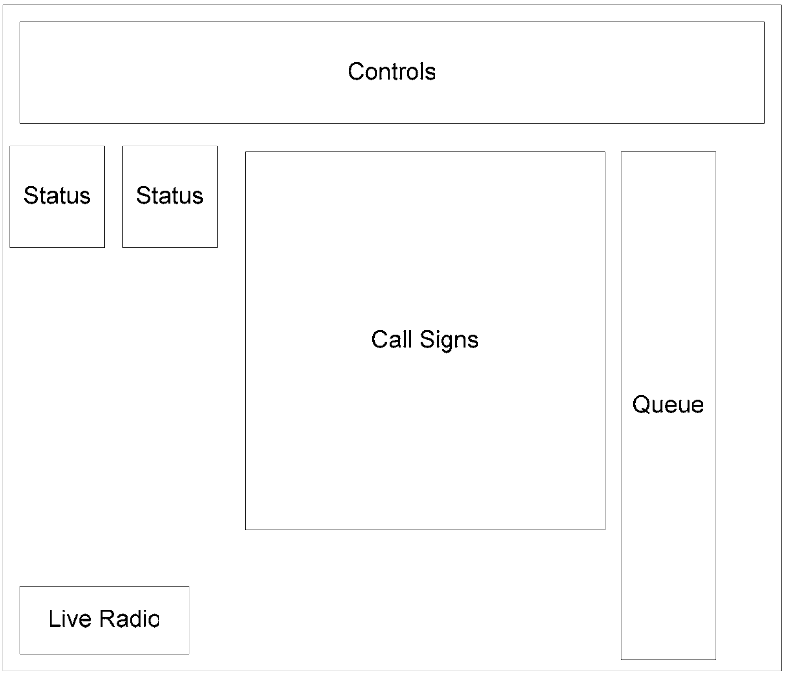
to this someone monitoring the statuses of crews will be aware that a crew on green and with a CAD should shortly accept that call. If the crew remains green they may have to be verbally prompted to accept the MDT.

ISSUES

- It appears that a number of heuristics could be recognised to aid in the monitoring of vehicle statuses e.g. a vehicle on green with a CAD could flash after a certain period of time, and a vehicle with ‘red at scene’ that is detected as moving by the computer system could also flash. The method of organising those items that are likely to need attention could be something different from flashing, which is just an initial suggestion. These heuristics could also activate reminders in the vehicles themselves and so partially automate the need to verbally remind crews.
- The organisation of the vehicles and their statuses should be one that maximises the user’s ability to detect items that may need attention. This may include a static representation, a representation that changes with priority or an order that the individual may choose themselves.

Description of the Radio Control Screen

Figure 13: Diagram of the Radio Control Screen



- This is a touch screen and is how the radio operator controls the radio.
- When crews want to talk to the radio operator they call in and get put in a queue. The crew's call sign goes in the 'queue' column with the most recent towards the bottom. This representation allows the radio operator to see their system status, a history of who has called in which order, and a plan of how to proceed (i.e. top to bottom).
- To make an outgoing call the radio operator will press one of the 'call signs' which are ordered alphabetically and numerically. This order allows the radio operator to quickly find the crew that they are looking for. To activate the radio a button is pressed in the control section.
- The 'Live Radio' part goes red to signify when the radio is live and ready to receive sound from the radio operator's end.
- The radio has a dial function which allows a three way conversation with a person on the phone but it was reported that this is rarely used.

ISSUES

- The radio's three way conversation facility could be used to transfer details of blue calls more effectively. At the moment this information is recorded from the crew by the radio operator and then passed on to the telephone dispatcher to notify the hospital.

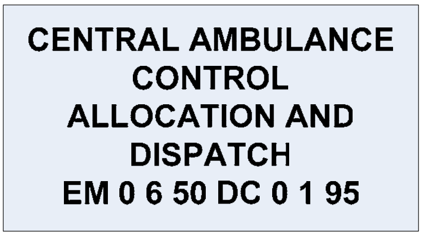
Call Taker Status Board

SUMMARY

These boards show the status of the call taker's performance and are placed around the room so every member of staff has access to them (see physical model).

DETAILS

Figure 14: Diagram of the Call Taker Status Board



- The board shows emergency calls (EM) which come through on the 999 number; and doctor's calls (DC) which come through on their own dedicated line.
- From left to right the numbers (for EM and DC) stand for the number of call takers available, the number of calls waiting, and the percentage of calls answered with their ORCON target. For example, Figure 14 shows there are no free call takers; there are 6 emergency calls waiting and one doctor's call waiting; emergency calls are 50% in target and doctor's calls are 95% in target.
- The display is further enhanced by showing positive figures in green and negative figures in red. Hence a board displaying all green numbers shows that the call takers are well within their targets. Without a visual display signifying the number of waiting calls this information would be hidden from the entire system i.e. no one would be able to tell how many people were waiting by the ringing phones alone.
- The board can be used by the LAS staff to background monitor the flux of calls e.g. a sharp rise in the number of calls could signify a major incident.

ISSUES

- This display has potential to show more information on targets and figures that are relevant for the whole room e.g. crews reaching incidents within their targets. The LED display would not be hard to change but the consequences of showing any alternative information should be carefully considered.

Summary of Results

This section provides a summary of the main results found in each of the three models. It is important to note that changes in one area are likely to affect other areas, and so any changes should be considered with due caution.

Information Flow Model

- The question referring to chest pains on the AMPDS system might be worth revising given its reported abuse.
- Action could be taken to discourage doctors using the 999 line if they don't want to wait on their dedicated line.
- The system could recognise a repeat caller so their details are immediately available, particular if they are following up a recent emergency incident.
- Transferring a call to another sector desk should not be delayed because the call hasn't finished.
- The communication of Police updates could be streamlined.
- Allocating a crew at a station could be streamlined.
- The crews' communication channels could be reviewed to allow greater flexibility in the system, perhaps following the FRU model.
- The nearest vehicle screen calculates distances as the crow flies, this could be improved by using a system based on road distances.
- FRU desk could be given greater flexibility in the use of its vehicles e.g. helping out on an amber call if it has been mis-prioritised or if there are multiple victims. This practice does occur in the smooth running of the system but the desk is technically unable to send MDTs delaying their activity.
- The handling of duplicate calls could be reviewed.

Physical Model

- The tray, printer and card box take up considerable room on the desk, without these alternative configurations could be tried.
- The communication of 'blue calls', from a crew to a hospital, could be streamlined as it currently involves both the radio operator and telephone dispatcher that are sat far away from each other.
- Allocators are not always in easy reach of each other making cross-boundary working more effortful, which could be particularly prominent in dealing with a major incident.

Artefact Model

- The card and tray system is perceived by some as being superfluous to the central role of allocating. However, this physical system does allow for a number of advantages in communication, planning and recall which will need to be thought about fully if it is to be replaced.
- The handling of computerised duplicate calls could be an area of development.
- Disappearing red calls on the FRU screen might lead to inefficiencies, this display could be improved using heuristics to prioritise calls via the screen layout.
- Simple heuristics could be used to help monitor ambulance and crew statuses.
- The communication of 'blue calls', from a crew to a hospital, could be streamlined.

The Codified Distributed Cognition (DC) Method

The aim of this paper has been to take an exploratory approach in developing a useable ‘off the shelf’ DC method of analysis. This has involved a process of iteration in reviewing literature on both DC and on performing contextual studies, whilst gathering data and building up an understanding of the area that the method would be applied to. Without a practical application it would be difficult to see what was right and what was wrong. This section contains the abstracted codified DC method that has been developed in this process.

Overview

Unlike other cognitive theories DC looks at the propagation of information in a system which is not localised inside the head of an individual but dispersed in the environment. This gives rise to a richer interaction of factors that influence the performance of a system, particularly where more than one individual is concerned, e.g. communication channels, the order of events, the support of artefacts, the physical layout of individuals and their access to information, etc. The method outlined in this section gives a structured approach in performing a DC analysis. It is recommended that the analyst familiarise themselves with DC literature so they are aware of what sorts of observations to take notice of in a field setting and why (newcomers to the area may wish to start at the Introduction to DC towards the beginning of this paper).

Data Gathering

There is an array of different data gathering techniques for contextual study and each have their advantages and limitations. In any approach it is best to pick those techniques that suit the constraints and requirements of the task at hand. These methods can be combined to enrich the analysis.

Video analysis and Contextual Inquiry (Beyer & Holtzblatt, 1998) are suitable ways to gather the data required for a DC analysis although this is far from exhaustive. The video analysis allows for a detailed repetitive analysis, here the analyst can concentrate on a set of events in an iterative fashion. This contrasts with observing ‘live’ data that cannot be returned to once it has happened. Contextual Inquiry is an excellent way to develop an understanding of the situation. It involves observing the context and asking questions about it at opportune moments, so as well as observing the environment you have the expertise of the users available to you, along with their attitudes and matured opinions of the system that they are using.

It is strongly recommended that data is gathered in at least two different visits with enough of a gap in-between to perform a preliminary analysis of the initial visit. By doing this preliminary analysis the analyst will develop a greater understanding for the situation and identify specific issues that need a further level of inquiry on the second visit. Hence the two visits will have different objectives: the first being exploratory, and the second being directed at finding the necessary information for completing the task. The preliminary analysis should also include the production of representations of the system that can be verified and annotated on the second visit. It will also help if a list of questions is developed from the preliminary analysis to make sure that the information that needs to be found out is not forgotten. The production of artefacts to aid the second analysis uses the theory of DC by providing the analyst with external support to perform their tasks more effectively.

No matter how much time the analyst is allowed the process will involve the development of understanding as the analysis progresses. To aid this development the analysis should be spaced out to allow for reflective time and at least a second visit should be organised to fill gaps in the data. More time will allow the analyst greater flexibility in applying the process, both in choosing what to study, for how long and when. Of course, the amount of data that needs to be gathered will vary with the analyst's objectives and the context of study. A further resource that could improve the quality of the results is a research partner; this would allow for a wider scope of observation, discussion to help build understanding, and joint error checking. The responsibility of organising the analysis effectively will involve the consideration of the research objectives, the context of study, and the constraints on resources; all of which lies with the analyst.

In all cases the data gathered should be related to DC theory, which includes everything that has a functional influence on the system. This covers a wide scope, but can be guided by the theoretical principles recognised in Table 3 which outlines DC concepts, ideas and insights, and by the structure of the three models that are described below. These models provide three clear but overlapping focuses for the analysis. Table 3 aims to be an accessible resource by which analysts can build familiarity with the theory and use to guide their observations.

Depending on the situation being observed the analyst should choose to adapt their observation technique to produce the best results. For example, the analyst may choose to track an artefact if it plays a big role in the system and moves between different actors; the analyst may observe one actor in detail if they recognise that that person plays a large role or are having difficulties; the analyst may choose to photograph screen shots or to copy artefacts to analyse representations in more detail; and sketches of visual representations and room layouts may be taken so they can be referred to and analysed after the visit. This advice relates to relatively substantial changes in focuses in observation which could be decided before a visit.

As well as thinking about the structure of the method of observation prior to a visit a productive analyst might also react to opportune situations whilst gathering data. More productive data gathering styles for this DC analysis will be flexible and dynamic, changing to suit the needs and circumstances of the situation. Given the need to be productive in a constrained analysis, either by time or another resource, the mode of analysis becomes a rigorous investigative and exploratory endeavour, where the analyst will continually adapt their data gathering technique for the task at hand. This could be in recognition of a particular data set that would be useful for the analysis or a response to an opportune moment that has arisen in the context of study e.g. coping with a major or unexpected incident may lead to a reorganisation of roles within a team.

Building a Description: The Models

The Hierarchical Levels within the Models

The core of the analysis involves building three separate overlapping models that were informed by Contextual Design (Beyer & Holtzblatt, 1998). Within each model there is a hierarchical description which aids the analyst in being able to drill down and add detail as they progress in building the description. The levels of the hierarchy in are:

- Summary: This should provide a brief overview of the area.
- Detail: This should expand on the detail to describe the area focusing on the principal and routine activity.
- Further Notes: This level of description adds flexibility by allowing those notes that do not have a place on the above two levels to be included e.g. events and cases which may not fit with the routine activity, comments and other observations.
- Issues: As the description is built design issues may be recognised by the analyst which should be noted in this section.

Each model recognises specific issues that arise within it; this is important because even though they overlap they each have their own issues that influence the performance of the system.

The Models

The three models developed have been informed by Beyer and Holtzblatt (1998) but differ in the content of the models and the use of annotation, which has been cut down to make the method more accessible to newcomers; so it is closer to being considered an ‘off the shelf’ methodology. In the activity of building these models the analyst should gain a richer insight into the workings of the system than if they were used as a reference source alone. The hierarchical structure of each model has been developed to allow for a systematic inquiry into the workings of the system; whereby the analyst is encouraged to drill down into the detail of the system and note design issues as they arise.

High Level Input/Output Diagram
The power of this representation is in its high level summary of the system. It should include what information goes into the system, what the main purpose of the system is, and the output of the system. This focuses the analysis on the information processing capabilities of the system e.g. what happens to the information and how it is transformed. The rest of the analysis will look to explain this system in more detail; composed of actors, artefacts and representations; telling the story of how it works, what influences its performance, and what information processing issues there are.

Information Flow Model
Introduction
This section of the analysis provides a description of the flow of information in the system. More specifically this turns the focus of the analysis to the communication between the participating members, what their roles are and the sequence of events, which provide the mechanics of the system. Within a team setting the process of the task and the communications between team members are often so entwined that neither is worth separating.

Representation

The representation of this model can take the form of a flow model to recognise the high level communication channels between the different actors. Once this representation has been developed it might be worth analysing on two levels: the first level on the detail and the specific issues that will arise from each communication channel (like links to nodes on a network); and the second at a more abstract level of analysis that will recognise information processing properties of the system e.g. where there are information buffers and potential bottle necks in the system.

Issues to note

These issues have been informed by the experience of applying the DC analysis to the LAS CAC and DC literature. Where possible I have cross-referenced these issues with Table 3 which lists abstracted DC concepts, ideas and insights. This can act as a useful aid to inspire and guide observations.

- Communication issues between individuals.
- Implicit communication by overhearing e.g. being situated near an individual or having a communication device such as a radio that allows this to happen. (Table 3: 12)
- Information buffers and slack in the system where information can be held up and stored without interfering with the current activity. (Table 3: 15)
- Information or decision hubs where a lot of information is assimilated and considered. (Table 3: 14)
- Information interference where channels can conflict and mix. (Table 3: 15)
- How information is transformed from one individual to another e.g. asking a person questions to provide structured data for a computer system. (Table 3: 6)
- How differences in the bandwidth of communication affect processing e.g. face-to-face communication has a higher bandwidth than over the phone. (Table 3: 17)
- How social organisation affects processing e.g. keeping communication of teams separate can lead to independent ideas and validations that can enhance the whole group's decision making. (Table 3: 22)
- How error checking is accommodated between individuals. (Table 3:22)
- How informal as well as formal communications can contribute to system performance. (Table 3: 18)
- How communication can lead to the propagation of knowledge between individuals for training purposes e.g. informal communication, story telling, and joint error checking. (Table 3: 18, 22)
- Who does what? Who oversees what tasks and goals? (Table 3: 21)

Observation Guidance

In terms of the process, the tasks of individuals and the team should be tracked so that an order of activity can be constructed. In terms of communication the analyst should note what is being said to whom and for what reason.

Physical Model

Introduction

This level of analysis aims to describe those factors that influence the performance of the system, and performance of components of the system, at a physical level. This level of description is important from a distributed cognition perspective as those things that can be physically heard, seen and accessed by individuals will have a direct impact on their cognitive space and hence will shape, empower and limit the calculations that individuals perform.

Representation

The representations that will typically be most useful for this model will be schematic diagrams of the physical layout of equipment, including where actors and key artefacts are situated within it. This itself can be broken down into different levels from an individual's physical environment (e.g. their desk), to a teams physical environment (e.g. a team's area); to a broader level of analysis (e.g. a control room).

Issues to note

These issues have been informed by the experience of applying the DC analysis to the LAS CAC and DC literature. Where possible I have cross-referenced these issues with Table 3 which lists abstracted DC concepts, ideas and insights. This can act as a useful aid to inspire and guide observations.

- What artefacts are accessible to each individual? (Table 3: 16)
- What do individuals have access to in their horizon of observation? (Table 3: 13)
- What can individuals hear implicitly in the background? (Table 3: 12)
- What individuals are sat close together and who do they communicate with that are further away? (Table 3: 16)
- What can be heard in the zone of normal hearing and what can be heard when voices are raised? (Table 3: 12)
- Note where individuals normally face and how this affects their computations e.g. they might be facing someone or have a supervisory role and so see the whole room. (Table 3: 13)
- What artefacts are physically passed around and how easy is it to do this given the layout of equipment? (Table 3: 7)
- What environmental factors play a role in the cognitive system e.g. one part of the room might be busy and louder than another? (Table 3: 16)
- What barriers are provided to shield individuals from certain information and stimuli e.g. distractions can disturb attention? (Table 3: 13)
- How do people move around the physical space? What information do they pick up and give out? (Table 3: 7)

Observation Guidance

Through observation graphical representations of different physical layouts can be constructed. These should be focused on clearly defined areas and include the locations of key artefacts and individuals. These can form the basis of cognitive simulations after the observation phase has finished, so physical constraints and affordances can be identified.

Artefact Model

Introduction

The influence of artefacts on the performance of system components and hence the system as a whole is very important for an analysis using distributed cognition. According to distributed cognition our cognition extends outside the skull into the world. This means that the environment that we inhabit plays an intrinsic part in the types of cognition we are involved in; bringing artefacts, representations, and environmental affordances centre stage in a cognitive analysis.

Representation

It is recommended that graphical representations are used to form the basis of an artefact's description and evaluation. However, these representations can be adapted to suit the particular level of analysis for that artefact. For example, a screen shot will most likely be a single representation; in contrast to an artefact that is physically passed around which may include a representation tracking where it has been passed and for what reason. Using and annotating photos is another option that an analyst may consider.

Issues to note

These issues have been informed by the experience of applying the DC analysis to the LAS CAC and DC literature. Where possible I have cross-referenced these issues with Table 3 which lists abstracted DC concepts, ideas and insights. This can act as a useful aid to inspire and guide observations.

- How does the structure of the artefact aid or hinder its use? (Table 3: 2, 4, 5)
- Who uses the artefact? (Table 3: 2)
- What do they use the artefact for? (Table 3: 2)
- What is good and bad about the artefact? How could the artefact be improved?
- Is the artefact shared? What influence does this have on the system? (Table 3: 7, 12, 22)
- How does the representation aid cognitive thought? (Table 3: 4, 5, 9)
- How are plans, histories, and the recall of individuals supported by external artefacts? (Table 3: 9)
- What informal strategies are employed to structure the environment to aid performance e.g. are papers piled and organised on the desk; are more urgent items placed closer to the area of activity and attention; and do individuals make notes, and if so ask why, what, where and when. (Table 3: 1, 10)
- Are there any examples of 'retrofits' to help organise the system? e.g. labels on buttons. (Table 3: 1)
- If artefacts are passed from person to person how do they influence each person's behaviour? What order is the artefact passed in? (Table 3: 7, 20)
- How close is the representation to fulfilling its specific need i.e. can the individual easily gather the required information from the representation or do they have to think about it and perform calculations to get their answer? (Table 3: 3)

Observation Guidance

It is recommended that a table first be drawn to identify all those specific artefacts that specific individuals come into contact with. This will provide an overview of all the different tools that a person uses, formally and informally, to help them complete their task. The analyst can then choose to concentrate on particular artefacts in more detail (assuming that the analysis is constrained there may not be enough time to do a full analysis on each artefact).

The analyst should pay careful attention to the artefact's structure and properties in influencing its use. What role does it play in supporting the system's information processing?

The analyst may also approach the area from the other direction by looking at the individuals working and asking how the artefacts support their tasks. This angle is more likely to pick up informal strategies that people use to organise their work as this may be contained within the structure of piles of paper on the desk, PostIt notes and other such things that may be considered as 'noise' and 'mess' when slightly distanced from the actual work setting.

The analyst may also draw specific attention to what actors do in quiet, normal and busy situations; where they look, what they check, and how they prioritise their work with particular regard to the artefacts used and the structure of their environment.

Conclusion

The data gathering advice, the hierarchical structure of the models, and the description of the models form the outline of the codified DC method that has been developed in this paper. This description should be considered in conjunction with the implementation of this analysis on the LAS CAC included in the previous section of this paper. This offers a practical example of how the information is represented and suggests a level of detail that the analysis might entail.

Throughout the description of this codified method I have been careful to maintain an advisory role. The reasoning for this is that every context is likely to exhibit their own challenges and focuses, for which methods should be intelligently adapted to gain the best and most productive results. This codified DC method should provide a structure and foundation for carrying out other such analyses that differ from the LAS CAC context that was focused on in this paper.

Distributed Cognition Design Scenarios

With the high descriptive content of DC research it is no wonder that some researchers have interpreted it as principally a descriptive theory (e.g. Decortis et al., no date). Progress has already been made, in this paper, in conceiving of DC as a systematic analytic tool; this section aims to go further by introducing a conception of how to use DC theory to deliberate about potential design arrangements.

General Approach

Design is widely recognised as a complex activity that involves a variety of tools, methods and tradeoffs; many techniques are available to be employed, all of which are applicable under different circumstances and constraints, and in different stages of the design life cycle (Newman & Lamming, 1995; and Rosson & Carroll, 2002). The scope of the context under analysis in this paper (i.e. that of a control room) means that a physical simulation or prototype would be unfeasible; meaning that any simulation of a potential design will be largely conceptual and cognitive in nature.

Cognitive simulations have their own pros and cons: they can be employed where more substantial simulations are not feasible; they are cheap; they can develop a greater understanding of design issues, particularly at the beginning of a design cycle; but they are a best guess at what will take place, so errors may occur through oversight, misjudgements and misunderstandings.

Beyer & Holtzblatt (1998) state that familiarisation with the model of the system in Contextual Design, causes a translation whereby designers envision work being done through the model itself rather than viewing the model as an abstract representation. This claim underlies the step from building up a description of the system through a DC analysis and moving toward a state where the analyst can deliberate about different organisations of the same DC system.

The idea of building up a description of a system and using this description as a basis for a discussion of design has been developed through ‘scenario-based methodologies’ (Rosson & Carroll, 2002). Rosson and Carroll (2002) describe a number of important design considerations, with relation to scenario-based methods e.g.:

- the consideration of tradeoffs is a central design activity;
- design rationales of these tradeoffs should be documented; and
- scenarios are accessible, allowing discussion and the possibility of participatory design.

A method that incorporates these principles is ‘claims analysis’. This involves writing down the features that have an important influence on the system, and recording the pros and cons of each (Rosson & Carroll, 2002, pp 72). By incorporating this in the DC context the design rationale is externally supported, it remains accessible for novices to apply and it can form the basis of communication with stakeholders. Given the complexity of the DC context and the different levels of analysis under consideration (e.g. information and communication flow, physical layout and artefacts) the need for external support for considering design issues increases.

Through the familiarity of the DC description of the system, built in the analysis, the analyst should be in a position to deliberate about alternative arrangements of the system. These deliberations can be aided by further descriptions and diagrams. Furthermore, they can be aided by techniques developed and informed by scenario-based methods e.g. claims analysis. However, it is worth noting that cognitive simulations involving such a complex, interacting set of factors will be necessarily limited; but this should not negate its use in designing such systems. These issues should be engaged with in a redesign even though it may be challenging to do so and limited in its validity; some thought and deliberation is better than none.

Introduction to Alternative LAS CAC Designs

As a demonstration of how alternative designs may be configured and deliberated about I will concentrate on two variations from the current design:

1. A retrospective design looking at what issues could be predicted from how the system used to be (without technologies such as MDTs and satellite tracking);
2. A progressive design that takes on board the issues that were raised in the analysis and tries to configure an alternative system to optimise performance.

The outline of these two alternative designs loosely fulfils their design objectives at a very high level. It is important to have an idea of where the design is going so efforts can be focused on achieving this goal; how detailed or loose these design requirements are at the outset depends on the project and situation.

1. Retrospective Design

Outline and Objective
This design aims to look at what issues could be predicted from how the system used to be i.e. without technologies such as MDTs, satellite tracking, and global positioning on ambulance vehicles.

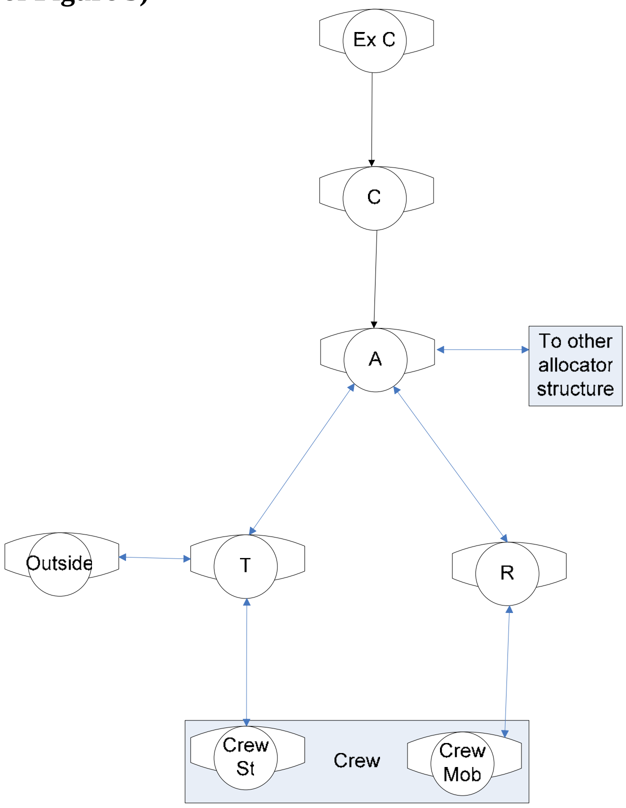
Initial Thoughts
The changes in this system will lead to an increased cognitive load, changes in individual work loads, and possibly a change in strategies in allocating ambulances given the information available.

Design Rationale
As this is a retrospective account this section is not applicable.

Description
Given this is a retrospective account envisioning this design relies on looking at the current system, which physical hasn’t changed much, and detaching the supporting technologies outlined above (in Outline and Objective). In doing this we must highlight the main functional changes to the system.

Firstly, the communication channels will see a marked change as the absence of the MDT system will prevent the allocator transferring information straight to the vehicle (refer to Figure 15). This will lead to more traffic down through the telephone dispatcher and the radio operator. Also, due to the difficulties in tracking mobile vehicles it is predicted that the telephone dispatcher is more likely to be asked to allocate a crew at a station, further increasing their workload.

Figure 15: Retrospective Flow of Information and Communication Channels (Variation of Figure 3)



Key

Letter	**Actor**	**Role**
Ex C	External Caller	People who make the incoming emergency 999 calls.
C	Call Taker	Takes the details of the incoming calls and enters it into the computer system.
A	Allocator	Person who decides which ambulances should go where and when.
R	Radio Operator	Speaks to ambulance crews via the radio.
T	Telephone Dispatcher	Speaks to ambulance crews via the telephone.
Crew St	Ambulance Crew	Ambulance crews based at the station.
Crew Mob	Ambulance Crew	Ambulance crews which are mobile.
Outside	Outside contacts	Anyone that needs to be contacted via phone e.g. calling external callers or other emergency services

Without the global positioning of each vehicle all the distances currently available on the system would disappear. This would leave a ‘black hole’ for allocators tracking mobile vehicles, save their own internal mental representations of their own vehicles. It is predicted that this would decrease communication between sector desks as those ambulances travelling close to borders and through other sectors would not be visible to other sector desks. It would also increase the cognitive load of the allocator and make them less likely to effectively use vehicles already on the move.

The satellite navigation maps that automatically give the location of the incident and the crews, whether mobile or at the station, would be unavailable. Instead, paper based maps would have to be used, with coordinates and page numbers, to locate where incidents are. This will slow the process and increase the cognitive and manual activity on the staff of the LAS for a process that is now largely automated. This would particularly effect the allocator who would need to coordinate different locations for making their decision about which crew to allocate to an incident, and would also significantly effect the power of the call taker who can now visually locate the incident being reported on the electronic map e.g. if someone names a road that appears very long on the map the external caller may be asked for more detail to locate the incident better. An example of the added power of the new system, from my observations, appeared when a radio operator was directing a vehicle to an incident using their electronic representation on their satellite screen as the crew moved along.

Issues

- Without the ability to track mobile vehicles, and have that data readily available, the ability to easily deploy mobile vehicles to incidents that they are near is heavily compromised. The successful performance of this activity would be reliant on the skill of the expert users (allocators) monitoring where ambulances are, where they are going and where they will be. This would promote the use of the paper based system as a support for monitoring and would lead to a decrease in the opportune use of moving ambulances.
- The ability to intelligently use ambulances from other sectors would also diminish as the position of these ambulances would be hidden from any other sector. Other sectors would not know where ambulances are going, only that there should be some at the stationary stations in the different sectors.
- The operation of the FRU desk would be heavily compromised because it relies on the tracking of mobile vehicles. Each FRU vehicle does have a place of rest but the geographical area that the desk covers and the quick nature of responding to calls means that the efficient working of such a system would be highly debatable.
- Without the MDT system it is likely that both the radio operator and the telephone dispatcher would have a lot more communication traffic, largely due to the repetition of the details of incidents to crews in their vehicles or at their station.
- Making mobile vehicles easier to allocate through tracking and the MDT system would have reduced the reliance on crews situated at the station. This would have further reduced the telephone dispatchers' routine workload. However, it may mean that is a greater potential for sharing incidents among ambulance crews unevenly if they are reallocated to incidents once mobile rather than using the next crew at a station.
- Without the MDT the record of the actions for each call would be much more focused on the paper based system and so there would be a greater workload and an extra emphasis for the whole desk to keep this paper system up-to-date.
- Due to the emphasis on the paper based system, the increased cognitive load of monitoring the calls, and the extra reliance of both the telephone dispatcher and radio operator, it is essential to have the three individuals on the sector desk working in close proximity.

Conclusion

It would appear from the predicted design issues that the addition of the computer support in the LAS CAC has led to improvements in functionality and efficiency. The addition of the computer support has not just led to a change in speed but changes in the strategies for allocating ambulance crews. In this sense the added computational power of the system affords new possibilities for how the system functions. Particular points to note include the decrease in potential for cross sector desk working, the reduced activity of the telephone dispatcher and the diminished role of paper based systems.

2. Progressive Design

Outline and Objective

This design aims to look at possible developments of the LAS CAC based on the issues recognised in the analysis. In any design there are different parts of a system that can be focused on. This design will mainly focus on the physical layout and communication flow levels rather than the design of specific interface representations. This choice of focus is in part practical, given more time and resources other areas could also be addressed, but it also looks to explore the changes in emphasis of individual roles as a consequence of the added computational support i.e. the decrease in the role of the telephone dispatcher and significance of the paper based system, and increase in cross-sector desk working.

Initial Thoughts

In terms of the physical layout of the system I will explore bringing the different sector allocators closer together to further facilitate cross-boundary working, which has already been encouraged by the vehicle tracking system. I will also explore the possibility of moving telephone dispatchers further from the allocator and radio operator as it appears their roles have diminished from the addition of the computer support. The potential rearrangement of these individuals is not just a physical matter but will involve the careful consideration of the functional consequences of the system, particularly its effect on the flow of information and communication.

Design Rationale

Table 9: Claims Analysis of Potential Design Arrangements of the LAS CAC.

The consequences preceded with plus signs are referred to as "pros" or "upsides" of a feature; those with minus signs are the "cons" or "downsides" of a feature. As a group they illustrate the tradeoffs associated with the feature (Rosson & Carroll, 2002, pp 73).

Design Feature	Hypothesized Pros (+) or Cons (-) of the Feature
Moving allocators closer together	+ easier communication between allocators, further facilitating cross-boundary working, which might be particularly needed in large emergency incidents - reorganisation potentially compromises the close working relationship between allocator, radio operator and telephone dispatcher
Move telephone dispatchers further away	+ frees room for alternative physical arrangement - degradation of buffer for the allocator affecting the operation of the whole sector desk - reduction in system slack causing resources to be strained when work fluctuates - reduction of implicit learning and the transfer of knowledge between people in different roles
Moving allocator and radio operator opposite each other rather than working side-by-side	+ allows for alternative arrangements - reduces peripheral awareness of each others work as they can see what the other is doing
Withdrawal of paper system	+ frees room for alternative physical arrangement - alternative system will need to account for subtle functional supports of paper system e.g. piles of paper creating plans, paper arranged to draw attention and to aid recall

Have a one-stop communication channel with crews	+ allows greater flexibility in contacting crew + could open potential for telephone dispatcher and radio operator to job share + can improve communications between crew and external party e.g. reporting blue calls
Further automate allocating crews at a station	+ telephone dispatchers call to station is automated freeing them for other tasks + allocator can treat allocating a call to a station in much the same manner as a mobile vehicle - automation will need further equipment and the addition of activities performed by the crew - reducing verbal communication between LAS staff and crews might have social consequences
Allow closer computerised working for cross-boundary allocation	+ reduces need for physically rearranging allocators to be seated closer together + improvement in speed and efficiency of allocating the most suitable crew

Description
In deliberating about a possible design one normally tends to entertain a number of ideas and consider the consequences of each i.e. their positive and negative implications. In this respect I will consider a number of potential scenarios for a redesign.

Scenario 1
Figure 16 shows a variation of the current room layout, a suggestion aimed at bringing the allocators closer together to encourage and make cross-boundary working more efficient. The diagram itself is limited in the sense that it is not to scale and only contains the locations of allocators and radio operators; because of the limitation in scale it is not clear whether a telephone dispatcher could be sat in between the radio operators. The essential premise of this arrangement is that the need for having allocators closer together is more important than having telephone dispatchers in close proximity to the allocator.

To facilitate this design arrangement further we can make changes in the information flow structure so the need to have a telephone dispatcher close by is further reduced. By reviewing communication between the sector desk and the crew more flexible communication channels could be added (e.g. personal radio or other mobile device) so the crew could be contacted regardless of whether they are at a station or mobile (refer to Figure 17). Also, the allocation of a crew at a station could be more automated e.g. an allocator could allocate a station, an MDT would then alert all crews of the details at the station, the crews would accept the call at the station MDT which would then forward it to their vehicle. Both of these communication changes would reduce the need for a telephone dispatcher. An alert for station MDTs could even be incorporated on the new communication devices e.g. it could operate something like a pager.

Figure 16: Room Level Diagram (Variation of Figure 6)

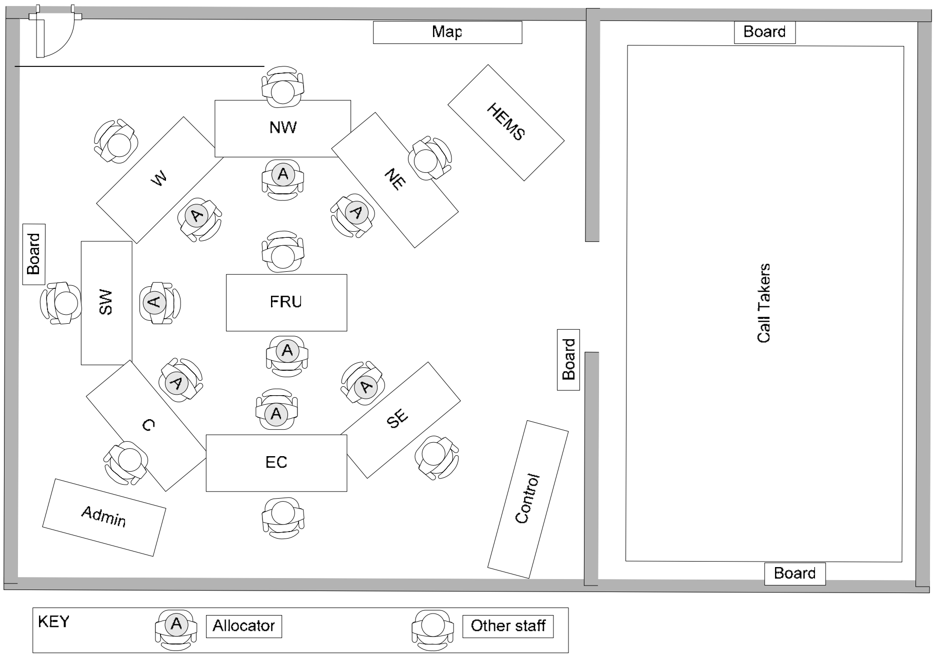
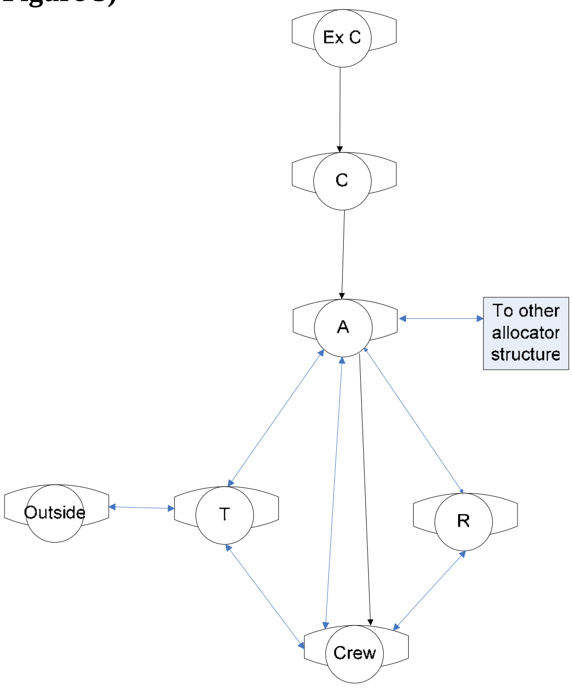


Figure 17: Possible Flow of Information and Communication Channels (Variation of Figure 3)



Key

Letter	Actor	Role
Ex C	External Caller	People who make the incoming emergency 999 calls.
C	Call Taker	Takes the details of the incoming calls and enters it into the computer system.
A	Allocator	Person who decides which ambulances should go where and when.
R	Radio Operator	Speaks to ambulance crews via the radio.
T	Telephone Dispatcher	Speaks to ambulance crews via the telephone.
Crew	Ambulance Crew	Ambulance crews, both at the station and mobile.
Outside	Outside contacts	Anyone that needs to be contacted via phone e.g. calling external callers or other emergency services

An important role of the telephone dispatcher is performed as a buffer and to add slack in system resources (shown in Figure 4). This is very important in EMD as fluctuations in workload and communications can vary greatly from moment to moment. Without a buffer or some slack in the system the system will be strained at times of high workload and will consequently become ineffective. There is a possibility that the buffer or slack could be remotely placed from the allocator but this would cause a great degradation in the support and close working of the team. When buffers are used effectively it is likely to be at times of high workload when members of a team will pick up information through overhearing, where information will be shared at opportune times (when an individual sees that another individual is in a state to receive that information), and where workers will flexibly organise themselves to cope with the situation at hand. All of these will greatly degrade with the distancing of the telephone dispatcher. Given this, I would not recommend locating the telephone dispatcher remotely – the properties of having an effective buffer and some slack in the information system is crucial for dealing with the fluctuations in EMD work effectively. Therefore I believe the arrangement in Figure 16 will only act sufficiently if buffering and slack are properly incorporated into it.

Without having the physical dimensions of the desk space needed by each of the three individuals that currently work on each sector desk it is hard to deliberate about the possibility of fitting all three in the arrangement shown in Figure 16. One thing that would increase the potential for this arrangement would be the withdrawal of the paper system which currently takes up a lot of room (can be seen in Figure 10). If the paper system was withdrawn then the computer system would have to replace the subtle supports offered by the paper system (recognised in the analysis of the incident card and tray system in the Artefact Model).

Scenario 2

A potential design scenario that needs to be considered is structured around the current physical layout of the LAS CAC (as shown in Figure 6). The core premise behind this arrangement is that communication between allocators across the room is not too much of a problem and certainly does not outweigh the importance of the close working arrangement between the allocator, radio operator and telephone dispatcher. To support this, the observations from the LAS CAC suggested that communication between allocators was intermittent and there was the impression that problems with allocating crews from another sector resided with the computer system rather than the communication within the room.

Arguments that support the case for the close working arrangements between the telephone dispatcher, allocator and radio operator (in Scenario 1 above) also apply in this case. Also, further support for keeping the three individuals together can be gained from deliberating about learning and the transfer of knowledge between them. By separating the three individuals there would be less implicit knowledge sharing between the different roles. With the close working in the current situation knowledge about what each other does and how this is done is transferred between individuals implicitly. This improves staff training and the maintenance of knowledge and experience within the system in the long term.

Considering how the three individuals should be arranged together it would appear that the relationship with the radio operator and allocator should be considered above that of the telephone dispatcher and the allocator. The radio operator and the allocator work closely on dealing with mobile crews which has become more important now that they can be tracked and allocated easily using satellite navigation and the MDT system. The radio operator and allocator currently share the paper tray system but even without this paper system it is important to have these two individuals working close together so they can communicate easily. It would also appear that working side-by-side will improve the information that flows between them as they have peripheral access to what the other is doing, working opposite each other would degrade this peripheral awareness. Working opposite each other would allow access to the others facial expressions but this still lacks the important detail of the activities they are currently pursuing and hence the implicit synergy between their work is degraded.

Given that the current system seems a good arrangement in terms of keeping the three individuals of the sector desk working in close proximity more could be done to smooth the process of allocating ambulances via the computer system. Two specific examples include improvements in allocating ambulances from other sectors and the process of allocating crews at a station. A possibility is that if an available ambulance is identified as being the ideal vehicle for a call then it should be able to be allocated by that sector desk and then confirmed or denied by the sector desk that actually has responsibility of the ambulance. All correspondence for that call could then go to the sector desk that has the responsibility for that ambulance. A possibility for allocating crews at stations involves the allocator being able to allocate a call to a station, the crew could then view the details on a station computer and pick it up from there, agreeing to the station request would involve identifying the crew at the station which would automatically lead to the details being forwarded to their vehicle. This automates the involvement of the telephone dispatcher in this process and aims to compact the activity and reduce the mental workload of the allocator.

Issues

- Moving the positions of individuals can have a variety of effects in the functioning of the system, including the implicit transfer of knowledge for learning and the close working between individuals. These effects should be carefully considered before people are moved.
- The value of the telephone dispatcher as an information buffer and a source of potential slack in the sector desk system is an important factor for keeping the system running efficiently through periods of high activity.
- The computer system could be improved to better facilitate cross-boundary working, this would also reduce the need to improve the opportunity for physical communications between allocators.
- The communication channels between the sector desk and the crews could be improved to give the sector desk greater flexibility in contacting them. This opens the opportunity for work sharing between the telephone dispatcher and the radio operator, and progression towards treating the allocation of mobile crews and crews at stations the same.
- More could be done to improve the allocation of ambulance crews at their stations with the aim of making the process as easy as allocating mobile crews from the sector desk end.

Conclusion

The consideration of these alternative designs has led to the expression of potential design issues that need to be considered if the system is to be reorganised e.g. distancing the telephone dispatcher has a number of negative impacts that would have to be accounted for if this option was chosen. Those design ideas that appear to have the best chance of improving the current system are not big structural changes but incremental ones e.g. reviewing the communication channels between the sector desks and crews, and improving cross-boundary working through the computer system.

Discussion

Overview

The aim of this paper has been to develop a structured method of analysis for DC, this structure brings a degree of guidance to the application of the theory so that it can be more readily utilised by the HCI community, and so that its concepts become more visible. As there is more body in the method of applying DC there is more academic substance to practice, criticise and develop for the future.

This section will discuss the development of the method, the codified DC method itself, DC design scenarios, and their application to the LAS CAC context.

The Development of the Method

The development of the method involved an exploratory process of reviewing contextual study literature, DC literature and the data of the context under study. This led to the development of a method that was guided by practical advice on contextual study research, that explored relevant DC concepts and that was suitable for the LAS CAC context of study.

A suitable context of study had to be utilised in this process otherwise the method would have been purely academic in the sense that it would have been solely derived from the literature. This iterative approach was favoured over solely developing a method through the literature and then applying it separately because this was an exploratory area: DC is associated with lengthy studies (e.g. Hutchins, 1995) and has not been developed into an 'off-the-shelf' approach (Rogers & Scaife, 1997). A suitable context to study and adapt the method benefited this process by incorporating practical limitations, complexities and constraints; and it gave a continual check through constantly evaluating what was done well, what was not, and what needed to be included to make the method work practically.

In utilising this context to develop the codified DC method it has influenced its structure, so we might ask what sorts of things could have limited its validity i.e. was it a suitable context to use, is it representative of all future contexts that will be studied, and if not, what things is it missing that might limit the applicability of the method that has been developed? The LAS CAC is a rich contextual environment where the task of allocating ambulances is divided into a structured process. This structure comes through social organisation; communication channels; tools, representations and artefacts; all of which influence the functioning of the cognitive system. Because of this I would claim that the LAS CAC context is a rich environment to study DC, involving both individuals and teams working under social and physical structure. Furthermore, it is a suitable environment for the study of DC in HCI as it involves the integration of different computer systems, representations, technologies and communication devices to perform the task of allocating ambulances effectively.

The question as to whether the LAS CAC context is representative of all future contexts that will utilise the theory is much more difficult, and its answer is most likely to come with future applications of the method. A possible limitation of the method is its application to contexts where social factors play an increasingly significant role. For example, a DC system could principally incorporate many different groups of people that might have political motives and agendas in their communications and decision strategies. This would functionally affect the cognitive system and hence would need to be addressed in an analysis. In its current state I would say the model is most suited to analysing close proceduralised team systems; hence systems that have more informal procedures might also be more challenging to describe and analyse. So, larger systems involving a significant interplay of politics and informal procedures might require the development of an additional layer of the model and further guidance to adequately account for these functional effects. In any case, the contextual study literature reviewed suggests that a productive practical method will be derived by intelligently adapting and deploying methods to suit the needs of the situation, so the analyst should have an eye for the suitability of the method to the context being studied. It seems that this model will not be fully validated until it has gone through further iterations of deployment and development, but it is worth noting that all contextual methods are likely to be limited in some respect in light of the complexity of factors they try to engage with, and so we are only left with acknowledging the usefulness, constraints and limitations of each method even when they are fully developed.

The Codified DC Method

The codified DC method has been developed with the aim of being a practical tool for practitioners and researchers to use. In recognition of this the method is: systematic in its deployment and encourages exploration of further detail through its hierarchical layers; flexible in not prescribing every detail but guiding the analysis; not laden in abstract annotations, that are demanding to learn, which would make it harder to pick up; and has an ‘issues section’ which should be utilised as the model is developed and insights are gained. The method of analysis is not just something to help build a data set or a set of representations but something to help the active investigation of the field of interest i.e. to direct and guide attention to specific areas of focus in certain levels of detail.

The method provides a focus on the communication flow of a system, the physical layout of a system, and gives attention to the functional aspects of artefacts and representations in its three models. DC theory looks to analyse the functional elements that influence the propagation and transformation of information in a system and I would claim that these three models give adequate coverage to DC theory for analysing the LAS CAC and similar contexts. Many of the functional elements are explicitly addressed in the three models of the method as this is what they have been designed to do. With the nature of the DC theory and the flexibility of many real cognitive functional systems I would expect the level of insight to be correlated with the analyst’s familiarity with the DC theory. In recognition of the fact that this may have an influential impact on the performance of any analyst, work should be done on representing ‘bites’ and ‘patterns’ of previous influential work so novices can more readily familiarise themselves with the literature at hand. Similar suggestions of using patterns in HCI work have been made before (e.g. Erickson 2000; and Martin and Sommerville, 2004) to increase the transfer of knowledge between designers and analysts. This appears that it could be a fruitful method of distributing DC theory, making it more accessible, encouraging its use and improving analytic performance in the area (discussed further in Future Directions below).

The codified DC method presented in this paper has been informed by Contextual Design (Beyer & Holtzblatt, 1998) both in its method of data gathering and data representation. We might ask ourselves how this new method is significantly different, why changes have been made, and what difference there would be if we just use the original method?

I believe the Contextual Inquiry method of data gathering affords the analyst a rich opportunity to familiarise themselves with the context, through the combination of observing the working context 'live' and asking questions about the work as it happens. For the purposes of the current method this remains unchanged, along with Beyer and Holtzblatt's (1998) advice in taking examples of artefacts if possible. Given the practical advice of the contextual study literature I would not constrain the methods of data gathering the analyst sees fit to employ in a given situation; including interviews, recordings, photos, and think-alouds within the contextual environment.

I think there is a significant difference between the representation and recording method used in the codified DC analysis and the clear recommendations made by Beyer and Holtzblatt (1998). Beyer and Holtzblatt (1998) offer a comprehensive set of five models in their description of a system, and focus on the graphical annotations used as a powerful medium for representation and communication between a design team. The DC method developed in the paper differs significantly in these respects. It has three models as it was found that this suited the practical application of DC theory in the LAS CAC context. One of the reasons for this was that the process of the task and communication in it were so closely entwined that they were considered together; in this team situation it was found that the passing of information was often not about the task but was part of the sequence of the task itself (arguments to support this observation are represented in Winograd and Flores, 1986). Another reason is that the cultural model described by Beyer and Holtzblatt (1998) was not deemed as relevant for the DC analysis in the LAS CAC, as the system did not exhibit significant cultural factors. It was questioned whether the cultural model may be detracting away from the core functional principles of a DC system (e.g. the flow of communication, physical layout and artefact structure) but in hindsight this model may have a part to play in larger systems that do have culturally significant influences on functional cognition. Work of this nature has not been investigated in this paper and may form part of the future development of this line of analysis.

Contextual Design (Beyer & Holtzblatt, 1998) is described as a system that involves multiple analysts that gather data, represent that data by using specific annotations meaningful to the group, and then collate their data together with their combined representation representing the entire system. From this we might imply that the core of Contextual Design is in representation and communication between a design team, so that a comprehensive description of the system can be constructed so that it can be the subject of debate and analysis at a later stage in the design process. The DC method developed in this paper focuses on an entirely different area. Here the method has been designed systematically to aid the lone analyst to investigate the area by delving into detail through the hierarchical levels of the model and recording insights as they develop. The heavy emphasis on graphical annotations has also been discarded as the emphasis for its use in communication is no longer required, and so that analysts find the method easy to 'pick up'. The graphical representations that are recommended can vary between different analyst's descriptions and are aimed at being an aid for the description rather than being the description itself, which appears to be the case for Contextual Design. What the codified method of DC loses in representation and communication, by simplifying the models and annotations, it gains in developing a structure for systematic analysis and making the method more accessible.

DC Design Scenarios

The conception of how DC can be used as a design tool is an extension of the analytic method which has been the main focus of this paper. In this sense, the conception that I have outlined should be viewed as an introduction to a possible approach to developing DC as a design tool rather than a complete account. The possibility of such a use for DC has been alluded to elsewhere but it has not previously been described. The use of cognitive simulations in this context seems like a suitable way to proceed given that large complex system (e.g. control rooms) cannot just be physically built and tested due to practical reasons. There is a question as to how valid and useful these simulations might be, and these concerns are likely to be further amplified if the designer has little experience of DC and the particular context under study. It seems like some deliberation in this area would be more beneficial than if none was done at all, but further studies need to be conducted with reference to literature related to scenario-based methodologies and cognitive simulations. Claims analysis has been used as an approach to aid design in this area but there may be further methods, guidance and advice that have not been accounted for in this paper.

The Results for the LAS CAC

A number of design issues were identified as a result of the analysis of the LAS CAC which might be the subject of future development. These developed from the insights directly gained through the use of the codified method of DC and from the opinions and judgements of staff working at the LAS CAC (an advantage of using Contextual Inquiry as a method of data gathering). The design issues were further explored in the DC design scenarios which highlighted the benefits of some relatively conservative changes and cautioned against radical reorganisation e.g. distancing the telephone dispatcher from the allocator.

Possible limitations of the results gained include the relatively short period that data was gathered (just over 6 hours for the two visits), and that the video recordings were taken before the introduction of the MDT and satellite tracking technology. The fact that the video recordings represented a different data set was accounted for in the analysis but the possibility of contamination has to be acknowledged.

Future Directions

Given the applicability of DC theory to HCI design and analysis and the recognised problems of its visibility within the HCI community it suggests that there is work to be done in narrowing the gap for its wider use and application. One area explored in this paper is creating a structured codified approach of implementing a DC analysis. This has been developed through its iterative application to a data set provided by the LAS CAC, and so a future direction, is in exploring the method's applicability to other contexts. An acknowledgement in the paper is that it may be suited to proceduralised team working environments and may be lacking in larger organisational and cultural dimensions of a DC analysis more pertinent to larger contexts.

For a structured and guided DC method to succeed accessibility to its content must also follow. It was acknowledged that an analyst's insights are likely to be correlated to their familiarity with the DC literature and so there is a need to make its literature more accessible. One suggested way to proceed is the cataloguing of 'bites' and 'patterns' in a useful and accessible manner that will disseminate the current insights of DC theory and provide a framework for those that are gained through future work (Table 3 in this paper might be considered a prototype of such an idea). In recognition of the importance to feed insights through from theory to practice, in an accessible manner, the description of the codified DC method in this paper contains explicit cross-references with Table 3 where applicable. In this vein further work on developing DC ‘bites’ and ‘patterns’ will further enrich future analyses in this area.

The potential for using DC as a tool for deliberating about potential design scenarios has been introduced in this paper, but this preliminary conception has not been fully developed. Further work in this area could look at building methods, guidance and advice with reference to scenario-based methodologies and the literature on cognitive simulation. It is likely that the approach will remain limited in its validity, as is the nature of cognitive simulations in such complex areas, but it could nevertheless be a useful tool in deliberating about design ideas when other approaches are unfeasible. Approaches to design and evaluation each have their own constraints, strengths and weaknesses, and specific areas that they are applied to; in this vein any development of a DC design tool should aim to explicitly outline its applicability, usefulness and weaknesses for those that may consider using it.

Recognition has also been given to the fact that the method is a needed and novel step in the DC area for HCI. Because of this it should undergo academic scrutiny in its practice, criticism and development. This should bring benefit to DC’s general applicability to HCI, as it directly opens up the debate on exactly how it can be applied as a structured method of analysis and whether it is useful. From the contribution of this paper, I hope it has shown that DC can be applied through a structured methodology and that its output is both relevant and useful to HCI researchers and practitioners.

Conclusion

The central motivations behind this paper are the claims that DC lacks visibility within the HCI community although relevant for analysis and design (Wright et al., 2000); and that DC cannot currently be used as an ‘off the shelf’ methodology (Rogers and Scaife, 1997). I believe that these problems are related, and a potential solution can come from the codified DC method of analysis developed in this paper and the future work that it suggests. By making the theory more accessible to understand and apply it is hoped that practitioners and researchers will be in a closer position to engage with it through practice, criticism and development.

References

Bannon, L. (2000). Situating Workplace Studies within the HCI Field. In Luff, P., Hindmarsh, J. & Heath, C. (eds). *Workplace Studies: Recovering work practice and information system design*. pp 230-241. Cambridge: Cambridge University Press.

Beyer, H. & Holtzblatt, K. (1998). *Contextual Design: Defining customer centred systems*. Morgan Kaufmann.

Blandford, A., Wong, W., Connell, I. & Green, T. (2002) Multiple Viewpoint On Computer Supported Team Work: A Case Study On Ambulance Dispatch. In Faulkner, X., Finlay, J. & D étienne, F. (Eds.) *People and Computers XVI: Proc. HCI'02*. pp 139-156. Springer.

Blandford, A., Green, T. & Connell, I. (2003). Surface and Structural Misfits Using CASSM and Cognitive Dimensions. Retrieved 12/08/04, from http://www.cs.ucl.ac.uk/teaching/hcie/CASSMnotes.pdf.

Blandford, A. & Wong, W. (forthcoming). Situation Awareness in Emergency Medical Dispatch. To appear in International Journal of Human Computer Studies.

Bodker, S., Greenbaum, J. & Kyng, M. (1991). Setting the Stage for Design as Action. In Greenbaum, J. & Kyng, M. (eds) (1991). *Design at Work: Cooperative design of computer systems*. pp 139-154. London: Lawrence Erlbaum Associates.

Brown & Duguid. (2000). *The Social Life of Information*. Boston: Harvard Business School Press.

Checkland, P. & Holwell, S. (1998). *Information, Systems and Information Systems: Making sense of the field*. Chichester: John Wiley.

Clark, A. (1997). *Being There: Putting Brain, Body, and World Together Again*. London: MIT Press.

Cottingham, J. (1986). *Meditations on First Philosophy: With selections from the objections and replies*. Cambridge: University of Cambridge.

Decortis, F., Noirfalise, S. & Saudelli, B. (no date). Distributed Cognition as Framework for Cooperative Work. Retrieved 12/08/04, from http://www-sv.cict.fr/cotcos/pjs/TheoreticalApproaches/DistributedCog/DistCognitionpaperDecortis.htm

Dreyfus, H. & Dreyfus, S. (1986). *Mind Over Machine: The power of human intuition and expertise in the era of the computer*. Oxford: Basil Blackwell.

Erickson, T. (2000). Lingua Francas for Design: Sacred places and pattern languages. In *Proceedings of Designing Interactive Systems: Processes, Practices, Methods, and Techniques*, August 17-19, Brooklyn, NY.

Fields, R., Wright, P., Marti, P. & Palmonari, M. (1998). Air Traffic Control as a Distributed Cognitive System: a study of external representation. In Green, T., Bannon, L., Warren, C. & Buckley, J. (eds) *ECCE9: Proceedings of the Ninth European Conference on Cognitive Ergonomics*. pp 85-90.

Fisher, C. & Sanderson, P. (1996). Exploratory Sequential data Analysis: Exploring continuous observational data. *Interactions*, 3 (2): pp 25-34. March 1996.

Gauld, A. & Shotter, J. (1977). *Human Action and its Psychological Investigation*. London: Routledge & Kegan Paul.

Gray, W., John, B. & Atwood, M. (1992). The Précis of Project Ernestine or An Overview of a Validation of GOMS. In *Proceedings of CHI '92*, May 3-7, 1992.

Gross, R. (1996). (3rd ed). *Psychology: The science of mind and behaviour*. London: Hodder & Stoughton.

Hollan, J., Hutchins, E., & Kirsh, D. (2000). Distributed Cognition: Toward a New Foundation for Human-Computer Interaction Research. *ACM Transactions on Computer-Human Interaction* 7: pp 174-196.

Hutchins, E. (1995). *Cognition in the Wild*. London: MIT Press.

Jha, S. (2002). *Reconsidering Michael Polanyi's Philosophy*. Pittsburgh: University of Pittsburgh Press.

Jirotka, M. & Wallen, L. (2000). Analysing the workplace and user requirements: challenges for the development of methods for requirements engineering. In Luff, P., Hindmarsh, J. & Heath, C. (eds) *Workplace Studies: Recovering work practice and information system design*. pp 242-251. Cambridge: Cambridge University Press.

Jordan, B., Henderson, A. & Tatar, D. (In prep.). Interaction Analysis: Foundations and practice. Palo Alto: Palo Alto Research Centre. Cited in Suchman, L. & Trigg, R. (1991). Understanding Practice: Video as a medium for reflection and design. In Greenbaum, J. & Kyng, M. (eds). *Design at Work: Cooperative design of computer systems*. pp 65-90. London: Lawrence Erlbaum Associates.

Kaptelinin, V., Nardi, B., Bodker, S., Carroll, J., Hollan, J., Hutchins, E. & Winograd, T. (2003). Post-cognitivist HCI: Second-Wave Theories. In *Proceedings of CHI '03,* April 5-10, 2003.

Kirsh, D. (1995a). The Intelligent use of Space. Artificial Intelligence 72: pp 1-52. Cited in Clark, A. (1997). *Being There: Putting Brain, Body, and World Together Again*. London: MIT Press.

Kirsh, D. (1995b). The Intelligent use of Space. Artificial Intelligence 72. pp 1-52. Cited in Hollan, J., Hutchins, E., & Kirsh, D. (2000). Distributed Cognition: Toward a New Foundation for Human-Computer Interaction Research. *ACM Transactions on Computer-Human Interaction* 7: pp174-196.

Kirsh, D. & Maglio, P. (1994). On distinguishing epistemic from pragmatic action. Cognitive Science 18: pp 513-549. Cited in Clark, A. (1997). *Being There: Putting Brain, Body, and World Together Again*. London: MIT Press.

Luff, P., Hindmarsh, J. & Heath, C. (2000). Introduction. In Luff, P., Hindmarsh, J. & Heath, C. (eds). *Workplace Studies: Recovering work practice and information system design*. pp 1-28. Cambridge: Cambridge University Press.

Marr, D. (1982). Vision: A Computational Investigation into the Human Representation and Processing of Visual Information. Freeman. Cited in Hutchins, E. (1995). *Cognition in the Wild*. London: MIT Press.

Martin, D. & Sommerville, I. (2004). Patterns of Cooperative Interaction: Linking Ethnomethodology and Design. *ACM Transactions on Computer-Human Interaction*, 11 (1): pp 59-89. March 2004.

Nardi, B. (1996a). Studying Context: A comparison of activity theory, situated action models, and distributed cognition. In Nardi, B. (ed) *Context and Consciousness: Activity theory and human-computer interaction*. pp 69-102. MIT Press.

Nardi, B. (1996b). Activity Theory and Human Computer Interaction. In Nardi, B. (ed) *Context and Consciousness: Activity theory and human-computer interaction*. pp 7-16. MIT Press.

National Centre for Defibrillation. (2002). The case for early defibrillation. Cited in Wong, W. & Blandford, A. (forthcoming). Information Handling in Dynamic Decision Making Environments. To appear in Proc. ECCE-12. Retrieved 28/01/04, from http://www.early-defrib.org/04_01advocacy.html.

Newell, A. & Simon, H. (1976). Computer Science as Empirical Inquiry: Symbols and Search. In Haugeland, J. (ed.) (1997). *Mind Design II: Philosophy, Psychology and Artificial Intelligence*. pp 81-110. London: MIT Press.

Newman, W. & Lamming, M. (1995). *Interactive System Design*. Addison Wesley.

Norman, D. (1988). *The Psychology of Everyday Things*. New York: Basic Books.

Norman, D. (1995). *Things that Make Us Smart*. Addison Wesley.

Rogers, Y. & Scaife, M. (1997). Distributed Cognition. Retrieved 12/08/04, from http://www-sv.cict.fr/cotcos/pjs/TheoreticalApproaches/DistributedCog/DistCognitionpaperRogers.htm.

Rosson, M. & Carroll, J. (2002). *Usability Engineering: Scenario-based development of human-computer interaction*. London: Morgan Kaufman.

Sanderson, P. & Fisher, C. (1994a). Introduction to this Special Issue on Exploratory Sequential Data Analysis. In Human-Computer Interaction 9: pp 247-250.

Sanderson, P. & Fisher, C. (1994b). Exploratory Sequential Data Analysis: Foundations. In Human-Computer Interaction 9: pp 251-317.

Simon, H. (1981). The Sciences of the Artificial (second edition). MIT Press. Cited in Hutchins, E. (1995). *Cognition in the Wild*. London: MIT Press.

Suchman, L. (1987). *Plans and Situated Actions: The problem of human computer communication*. Cambridge: Cambridge University press.

Suchman, L. & Trigg, R. (1991). Understanding Practice: Video as a medium for reflection and design. In Greenbaum, J. & Kyng, M. (eds) *Design at Work: Cooperative design of computer systems*. pp 65-90. London: Lawrence Erlbaum Associates.

Sumner, T. (1995). The High-Tech Toolbelt: A study of designers in the workplace. *Proceedings of the SIGCHI conference on Human Factors in Computing Systems*. pp 178-185. May 07-11, 1995, Denver, Colorado, US.

Thomas, C. & Kellogg, W. (1989). Minimizing ecological gaps in interface design. IEEE Software. (January): 78-86. Cited in Bannon, L. (2000). Situating workplace studies within the human computer interaction field. In Luff, P., Hindmarsh, J. & Heath, C. (eds). *Workplace Studies: Recovering work practice and information system design*. pp 230-241. Cambridge: Cambridge University Press.

Wason, P. (1977). The Theory of Formal Operations: A Critique. In Geber, B. (ed.) *Piaget and Knowing*. pp 119-135. London: Routledge and Kegan Paul.

Wenger, E. (1998). *Communities of Practice: Learning, meaning and identity*. Cambridge: Cambridge University Press.

Winograd, T. & Flores, F. (1986). *Understanding Computers and Cognition: A New Foundation for Design*. Norwood, N.J.: Ablex Publishing Corp.

Wong, W. & Blandford, A. (2001). Situation Awareness and its Implications for Human-System Interaction. In Smith, W., Thomas, R. & Apperley, M. (Eds.) Proceedings of the Australian Conference on Computer-Human Interaction OzCHI 2001, 20-22 November, 2001. pp 181-186. Perth, Australia: CHISIG, Ergonomics Society of Australia.

Wong, W. & Blandford, A. (2002). Analysing Ambulance Dispatcher Decision making: Trialling Emergent Themes Analysis. To appear in *Proc. HF2002*.

Wong, W. & Blandford, A. (2003). Field Research in HCI: A Case Study. In *Proc. CHINZ03. NZ Chapter of SIGCHI*. pp 69-74.

Wong, W. & Blandford, A. (forthcoming). Information Handling in Dynamic Decision Making Environments. To appear in *Proc. ECCE-12*.

Wright, P., Fields, B. & Harrison, M. (2000). Modelling Human-Computer Interaction as Distributed Cognition. *Human Computer Interaction Journal* 51(1): pp 1-41, 2000.

Wynn, E. (1991). Taking Practice Seriously. In Greenbaum, J. & Kyng, M. (eds). *Design at Work: Cooperative design of computer systems*. pp 45-64. London: Lawrence Erlbaum Associates.

Zhang, J. & Norman, D. (1994). Representations in distributed cognitive tasks. Cognitive Science 18: pp 87-122. Cited in Norman, D. (1995). *Things that Make Us Smart*. Addison Wesley.