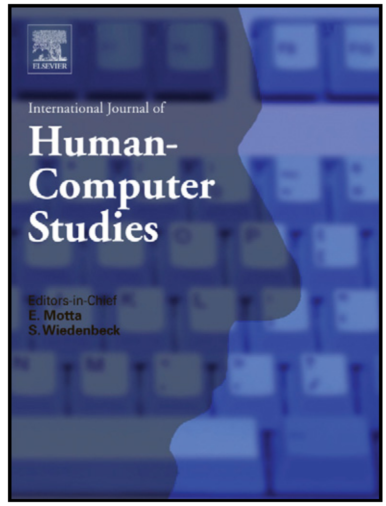

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G. Doherty, J. McKnight, S. Luz

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Fieldwork for Requirements: Frameworks for Mobile Healthcare Applications

G. Doherty, J. McKnight, S. Luz

Department of Computer Science, Trinity College Dublin, Ireland

Abstract

Ethnographic approaches to study of work in the field have been widely adopted by HCI researchers as resources for investigation of work settings and for requirements elicitation. Although the value of fieldwork for design is widely recognised, difficulties surround the exploitation of fieldwork data within the design process. Since not every development project can support or justify large-scale field investigation, the issue of how to build on previous work within a domain is particularly important. In this paper we consider this issue in the context of development of mobile healthcare applications. Many such systems will be built in the coming years, and already a number of influential studies have derived concepts from fieldwork data and used them to support analysis of healthcare work. Using a patient review process as an example, we examine how the concepts from such exemplar studies can be leveraged to analyse fieldwork data, and to facilitate requirements elicitation. The concept, previous interpretation within the domain, prototypical requirements and associated critique together provide a framework for analysis. The concepts are used to highlight issues that must be addressed and to derive requirements. We make the case that these concepts are not "value free" and that the course of our analysis is significantly altered through the palette of concepts used. The methodological implications of this proposition are also considered.

Keywords: healthcare, mobile applications, requirements, conceptual frameworks, fieldwork

1. Introduction

The healthcare environment raises many challenges for design, with many different roles and stakeholders involved, safety critical tasks being performed, large volumes of information being generated and accessed, and highly mobile workers carrying out their activities in a variety of different settings. Due to the nature of the work, and recent improvements in technology, there is increasing use of mobile technology within the environment. Thus, as use of these technologies becomes commonplace, a large number of development projects can be expected. For such complex work systems, understanding the context of use and the practical realisation of the work in the field is critical for successful design.

Email addresses: gdoherty@cs.tcd.ie (G. Doherty), mcknigjg@cs.tcd.ie (J. McKnight), luzs@cs.tcd.ie (S. Luz)

In recent years, fieldwork based techniques have been increasingly employed in the healthcare domain with a number of research efforts producing influential studies, and motivating fieldwork-informed designs. Typically, a field investigation will yield a lot of information on the different users, working practices, use of artefacts and information, and activities as they currently happen. Many of these field studies involve the use of ethnographic or ethnomethodological analysis. Ethnomethodology in particular has had a substantial impact on Human-Computer Interaction research. A useful definition of Ethnography is that it is a method for understanding what activities mean to the people who do them (Harper, 2000, p. 244). One breakdown is that it comprises the fieldwork program, an analytic program, and documentation and presentation of the results (Rönkkö, 2010). Other approaches making use of a fieldwork program can be seen as coming under the broad umbrella of case study methodologies.

While there are a variety of views on how to incorporate design fieldwork into the development process (Randall et al., 2007), a number of difficulties remain. Whereas textbooks on requirements engineering typically focus on modelling (Lamsweerde, 2007), it is widely acknowledged that "contextual approaches based on ethnographic techniques" do not map well onto current formal specification and analysis modelling methods (Nuseibeh and Easterbrook, 2000). Difficulties in translating the observational record into a requirements document have also been noted in studies of ethnographically-informed system development (Bentley et al., 1992).

There has been considerable debate on the role of ethnography in requirements engineering (Hughes et al., 1995; Shapiro, 1994). It has been argued that it should assume *an exploratory role in innovative technical research* (Crabtree, 2003), and identify researchable topics. However, in spite of the above mentioned difficulties, there has undoubtedly been successful progress on integrating fieldwork study techniques into a requirements process. Much of this work is predicated on including an ethnographer in the design team, but this option is not always available. When it is, establishing effective communication between ethnographers and developers can be difficult, even within a multi-disciplinary design team (Denley and Long, 2001). In some cases ethnographic study may not be the most appropriate approach. Anderson (1994), for instance, states that: "Many designers of CSCW and other types of collaborative end-user systems are now turning to ethnography as a means of requirements capture. In my view, it is not ethnography they want but field experience. To get out into the real world and understand the context of use may provide them with all the access and insight they feel they need". We take the position that designers should base a significant portion of their decision making on such fieldwork data. It is on the use of fieldwork data for identifying requirements and critiquing designs for mobile healthcare work that we focus in this paper.

There is also a pragmatic concern that previous fieldwork studies within a domain are built upon and exploited in a way which is accessible not just through the experience and knowledge of the analyst. Plowman et al. (1995) ask the question, "Is it desirable, practical, useful and economical for a workplace study to be carried out *ab initio* every time a CSCW system is to be developed?". This is particularly the case for small-scale development projects and for cases where a generic software system requires bespoke tailoring work in order to fit in with the working practices and requirements of a specific setting. Such projects are unlikely to justify large-scale field investigation, and so it is important to derive benefit from previous studies within the same domain where possible.

1.1. Conceptual frameworks

A number of general-purpose methodologies for analysis and design have been proposed, such as Contextual Design (Beyer and Holtzblatt, 1998) and Cognitive Work Analysis (Rasmussen, 1986; Vicente, 1999), each drawing on different traditions within HCI, and oriented towards a particular type of domain (e.g. business information systems, process control). These generally draw on similar fieldwork methods such as interviewing, observation and artefact analysis, and in many cases leverage models of the setting and of the work.

In this paper, our concern is not with generic methodologies, but in specific analytic concepts and frameworks which have emerged from the study of healthcare work. A number of analytic frameworks have emerged, which can help to transform fieldwork data into input to the design process. These frameworks are tied to particular case studies, but also have a relationship to broader theories used within HCI such as Distributed Cognition (Hutchins, 1995) and Activity Theory (Nardi, 1995), although the relationship between ethnography, theory and system design has been the subject of considerable debate (Macaulay et al., 2000).

Teams looking at the development of information systems to support mobile healthcare work are often faced with the choice of which framework to use. In the following sections we argue that this choice will have a strong effect on shaping the designs which are produced, and will also impact on the ability to reason about evolution of the overall system in response to higher level changes within the organisation, for example, the push towards multi-disciplinary team meetings (MDTM's) (Kane et al., 2007).

The use of frameworks in analysis of fieldwork data is something shared with ethnographic approaches. While some traditions in ethnography (particularly ethnomethodology) avoid commitment to particular models, this does not rule out the use of particular tropes or themes, some of which may be specific to a domain. While the frameworks we discuss in this paper are fieldwork-inspired rather than directly produced from ethnographic analysis, one potential point of contact with ethnography is it's use for "developing abstract design concepts by consulting perspicuous settings – i.e. workplaces that may shed light on what abstract design concepts might mean concretely" Crabtree and Rodden (2002). However, we are particularly interested in cases where a framework used for the analysis of fieldwork has resulted in the identification of concrete requirements, whether "ethnographically informed" or otherwise.

We make the case that using a conceptual framework helps to generate requirements from fieldwork data; that the set of concepts used has a profound effect on the requirements derived and the type of system that results; that a number of different concepts have been previously employed in the study of mobile healthcare work, and that a whole set of such concepts can be leveraged in the analysis of new projects within the domain. While many of these concepts will generalize across other kinds of mobile work, the interpretation will differ between domains, so we restrict the scope of our analysis to healthcare work.

We explore these issues by examining a specific case study of a patient review process within a cardio-thoracic surgery department.

2. Fieldwork and Systems Design

We review here a selection of literature which most closely relates to the issues raised in this paper; for a more varied and detailed survey see (Randall et al., 2007; Crabtree, 2003).

The turn towards context in systems design grew from the realisation of the importance of including the sociality of work in design, and the shortcomings of traditional methodologies in addressing real work environments. Workplace studies are now used extensively in the development of CSCW systems as a means of understanding complex social interactions. However, exactly how we perform, use (Plowman et al., 1995; Bossen, 2002), analyse (Crabtree and Rodden, 2002), represent and communicate the results of such studies in design (Viller and Sommerville, 2000), and what methods should be used (Shapiro, 1994; Anderson, 1994), are still contentious and unresolved issues within CSCW and related design disciplines.

These unresolved and related issues have been investigated with diverging solutions proposed. Representing ethnographic analysis is tackled by Viller and Sommerville (1999, 2000) using their Coherence approach, which is a fusion of other related work (Hughes et al., 1995, 1997). Coherence uses a checklist of social "viewpoint" questions for an analyst, which sensitises them to the social characteristics of the workplace, with UML used to communicate the results of the analysis to designers. The topics form part of the descriptive framework for the patterns and can be used to accommodate findings of studies together or describe a single study.

Dourish and Button (1998) provide a good account of ethnomethodology in CSCW and HCI research, proposing an approach to solving the paradoxes in what Grudin and Grinter (1995) called the "ethnographer's dilemma". These paradoxes point to the apparently contradictory characteristics of ethnomethodology, as an analytical method, and system design, as a synthesis activity which tends to disrupt the very elements of social action, interaction and categories of work ethnomethodology aims to study. Their approach, somewhat whimsically referred to as "technomethodology" (Dourish and Button, 1998), distinguishes itself from the typical use of ethnomethodology through a focus on the conceptual design of artefacts rather than overall system design. It attempts to bring system design and ethnomethodology together at a foundational level, offering as an example the case for combining the elements of *abstraction*, a basic concern in system design, and *accountability*, a fundamental notion in ethnomethodology. *Accountability*, in this particular sense, refers to the indexical properties of being "observable and reportable" which characterise particular actions in context. Technomethodology draws on the software architecture concepts of computational reflection and open inplementation to tackle this issue. It therefore seeks an integration at a more basic level of user interface design than the approach proposed in this paper.

Another approach to linking ethnomethodology with design is presented in (Martin and Sommerville, 2004) which makes use of regularities in work patterns (which are findings from at least two previous fieldwork studies). They contend that these patterns can be used as a resource to enable analysis and design in new settings, and become a lingua franca for design. Although an ethnomethodological perspective is taken, they put forward seven recurrent topics on which to orient and focus analysis of an ethnographic and ethnomethodological study. These topics include *working division of labor*, *representations of plans and procedures*, *orderliness of activity*, *distributed co-ordination* and *awareness of work*. They also describe various other advantages these topics can give to a "novice" ethnographer, from analysis through to design implications. The "EthnoModel" (Iqbal et al., 2005) is used as a tool for analysis of ethnographic data to assist in communication of the analysis and design practice. The model is based upon an ethnographic framework with 3 components – a subset of those considered in (Martin and Sommerville, 2004): plans and procedures, awareness of work, and distributed coordination. Each of these components is mapped onto a set of heuristics which can be used by ethnographers and designers. An example is the co-ordination heuristic of "Investigate how the work is monitored in the organisation". Randall et al. (2007) also introduce a number of topics or tropes commonly found to be useful in the study of work.

From review of this literature, we see a number of distinct issues when viewed with an orientation towards the generation of requirements. The first is the role of particular concepts or tropes in sensitizing the designer to particular aspects of the work. The second is the use of these concepts to parse and present the data. The third, is their role in exploitation of this conceptualization in generating concrete requirements. While a number of general frameworks have been proposed, it can be argued that requirements analysis activities in particular domains can benefit from a common interpretation of concepts, a common explication of what the concepts might mean in a setting, prototypical requirements and associated design critiques. It is this follow-through to requirements which distinguishes the work we consider here, although the relationship is stronger and more clearly spelled out for some of the frameworks we consider. In the sections below we present and explore a domain focussed approach based on the exploitation of concepts from previous studies and associated design efforts within the healthcare domain.

3. Healthcare Analysis Frameworks

We consider in this section concepts that have been used in previous fieldwork-informed case studies in the healthcare domain (see table 1). While these frameworks are not orthogonal, each contributes a unique conceptual lens through which the fieldwork data are analysed and interpreted. We consider the data on which each would focus (the sensitizing role of the concepts), the concepts involved (which play a role in the parsing and presentation of the field data), the general class of requirement which might emerge and specific prototypical examples, and specific points of analysis or design critique associated with both the concepts and the general requirements. Each of them instantiates a relationship between the healthcare work, the concepts and analysis, and the requirements generated. In an individual analysis it may well be that a concept is not found to be particularly relevant, or that the candidate requirements generated are ultimately rejected in the context of the development project.

Table 1: Concepts and Abstractions used in Analysis and Design in Healthcare

Concept	Purpose
Mobility Work	Explore effects of moving people and things (artefacts, equipment) to accomplish work.
Common Information Space	Interplay between common and personal information resources and role of common information space in co-operation.
Rhythms	Explore relationship between information seeking and providing activities and repeating work patterns.
Cognitive Artefacts	Uncover and understand the cognitive work in healthcare directly supported by digital artefacts.
Coordinative Artefacts	Understand how coordination and cooperation of healthcare workers is enabled through a network of artefacts.
Activity-Based Computing	Abstraction that bases support systems around main activities that clinicians perform daily.

3.1. Mobility Work

The concept of mobility work is used by Bardram and Bossen (2005a) to describe the spatial aspect of the co-operative work that is necessary for clinicians to accomplish tasks on a hospital ward. There are four aspects to mobility work, *people, places, resources* and *knowledge*, which must be correctly configured for task accomplishment, in an environment where these resources can also be mobile. Mobility work is the work that must be performed by clinicians to carry out tasks at specific locations. A good example is found in an ethnographic study of nurses shift changeover undertaken by Tang and Carpendale (2007); at the start of a shift, the nurse would gather together useful information on a paper artefact from a number of different sources. The information is thus readily available when needed over the course of the shift, regardless of location. We briefly discuss the different aspects of mobility work in terms of the fieldwork data and possible requirements.

Resources. A wide variety of resources are used by clinicians in the course of their work, including paper and digital artefacts, EHR's and specialised medical equipment. While some of these resources may be mobile, locating mobile resources when they are needed may not be easily achieved. Identifying the resources used by clinicians in performing tasks can help identify where, and what manner of support should be provided. Supporting clinicians with appropriate resources involves addressing problems due to mobility, availability and location. Reducing the mobility work performed by clinicians means keeping them aware of the status of resources used in tasks or, conversely, relieving them of providing information to others for resources they control. For example, if booking of diagnostic equipment is controlled by one person, providing information on availability would form part of their workload.

Knowledge. Due to the number of specialised professions that must cooperate in the treatment of patients, clinicians must regularly meet to engage in cooperative problem solving or for pooling or transfer of knowledge. This can be seen formally in a number of regular activities such as handovers, multi-disciplinary team meetings and team conferences. Observation of the face to face activities mentioned provides the analyst with an opportunity to discover the type of knowledge being sought by mobile healthcare workers, and again might lead to a recommendation that support for capture or transfer should be provided. Knowledge capture is another component of mobility work performed by clinicians and we must be aware of the future role of the information being sought when supporting capture of the information. In some cases, such as the MDT, the availability of knowledge in the form of active expertise is also important; reducing the mobility work associated with this cannot be achieved by simply distributing information.

Persons. Clinicians need to locate, travel to, and work with other people; it could be the need to contact a person in a specific role, e.g., a radiologist, or a specific person. The patient is a central source of information and can be moved around different departments or wards during the course of their treatment. If mobile clinicians provide information to (or seek information from) other clinicians, then the analyst might wish to investigate whether this can be achieved automatically via electronic support or more formally supported as part of a task. Feasibility will depend on the amount of information and the imperative for a face to face meeting.

Places. Hospitals are subdivided into a number of specialised areas where specific activities take place. Some places are special because of the intrinsic qualities of the place such as equipment or hygiene requirements; other places are used due to the need for privacy or a common place to meet. While awareness (by the analyst) of location status is important in order to understand the work and potentially provide contextual support, there may be a variety of reasons why tasks or meetings are carried out at specific locations (proximity, historical, availability). As this may constrain any support that is attempted, knowledge of task and location dependency must be factored in when attempting support.

3.1.1. Discussion

An analysis of mobility work would focus on the movement required in order to obtain resources, information, and access to people, and also the characteristics of the different locations in which work is carried out. Activities carried out prior to "going mobile" would be a focus, such as information foraging and transfer of information to mobile and personal artefacts. There are corresponding activities carried out when the mobile aspect of the work is completed, for example transferring updated information from mobile artefacts back to a fixed repository (such as an electronic health record).

Prototypical requirements, considered and critiqued by (Bardram and Bossen, 2005a) include the provision of an Electronic Health Record (EHR), supporting mobile information access and context aware information access (building on knowledge of place as well as activity), as well as the support for sharing knowledge, locating resources and locating people mentioned above. Another example would be facilitating the transfer of required information to and from personal artefacts. A common critique of such support would be that such preparatory work might well be contributing to situation awareness and hence the designer must be careful with automation.

3.2. Common Information Space

The concept of a common information space (CIS) (Bannon and Bødker, 1997) is used by (Reddy et al., 2001) to analyse the cooperative work of a heterogeneous group of workers on an intensive care ward, which is based on the use of a common information repository, HealthStat. The different clinicians in the study each have a different representation of the underlying information stored in HealthStat, so coordinating activities relies on each representation reflecting accurate shared data, with any change propagated to each representation. A richer elaboration of the CIS concept is presented in (Bossen, 2002), which examines the operation of a hospital ward, including a consideration of articulation work (a central component of the CIS framework). While articulation work is undoubtedly a feature of mobile healthcare work, the analysis is not taken to the point of suggesting and exploring concrete requirements, and so we omit these aspects, while noting that articulation is central to the mobility work concept presented above.

Information and Representations. Personal electronic mobile devices can support the requirements of having different representations of the same underlying information and can be tailored to support specific work practices and work groups. However this must be tempered by the need for stable communication between groups which maintain a CIS though discussion and comparison of representations. This requires a balancing of competing constraints, and becomes even more important if mobile technology uptake in healthcare continues to increase, as the use of personal and individually tailored representations, rather than shared representations could lead to communication problems and difficulties in building shared understanding. The sucessful elements that allow cooperation currently should be uncovered and factored into requirements for any new system.

Prospective and Retrospective Information Use. Physicians use of HealthStat differed from that of nurses in terms of the temporal dimension applied to the underlying information. As with the rhythms framework (Reddy et al., 2006), described in section 3.3, we can characterise this information use as prospective or retrospective. This dual use is of course connected to how this information is displayed and used in various tasks for the different groups, and gives us another insight into the CIS dynamic. These differing uses of the information are embedded in the tasks of the clinicians.

3.2.1. Discussion

In terms of observational data, there is a focus on the vetting and sharing of information, both by workers in physical proximity, and also through shared artefacts such as electronic health records, whiteboards and so on. Examining the consistency of data and propagation of changes would also be a theme for analysis. As discussed above, requirements might include facilitating access to shared information by means of multiple representations. Requirements may also be generated by identifying possible breakdowns in change propagation and addressing them by means of technology (e.g. by implementing safeguard mechanisms to ensure the consistency of distributed information repositories), and supporting tasks by which information is reviewed and placed within the CIS. One design critique is mentioned above - that differing representations might lead to communication problems; another, following (Bossen, 2002), would be to examine *the degree* to which different stakeholders actually need to understand the work of others in order to support collaboration.

3.3. Temporal Rhythms

Reddy and Dourish (2002) use the concept of temporal rhythms (broad repeating patterns of work) to describe the temporal organisation of collaborative work on a surgical intensive care unit (SICU). Temporal rhythms highlight the information seeking, providing and managing activities healthcare workers must achieve as part of collaborative work accomplishment. Reddy et al. (2006) later refine their work by proposing two new analytical conceptual extensions to temporal rhythms, i.e., temporal trajectories and temporal horizons.

Temporal Rhythms. Temporal rhythms are repeating patterns of work. They can be fine grained, such as shift change, morning rounds, medication administration, meetings and new arrivals, or course grained, for example the yearly change of interns.

In analysis of healthcare work, temporal rhythms highlight how the *information work* of clinicians is shaped by patterns within their activities. For example a nurse collects certain information during the days shift knowing it will be needed at the handover. The analytic focus is on the temporal dimension of collaboration and the information work performed around activities.

In analysis of observational data, time coded activity data would be used to identify patterns over the course of a patient case discussion (Kane and Luz, 2006), a shift (Tang and Carpendale, 2007) or working week. Interview data might also be used to pick up on longer term rhythms (e.g. junior staff changeover twice per year). Temporal rhythms are a key guiding resource used by clinicians in managing many of their activities; they enable the smooth running of hospital work in ways that may not always be visible at first. As Zerubavel (1979) states, "*They resemble glass walls, however, in that they are usually taken for granted, until someone tries to walk through them.*". Knowledge of working rhythms can feed into a design in several ways. It provides material useful for task analysis, such as information on the sequencing of activities, and it facilitates the identification of context-dependent functional requirements.

Temporal Trajectories. Temporal Trajectories (Reddy et al., 2006) are the timelines of care clinicians use when dealing with patient information. Different users will have specific requirements for access to information about past activities (retrospective information) or future activities (prospective information) in different situations. Physicians, for instance, are mainly interested in retrospective information when engaged in diagnosis and patient case discussion activities (e.g. at MDTMs), while nurses will have greater need for prospective information in tasks such as administering medicine, as pinted out by Reddy et al. This is evident in how clinicians use a chronological sequence of activities and events (future and planned, past and occurred) in the care of a patient. Reddy and Dourish describe how "*temporal trajectories help to contextualise both information and actions by emphasising the temporal context of patient treatment and care administration*" (Reddy et al., 2006).

Observational and interview data, concerning patient case discussions, can be analysed for examples of chronological discourse on patient related treatment information. This will reveal situations and activities where a trajectory of patient related information is applied or required. Patient information can be presented to clinicians in a way which allows them to place the patient in a trajectory of care. This would entail capturing and displaying the sequence of *relevant* events and actions, rather than all details.

Temporal Horizons. A temporal horizon is the time period between a repeating temporal rhythm (activity). Finer grained rhythms have a shorter temporal horizon, which results in a reduced window for completion of required tasks. Therefore the focus is on the individual clinician's tasks ahead of an activity and in particular how individuals organise their work to complete these tasks ahead of the constraining rhythm. The horizon provides a structure for completion of work and may be flexible or inflexible depending on the activity and the length of the horizon.

An analyst sensitized to the fact that clinicians gather information in an opportunistic manner during the course of their daily work, in advance of the activity where they are needed, might propose that they should be supported in doing so. Developing support for this could mean enabling the starting and suspending of tasks over a prolonged period of time, depending on the constraining temporal horizon.

3.3.1. Discussion

In terms of fieldwork data, all of these concepts will draw on sources with a chronological element, including direct observations of the rhythms of the workplace, and workplace artefacts such as schedules, appointment books, and care plans. Diary studies could also play a role. The rhythms concept itself motivates the design of information systems which are sensitive to these rhythms - providing information and affordances appropriate to the current part of the cycle. The analyst investigating a workplace might ask what are the trajectories of care for different classes of patient, and consider explicitly representing these trajectories in the information systems. An associated critique might be that a display based around a trajectory of care might end up representing a "trajectory of illness", inappropriate for either patients or caregivers. The temporal horizons concept suggests designs which help the users to maintain awareness of these horizons and which support the completion of work associated with the horizon (e.g. displaying status of tasks required for shift handover).

3.4. Cognitive Artefacts

Artefact analysis is a common theme in HCI, and a major element of many approaches, including Distributed Cognition (DCog) and Activity Theory (AT) analyses as well as more practice focused methods such as Contextual Design. The two forms of analysis we look at here are cognitive and co-ordinative, which can be understood from a DCog perspective as relating to individually distributed cognition (between internal and external representations) and socially distributed cognition (shared representations) (Perry, 1999).

The failure of automation in healthcare to improve clinical performance is examined by Nemeth et al. (2005) who suggest that this is due to the design concepts on which these systems are based. Healthcare displays often do not represent the underlying domain semantics – an issue originally raised by Woods and Hollnagel (1987) – and therefore are not suited to assisting clinicians in the cognitive work that they must perform. The design of displays that support clinicians in the work they perform requires a significant investigation of the *technical work* (Nemeth et al., 2004), i.e., non clinical work, that is performed in order to enable clinical work to happen. One way of uncovering this technical work is by examining the creation and usage of *cognitive artefacts* (Nemeth and Cook, 2004). The cognitive artefacts concept focuses investigation on the artefacts that are created and used by clinicians to uncover the work that the artefact directly supports. Discovering the relevant information required for the cognitive task at hand can help to design representations that are relevant to user goals and strategies.

In terms of requirements, there are two aspects, the first regards maintaining or replicating important affordances which exist within the existing system. Understanding artefact use is a pre-requisite for this. The second is with regard to the design of effective representations, which can help to externalise tasks, and facilitate perceptual processing of large amounts of data (eg. spotting unusual features within a data set). Artefact analysis provides elements for assessing the usefulness of a representation for different user groups. One critique that digitising an existing paper artefact carries with it a degree of standardisation, and would remove the ability of users to use personal representations, tailored to their work practice and preferences. For example, in (Tang and Carpendale, 2007), nurses used personal notes and annotations with a variety of information coding schemes.

3.5. Coordinative Artefacts

Bardram and Bossen (2005b) look at coordination and collaboration on a hospital ward by analysing usage of non digital *coordinative artefacts*. Artefacts (worksheets, whiteboards etc.) are analysed in terms of the way they facilitate locating patients and staff, cooperative planning, continuous coordination, status overview and passing messages. Development that digitises these artefacts, or the information contained in them, may need to retain key functionality provided to clinicians and the wider work system.

The focus within analysis is on co-ordination activities and artefacts used to mediate this co-ordination. Requirements generated would include maintaining the coordinative protocols distinguishable in existing artefacts in their roles as coordination mechanisms (Schmidt and Simone, 1996). There may be particular activities which have a focus on coordination and which produce coordinative artefacts (e.g. producing an operating theatre schedule). A number of different forms of technology solution are possible, with shared artefacts supporting activities such as scheduling, facilities for monitoring a distributed workflow, features for annotation of artefacts (e.g. a radiologist adding a comment to a scan which is intended to be read by the surgeon) to facilitate coordination, and so on. Again, there is a concern that naïve automation of existing coordinative artefacts could remove important features of the existing coordination mechanism and therefore disrupt its operation. One concern when digitising/changing an artefact is recognising its dependencies, ensuring that connections between artefacts are maintained or developed.

3.6. Activity Based Computing

The concept of Activity-Based Computing (ABC) is explored by (Christensen and Bardram, 2002) to investigate support for healthcare work, and is proposed as an alternative to document and application centred systems. The *activity* abstraction is used due to concerns about the suitability of traditional paradigms to an environment where work is "nomadic, collaborative, intensive and often interrupted". While fieldwork has been an integral part of development of the framework, the presentation of the work generally groups the concept, real-world example, and functionality provided. Beyond, the notion of "activity centred" the core concepts are *activity discovery*: hypothesizing activity based on context, *activity suspend-resume*: allowing the practitioner to deal with interruptions, *activity roaming*: allowing activities to be performed anywhere in the hospital, and *activity sharing*: for both handover and collaboration between healthcare workers.

3.6.1. Discussion

When looking at observational data, analysis would include classifying actions as belonging to a particular activity – e.g. discussing treatment options for a patient would be an activity. In looking at this activity data, interruptions could also be identified, as well as cases where interruptions generate new work (e.g. returning to a screen with relevant information, having gone to a different screen as part of an interruption). Requirements generated would include those which facilitate activity management. Users would be allowed to suspend and resume activities, they would be supported in maintaining the context of the activity when roaming (perhaps changing interface device), they would be supported in performing collaborative activities and a system based around activities could exhibit a degree of context awareness, providing information and affordances relevant to the activity. As with temporal rhythms, context aware systems could also take advantage of knowledge of current activities in order to provide appropriate information and affordances, as well as support for interruption management and recognition of critical non-interruptible activities (e.g. surgery). Among the possible critiques are the degree to which activities can be usefully predicted from context (Bardram and Christensen, 2007).

3.7. Summary

Each of the concepts or frameworks above brings focus to a particular subset of the fieldwork data. The view of the setting produced by each shapes the requirements identified, and influences design decisions; both in terms of concept generation (e.g. proposing that the system should support activity management) and concept reduction (e.g. proposing that parts of the mobility work which play a vital role in maintaining situation awareness should not be automated). While the fact that different analytic frameworks may yield different results is not a problem in itself, it is important to maximise our chances of identifying key requirements (through fieldwork), and to build on existing work in the domain.

4. Case Study – Lung Cancer Patient Review Process

In the previous section we have examined a number of existing concepts and looked at the way in which they can shape our view of the data and help generate specific requirements. A valid question to ask is the degree to which these can generalize to other case studies within the same broad domain. To explore this issue we examine the applicability of these conceptual frameworks to analysis of a patient case review process for lung cancer patients.

The study concerns a large tertiary referral and cancer treatment facility. The increasing numbers of patients requiring lung cancer surgery (59 in 1999 to 150 in 2007), a subset of all referrals, has led to problems following these patients through a complex pathway of investigation. While an EHR is used within the hospital to store medical information, currently no record is kept of the patient review process. The cardio-thoracic surgery unit receives 5 to 10 new case referrals per week. Each new referral must be managed through to initial treatment by a specialist oncology coordinator (hereafter referred to as the coordinator), while suitability for surgery is decided by the consultant cardio-thoracic surgeon.

The study arose from discussions regarding the development of support for the management of the patient review process. The motivation for such support was the perceived possibility of an unacceptable delay (or worse) in the review process of a patient. The study took place over a period of 7 months, and involved a series of semi-structured interviews with key staff, and observations at various work locations. Ten semi-structured interviews were conducted with the consultant. They took place before surgery commenced in the angiogram room beside the surgery theaters. They varied in length from 20 to 40 minutes on average, depending on the time constraints of the consultant, while waiting in the angio room before and during interviews also allowed for observation of a key work location. The coordinator took part in 16 semi-structured interviews of between 20 and 40 minutes on average in various locations (office, coffee rooms). During the study a desk within the shared office of the coordinator became available, which allowed more extensive observation of the work of the coordinator. These observations lasted between 2-6 hours on 6 occasions.

Examination of a number of paper-based artefacts supporting the patient review process has also been undertaken, and their use has also been observed within the working environment. The very serious nature of the disease, and low survival rate meant that there were ethical obstacles to carrying out interviews with patients. However the coordinator's telephone interactions with patients could be observed. A previous and highly detailed ethnographic study of the MDTM was also of much benefit in understanding these activities (Kane and Luz, 2006). The patient review process is managed using various paper artefacts maintained by the coordinator. The artefacts used include paper notebooks with relevant review status information, patient lists with planned treatments and status information, and a file for each patient with all documents (typically letters containing medical information) related to the patient's case. Even though the patient review process is managed by the coordinator from the tertiary referral hospital, scans and tests are typically carried out at the referring hospital. While the use of a paper-based system may seem atypical when compared to other domains, it is not unusual in healthcare – see (Hartswood et al., 2003), for instance. Even in facilities where there has been greater deployment of technology, the constant evolution of processes means that often workers have to fall back on ad-hoc methods while they wait for formal structures and technological support to emerge. The major components of the patient review process can be seen in Figure 1.

4.1. The patient review process

The role of the coordinator is central to the patient review process. The role aims to smoothly manage patients from referral and subsequent investigation right through to their treatment. In 2007, a 5-month audit of the coordinator's job was completed; during this period a peak of 445 patient cases where reviewed in one month, 265 of these over the phone to patients or families. These phone reviews are a vital part of the patient review process as they allow appointments and investigations to be organised and completed, while keeping patients aware of the review

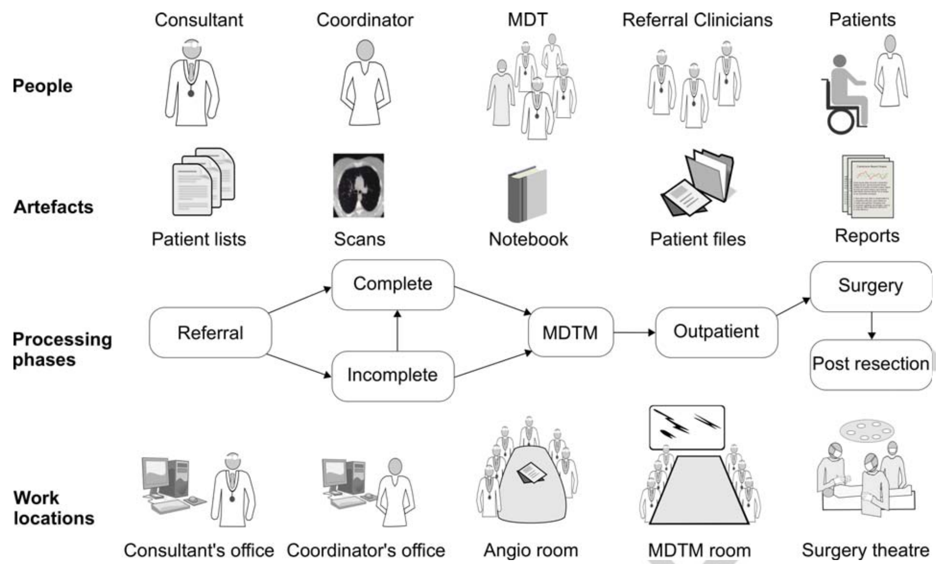

Figure 1: Patient Processing

process. Every week a number of MDT, family, ward rounds, and x-ray meetings/conferences must also be attended.

When a patient is referred to the consultant a letter of referral is received and transferred to the coordinator. The coordinator will record the patient's details in a notebook and store the letter of referral along with any other documents received to a file (plastic sheets). Whenever the coordinator feels the information in the files may be needed at a meeting with the patient or hospital clinicians (x-ray, MDTM, consultant) they are placed in a bag and carried around the hospital so the information is available when required. The coordinator must also book any tests and scans the patient requires while ensuring proper care until the main treatment is received, in coordination with referral hospital consultants, GP's and nurse specialists. A patient's review may be on hold (not actively being managed by the coordinator) until a scan is completed at another hospital or a test result becomes available. Unless these actions are followed up by the coordinator a delay in processing could result, with potentially serious consequences for the patient. A referral is classed as complete if the requisite scans accompany the referral and they are recent enough to be valid. This information allows the patient's case to be discussed at the next meeting between the coordinator and the surgeon. The meetings between the coordinator and surgeon allow decisions on the various patients review needs, as well as new patients suitability for surgery, which are all followed up and managed by the coordinator. The coordinator records required actions to a personal notebook when mobile throughout the hospital and follows up on these actions when back at the office. This involves ensuring tests and scans are booked at the hospital or referring hospital, informing the patient of the dates or managing by proxy with the referring hospital to arrange and carry out the treatments needed. Scans carried out at other hospitals will be forwarded to the tertiary referral hospital to be examined by the specialist radiologist before discussion at the MDTM[1].

When this initial phase of processing is complete the patient is added to the MDTM list for discussion at the next meeting, or referred back to the initial process if more information is needed. The coordinator is responsible for ensuring that the patients names are on the MDTM list. They also ensure that the relevant patient case information required to discuss the case is available on the Hospital Information System (HIS). At the MDTM the consultant presents the patient cases to the other MDTM clinicians, while the coordinator records and follows up actions and decisions made. The outcome of the MDTM is a clinical *staging* of the patients cancer based on the review of a several tests (x-ray, biopsy, bronchoscopy), but depending on the results other more extensive tests (CT, MRI, PET scans) may be required to stage the cancer. Once this classification has been made the patient's suitability for surgery can be assessed by the surgeon and MDT members. If unsuitable the patient may receive non surgical treatment such as chemo-/radio-therapy.

The patients that have been recommended for surgery at the MDTM must attend an outpatient clinic for an assessment of general health before any surgery can proceed. The coordinator will arrange and book the outpatient appointment and also a date for surgery after their outpatient assessment is completed satisfactorily. In addition to the work described above in the review process there are other "information tasks" that need to be carried out. For instance, the coordinator must answer queries on information related to the patient's review from patients and families, other hospitals, and colleagues. The distinct phases of the review process from referral to post resection (tissue removal) are shown in Figure 1 (Processing Phases).

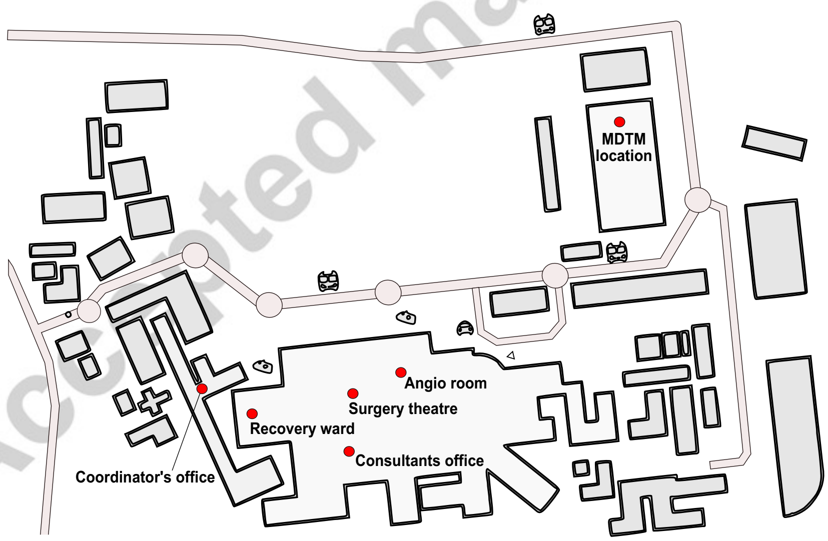

Figure 2: Layout of hospital with distributed work locations.

[1]Kane et al. (2007) define MDTMs as meetings to which both pathology and radiology contribute and at which physicians, surgeons, radiation and clinical oncologists, at minimum, have input.

4.2. Discussion

The coordinator's primary role is care of referred patients through to their main treatment and beyond. After surgery, a biopsy is carried out every 6 months (post resection), or if chemotherapy is carried out the patient may require surgery at a later date. The other side of the role is the support provided to patients and families trying to come to terms with a very high mortality rate illness, as the coordinator is often their only point of contact. The coordinator provides patients and families with information on how to come to terms with being diagnosed with lung cancer. The increased workload of the coordinator associated with managing the review process has made it impossible to see every patient "face to face". This has lead to a dilution of the coordinators role in dealing directly with patients.

The consultant decides on the suitability of patients for surgery via the information gathered in the review process. The coordinator has worked in the position with the consultant since 2001 and a deep understanding and trust has developed. While this means the coordinator can operate quite autonomously, only involving the consultant when absolutely necessary, this also means that the consultant relies heavily on the coordinator to manage the patients through the review process. Allied with the fact that the review process is managed by a number of personal paper based artefacts, there is very little awareness by individuals, outside of the coordinator, of the treatment state of the patients currently under review. Together, these factors increase the possibility of an adverse event occurring in patient processing if the coordinator is unavailable.

5. Analysis of case-study fieldwork data

In this section, we present an analysis of the situation outlined above with respect to the domain specific frameworks presented in Section 3. The initial analysis was carried out by one of the authors, who had no previous experience of development within the healthcare domain, and as such the output is not dependent on previous domain specific experience.

5.1. Mobility Work

As the patient review process is a collaborative task carried out at a variety of different locations, guided and controlled by the coordinator, we would expect the *Mobility Work* framework to yield insight into the work.

Knowledge. From the fieldwork, it is clear that pooling and sharing of information is a major part of many of the activities. The patient review process discussions (PPD)[2] and MDTM are activities occurring at different locations which require staff to pool and transfer knowledge for current and future tasks. As patients complete scans and new patients are added or removed from the review process, the coordinator and consultant use the PPD to share patient review process information from the previous meetings and conversations, and from specific pre-MDTM activities (Kane et al., 2007). The coordinator is also a source of more tacit knowledge concerning the general health of patients from the periodic contact with patients and family. A potential design motivated by this would be a shared artefact representing patients within the process which both the consultant and the coordinator could access and update, facilitating knowledge transfer. This could reduce the amount of information that must be transferred, and facilitate more autonomous

[2] We use the phrase "patient process" instead of "patient case" to avoid confusion with the patient case discussions which take place in the MDTM and other, similar meetings such as clinical pathology and radiology conferences.

work, but obviously cannot replace the PPD completely. The coordinator is the main source of patient review processing knowledge for the consultant, MDTM members, administration staff, referral hospitals and GP's connected with the case. Making this information available in an accessible electronic format would relieve much of this work from the coordinator.

Resources. Multiple resources are required at the PPD, MDTM, outpatient and ward rounds to support task accomplishment. MDTM and PFT (Pulmonary Function Test) equipment are fixed to the room location where they are needed. However, other resources are mobile such as patient files and notebooks carried by the coordinator, while radiology scans and reports are available in relevant areas of the hospital where network or PC access is present. Before the coordinator leaves the office to attend PPD, MDTM or outpatient clinics the files for relevant patients are loaded into a carry bag and carried around the hospital, Figure 3. The weight of this bag may vary depending on the amount of patient files needed, but on one occasion the coordinator was stopped by a clinician while walking through the wards and told that the weight of the bag posed a health risk. Preparation of these resources was observed:

> "I have to go meet some patients now" (coordinator)

At this point the Coordinator starts moving around the office lifting up piles of paper documents and taking what is needed and putting them into plastic sheets. This continues for 10+ minutes moving from document pile to filing cabinet to viewing the HIS and putting patient files in the bag before going to meet patients. When asked why they needed to bring so many documents with them, the co-ordinator responded:

> "When I'm with ***** (Consultant) he will ask for something that was written on the original letter of referral or some information in other letters or forms." (coordinator)

Other resources that must be created are lists of patients to be discussed at various meetings. Thus we see a particular subset of the observational data is the focus, namely the preparation of resources before going mobile to attend PPD and MDTM meetings.

Figure 3: Left: Coordinators desk. Center: Bag for carrying documents. Right: Document and folder pile.

Persons. The persons of interest can be broken down to a number of groups; local clinicians and administration, external (referral) clinicians and administration, patients and families. The coordinator is the only person that has contact with all groups and is involved in all stages of the review process. The specialist MDTM clinicians operate in different departments within the hospital and meet for the MDTM on a regular (weekly) basis to assist in patient diagnosis.

Place. The MDTM room is a specialised facility for medical team meetings for the hospital clinicians. The computers in the angio room where the patient case discussions take place allow access to patient radiological images, which are restricted in other locations in the hospital. The consultant and coordinator both have an office.

5.1.1. Requirements and Technology Support

From the descriptions generated by applying the mobility work framework a number of opportunities for support can be derived. The overhead in transferring knowledge for future tasks could be reduced with a shared artefact containing the relevant common knowledge of interest (MW-1 in list of prospective requirements below). This pooling of knowledge at meetings allows tasks be completed and leads to new tasks arising, mainly for the coordinator. Providing a means to record these new review tasks in an appropriate electronic format can allow for recording/reminding and possible completion of some tasks in situ (MW-2). Currently the coordinator annotates patient lists and notebooks in addition to relying on her own memory to support these tasks. Work associated with preparing resources ahead of meetings could be reduced if the information is already captured electronically, in which case relevant lists can be printed off or retrieved using an electronic device at the required location, the same also applies for patient files which are carried around (MW-3).

MW-1: Develop shared artefact to facilitate knowledge transfer between consultant and coordinator (*Knowledge and Persons*).

MW-2: Provide support to record decisions and future tasks which arise at meetings (*Resources and Place*).

MW-3: Support dynamic editing of patient lists and electronic capture of documents (*Resources*).

Requirement MW-1 raises some practical issues as no fixed, shared display can be provided since the work spaces are not for the exclusive use of the clinicians in the study. Web access to an application via PC or mobile devices could be a possible solution. Implementing MW-2 and MW-3 would involve developing a system in which all information is captured electronically and managed via mobile devices. This should result in a substantial reduction in the mobility work and overhead involved in knowledge transfer from the coordinator to other clinicians.

The concept of mobility work suggests increased support for mobilisation of resources and reducing the work of transferring knowledge. With regard to the role of preparing the patient case lists in maintaining situation awareness, this is an issue which would require further investigation. In the case study, the role of the coordinator in continuously dealing with patient cases would mitigate the possible negative impact of automating the task of patient case list construction. However, it is worth considering explicit support for maintaining awareness (e.g. continuous or default display of current patient cases).

5.2. Common Information Space

Our analysis uses the interpretation of CIS taken by (Reddy et al., 2001) in their application of the concept to a healthcare study. In effect our case study does not have effective support (electronic or otherwise) for maintaining a CIS but rather a series of personal information spaces (PIS) which are shared through explicit action and (often verbal) communication by the actors. The use of personal paper artefacts requires the coordinator to relay information verbally to the consultant when discussing patient cases. This is a transfer of knowledge (as described in Section 5.1) from a PIS so that tasks can be completed with a shared understanding and common knowledge. The consultant must perform a similar PIS transfer at the MDTM, and uses the HIS to show scans and reports. This temporary immersion and information transfer from a PIS to a CIS for the duration of a task could be supported explicitly by developing views on shared data for each clinician. Our observations parallel the findings from another healthcare study which used the CIS concept to analyse the introduction of a nursing plan (Munkvold and Ellingsen, 2007). Their study illustrates that the CIS is not fixed in time and space but rather "situated, temporal, contingent and achieved in practice" by a heterogeneous group of clinicians during the care of the patient. By developing technology support to replace the paper based artefacts of the coordinator, we are in effect using the coordinators PIS as the basis for a CIS which has more tangible support and is less explicitly dependent on the PPD to maintain it. This would constitute a major change, as the work practices through which the CIS is maintained would differ, and the obvious question would be whether the PIS of the co-ordinator is an appropriate basis for such a CIS.

Information and Representations. Supporting the staff in maintaining a CIS requires capabilities for capture and access of patient review information (CIS-1,2). The consultant is mainly interested in the status of patients in process and processing to date; while the coordinator is mainly concerned with future tasks related to patient processing which must be carried out or followed up. Although currently only one representation of the patient review process information is used, it appears that the consultant and the coordinator could benefit from different representations (CIS-3).

Prospective and Retrospective Information Use. Closely related to the above, the consultant is very much concerned with collecting retrospective information during PPD for presentation at the MDTM. At the MDTM, decisions will be made concerning further treatment of patients. This prospective information is of key concern to the coordinator (CIS-3).

5.2.1. Requirements and Technology Support

CIS-1: Support coordinator in capturing patient review information electronically so that it can be shared more easily (*Information and Representations*).

CIS-2: Patient review information relevant to clinicians and administration staff should be made available via a shared artefact (*Information and Representations*).

CIS-3: Tailor patient process review information to individual clinicians tasks, including those needed to maintain the CIS (*Information and Representations, Prospective and Retrospective Information Use*).

The CIS concept applied to healthcare highlights the need to tailor information to clinicians and the information they are interested in. Technology could provide more explicit and tangible support for maintaining a CIS, where currently there is a reliance on personal artifacts and work practice. One possible means of support would be to provide clinicians with mobile devices. This makes supporting these requirements easier as displays can be tailored to capture and display shared information with an awareness of the specific needs and interests of the different types of users.

5.3. Temporal Rhythms

The working rhythms in our study occur on a weekly (MDTM) and bi-weekly (PPD) basis. The PPD, MDTM and outpatient rhythms are central information providing and seeking rhythms in the patient review process. The information being sought by the consultant at the PPD meetings is the latest patient review information so that the patient may be presented at the MDTM and have their suitability for surgery decided, and patients who are ready for surgery can have a date scheduled. While the coordinator provides the patient process review information, the treatment decisions and new information provided/arising at these meetings and activities shape the future review tasks the coordinator must complete.

Temporal Trajectories. There are a number of processing phases which patients must complete before they are ready for surgery. These phases reflect partly best practice obligations, such as the MDTM, while the others reflect logical phases in processing for the consultant. Collectively they form the trajectory of a patient's review in which the consultant places patients when accessing suitability for surgery. While the coordinators role is inextricably linked with the consultant in processing patients, the temporal trajectory of care of interest to the coordinator is more immediate and future based. The coordinator is interested in the current status of the patient and the future plans in the review process. An entry in the coordinator patient list would resemble the following:

```
Status: New Referral from Dr ***** in ***** with a 14mm opacity
in RUL. Pet scan lesion FDG avid. No tissue diagnosis.
Plan: MDT on 09/03 BX non diagnostic ? repeat. for clinic on 30/03
```

This information places the patient at a particular point in the trajectory of care. In this case we see retrospective information regarding the referral, status information in the details of what is and what is not known (along with a query regarding a biopsy), and prospective information regarding the patient attending the clinic and discussion at MDT. While the language of prospective and retrospective information use can be employed, as with the CIS analysis, the concept of a trajectory yields a slightly different view on the design, as there is a stronger suggestion of a regular pattern which occurs in the treatment of patients. This might lead to more explicit representations of this trajectory within the interface.

Temporal Horizons. As the PPD and MDTM meetings approach there are a number of activities that must be completed by the coordinator and consultant. This includes preparing a list of patients to be discussed, patient treatment to complete, treatments to be discussed, and patients to be added to the MDTM list for discussion. At the end of the week the coordinator must finalise the patients on the MDTM discussion list and ensure that all necessary scans have been completed and their information available on the HIS. The observation notes reveal the activities as the deadline for completion of the list approached one afternoon:

The coordinator arrives back at office along with the MDT coordinator. Both are carrying large amounts of documents in their arms. They are discussing at length the different scans, tests and treatments that patients have had.

> "I'm sure he's had it (scan) but I can't seem to find it" (coordinator)

The MDT coordinator and the coordinator agree on the patient list and that all the requisite information has been located for the MDTM on Monday morning. The MDT coordinator leaves the office. When the coordinator is asked about the interaction with the MDT coordinator:

> "It's going to be a ****** (consultant) special on Monday morning; I think there are about 12 patients to be discussed" (coordinator)

In this case an unusually large number of patients of the consultant are to be discussed at the MDTM, which imposes a particular temporal horizon upon the work of the co-ordinator, such as ensuring that all of the information relevant to each patient has been collated in advance of the meeting.

5.3.1. Requirements and Technology Support

Identifying the information seeking and providing tasks oriented to working rhythms provides opportunities to support them (TR-3). Using trajectories suggests specific requirements on how information related to supporting these tasks should be displayed when supporting (TR-1), while an awareness of the temporal horizons can be used as contextual information to remind and support clinicians for completion of future tasks (TR-2). Implementation of these requirements could involve tailoring the presentation of trajectories of care for each clinician.

TR-1: Display the patients trajectory of care from the underlying review information (*Temporal Trajectories*).

TR-2: Use knowledge of temporal work horizons and the status of tasks to keep clinicians aware of closing temporal horizons (*Temporal Horizons*).

TR-3: Support the range of tasks which precede and follow on from the PPD/MDTM rhythms (*Temporal Rhythms*).

5.4. Cognitive Artefacts

Observation revealed that the main cognitive artefacts used to manage the review process are created personally by the coordinator. Patient lists, for MDTM and PPD, act as external representations of the patients actively in process. These lists are not annotated or stored, but used on a transient basis. A notebook is used to record important summary patient information such as scans, tests and patient status. Both of these artefacts support multiple activities and work processes, such as guiding review discussions and MDTM's, and supporting or representing tasks. The notebook contains the most important subset of information from the patient's file, and records significant events regarding the patient. This information is then readily at hand to answer queries at meetings, as well as from other administrative staff and from the patients themselves. The HIS provides numerous artefacts which are used at the MDTM, but both are beyond the scope of this analysis.

5.4.1. Requirements and Technology Support

Patient lists are created from, and are a subset of, the notebook information. Hence any electronic counterpart should support the migration of information. It should also support access and updating of this information at any time or place, in the same fashion as the notebook. This could involve the coordinator dynamically managing these lists using a mobile device *in situ* as required instead of en-masse prior to meetings (going mobile). The recorded scans, tests and reports in the notebook could be linked to the HIS, which could track and update a mobile device on their status automatically. This would remove the need to search for patient details on the HIS and recording them to the notebook. The artefacts should be continuously available to the coordinator, and should allow information to be added within any application. Essentially the system should provide similar affordances to the notebook and list, which are always to hand, and allow convenient annotation.

CA-1: Support creating patient lists electronically, using a representation which conveniently presents the information likely to be needed at meetings (*Cognitive artefact provides information to support meetings*).

CA-2: Support recording patient status and plan information electronically, which can be integrated with list generation (*Support construction of cognitive artefact*).

5.5. Coordinative Artefacts

The original study in (Bardram and Bossen, 2005b) was focused on a heterogeneous group of workers on a hospital ward and is not directly applicable to our case study as the non digital artefacts created by our clinicians are primarily created for their own personal use, with some minor exceptions. While it is possible that the work system could benefit from making greater use of such artefacts, it was not found to be immediately applicable in terms of interpreting the fieldwork data. From a design perspective, this concept motivates asking whether such a shared artefact would be useful. For example, a shared display giving summary information on the current status of patients in process (e.g. number of patients within each stage, distribution of waiting times across each stage) could be placed within a restricted access space such as the angio room. Such a coordinative artefact could facilitate effective collaboration within the system.

CO-1 Provide shared display giving overview of patients in process.

5.6. Activity Based Computing (ABC)

Activity management is an important aspect of the work in our study, and the issues targeted by the ABC framework (collaborative, intensive, nomadic, interruptions) are very relevant to healthcare work. However the framework was found to be applicable to the wider context of the application, rather than design for analysis of the review process itself. The issues that ABC targets are evident in the study as we can see that certain activities are space and time dependent and could be supported in the same "spirit" as the framework. For instance the coordinator has many activities that could benefit from functionality such as suspending and resuming, particularly given the interleaving of tasks which have a long time horizon for completion.

5.7. Summary

Each concept has provided individual requirements and some of these requirements are competing, interrelated and overlapping. While a coherent design must ultimately be achieved, these issues are common to any design task. For instance the CIS-3 requirement will have a constraining effect on all interface design for mobile devices as we must tailor the underlying information in the review process to the individual clinicians. Yet how we tailor this information is related to TR-1 (trajectory of care), the actions needed to maintain the CIS and the prospective/retrospective information use concept. Another example is how creating artefacts on a mobile device, CA-1/2, will affect the mobility work performed (MW-2). It is interesting to note how concepts such as the CIS and Temporal Rhythms are guiding the system design in a fairly specific manner from description to design. We also note that the requirements themselves are open to differing and negotiable interpretations (Rönkkö, 2002); the association with the concept, fieldwork data, and previous exemplars may support this activity.

The "application power" (Halverson, 2002) of this approach, is perhaps stronger than might be expected. The fact that artefacts are related to information issues and that the temporal and mobile aspects of work are related is hardly surprising, but the power of utilising the concepts is partly in the descriptive and rhetorical power they provide when analysing the data, and partly in providing a vehicle for the analysis itself. Application of the concepts suggests specific design features, which we can also critique using the same framework.

6. Future Work

A major issue within the current patient process management is the role of the patient. Currently, the system is very opaque to patients, which in addition to being an issue for the patients themselves, deprives the work system of a valuable source of resilience. This opaqueness is manifested in the number of calls the coordinator must deal with from frustrated patients who want to know the status of their review. These queries play a role as they require checks to be made on patient status, but such interactions with patients are not well supported.

Our fieldwork data revealed insights and issues affecting the patient review process and provided the base on which to build an initial design. As part of the exploration of requirements, a traditional task and functional analysis was carried out within a participatory design process with the consultant and coordinator. This led to the development of a system to track patients through review process and handled other related issues. The developed system is currently undergoing a pilot evaluation with the coordinator and consultant using real patient data. In the language of (Crabtree, 2004), this can be seen as a "breaching experiment", the investigation of which (in context) may yield additional insight on the process and work system. An interesting question to be addressed with respect to this future work is the role which the concepts and frameworks play in the interpretation of evaluation data from such probes or prototypes.

7. Discussion and Conclusions

Our intent in this paper has been to gather together a number of different frameworks in the healthcare domain, and to demonstrate that they can be applied together in the identification and analysis of requirements. The concepts drawn on are by no means complete, and could easily be added to, for example by applying the (Bossen, 2002) elaboration of CIS for the medical context to the generation of requirements. The *degree* to which the frameworks affect the requirements generated also remains to be explored.

From a methodological perspective, there are a number of issues to be resolved; is it the case that a particular framework provides a better match for a particular case study, in which case a key issue concerns the choice of framework? Alternatively, should a range of concepts be applied to each design situation? There is clearly some overlap between the requirements which might be identified by the different frameworks. While applying multiple frameworks would potentially take more time, and complicate any method encapsulating them, we can see the use of multiple concepts as a form of triangulation (Mackay and Fayard, 1997). For example, while several analyses might suggest a particular technology solution, a particular viewpoint might sensitize us to a greater degree regarding a potential pitfall of the technology (e.g. reduced situation awareness).

Our experience with the case study leads us to believe that for the healthcare domain the latter option (multiple concepts) is likely to be most appropriate for the identification and analysis of possible requirements. This is partly due to the fact that so much value was found in considering the different aspects of the system highlighted by the different frameworks, but also in part due to the "negative" cases; there were few shared co-ordinative artifacts in this case study, but it is definitely worth considering whether the work system would benefit from new ones made possible (or tractable in terms of work overhead) by technology.

If a range of concepts is to be applied to an analysis, is there a case for integrating it into an existing method intended to deal with a broader range of systems? This could mean augmenting a method such as DiCoT (Blandford and Furniss, 2006), which embodies a Distributed Cognition perspective. The DiCoT method contains a number of analysis themes, with accompanying heuristics and the range of themes could be extended to include those found to be particularly relevant to a given domain. We can see such work as moving to an extent towards "domain specific theories", or a domain specific analysis approach. While such efforts can be seen as a critique of generic frameworks, this is not the case; the generally applicable aspects of these frameworks are as valid to the healthcare domain as to any other. However it is because we want to build on domain specific studies in a more rigorous fashion that a case can be made for augmenting and extending these methods and theories.

Building such a domain-specific framework for another domain would require not just identification of relevant concepts, but explication of what they might mean in the domain, links to prototypical requirements, and associated critique. Thus, while it can be argued that some concepts are generally applicable to the world of work, their application within a domain is not obvious and represents a significant effort that we can benefit from in subsequent development efforts. The instantiation and interpretation of the concept within the domain is an important part of each framework; the designer is supported in understanding what the concept can mean in the domain through examples in the existing studies. We can relate this to the relationship between "documentary evidence" and underlying patterns in ethnographic studies (Rönkkö, 2007).

Concepts are ultimately "tools for thinking", they sensitize us to particular issues, and help in producing more concrete recommendations from fieldwork data. As can be seen from the sections above, they can also sensitize us to particular issues when considering possible technology solutions. While we believe the approach introduced above can give leverage on the problem of integrating fieldwork data into the design of systems to support mobile healthcare work, we don't wish to underestimate or downplay the significance of the problem. Obviously, there is no "silver bullet", but the application of domain specific concepts can yield benefit, and although much more remains to be done, it goes some way towards addressing the issue of practicality raised by Plowman et al. (1995). For critical domains in particular, we need to pick up on aspects of the work which are important, avoid known problems, generate design ideas, and critique these ideas; previous research in the domain can contribute to all of these aspects of the development.

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