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Sociotechnical Requirements Analysis for Clinical Systems

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Summary

Objective: We explore sociotechnical requirements by examining the use of a computerized patient record system in an intensive care unit of a U.S. hospital and present two sociotechnical requirements, awareness and coordination, embedded in the users' work.
Method: The study is based on observation during seven months of the use of a computerized patient record system in a surgical intensive care unit. During that period semi-formal interviews, informal interviews were held.
Results and Conclusions: A key step in the design of clinical systems is the development and analysis of requirements. However, traditional requirements analysis is based on a set of assumptions that break down in the highly collaborative, exception-filled clinical domain. Sociotechnical requirement analysis enabled the designers to gather a much richer description of the environment surrounding the computer system, highlighting awareness and coordination, embedded in the users' work.

Keywords

Sociotechnical requirements analysis, clinical systems, computerized patient record system, collaborative work, intensive care unit

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1. Introduction

Information system development is complex, costly, and critical to the success of many organizational endeavors. As a result, the primary concern of software engineering is to organize the software development process to maximize its efficiency and probability of success. A key step in this process is the development and analysis of *requirements* – qualities and features that a product must have [1]. However, despite the effort devoted to these endeavors, success is elusive. A survey of 8000 projects in 350 US companies found that one-third of software development projects were never completed, while one-half succeeded only partially [2]; managers identified poor requirements as the major problem in about half the responses. Clearly, the complexity of the requirements-gathering process is a major obstacle to system success. We will argue here that one reason for these failures is a mismatch between traditional construals of "requirements" and the richness of the settings in which computer systems are typically deployed. Traditional "requirements analysis" is based on a set of assumptions (e.g. that the application domain is stable, that information is fully available and known, and that most work is routine) that often break down in dynamic, real-world settings.

In particular, clinical health care is a highly collaborative, exception-filled domain that fails to exhibit the underlying assumptions of traditional requirements analysis. The adoption failure of a number of clinical systems built using these assumptions is a testament to the severity of the problem [3-5]. Goddard [6] identified various organizational issues that traditional analysis would miss, such as the complexity of the work, as key reasons for the failure of his organization's computerized patient record system.

To design successful clinical systems, we must examine different approaches to requirements analysis that do not make the assumptions of traditional requirements analysis. One approach is to view requirements analysis from a *sociotechnical* perspective – one that regards the technical features of the system and social features of the work as fundamentally interrelated. To uncover sociotechnical requirements, we need to closely examine the work that the system will support in addition to the technology itself. Jirotka and Goguen [7] describe three approaches to sociotechnical requirements analysis: integrating social processes into the existing technical requirements methodology; involving users more directly in the design process through methods such as participatory design; and viewing technical requirements as embedded in the work practices of the users. Taking these steps allows us to move away from a purely technical conception of requirements, and helps us design clinical systems that fit the organization and users' work.

The main goal of this paper is to highlight problems of traditional requirements analysis in the health-care domain, and, through our field study, illustrate the applicability of sociotechnical requirements analysis in medical informatics system design. In the paper, we detail some underlying assumptions of traditional requirements analysis and characteristics of clinical medical work that make these assumptions problematical. We then discuss sociotechnical requirement analysis and why we believe that it is particularly appropriate for the clinical domain. Next, to explore sociotechnical requirements in depth, we present an ethnographic field study of a successfully deployed computerized patient record system (CPRS) used in a surgical intensive care unit in a U.S. hospital. Our study reveals sociotechnical requirements embedded in users' work practices that play an important role in how the system is used. We provide two examples of sociotechnical requirements that we uncovered in the users' work practices. We conclude with some final thoughts concerning sociotechnical requirements analysis for health-care systems and why gathering and analyzing these requirements are essential steps in designing a system that fully supports the user.

2. Traditional Requirements Analysis

A serious challenge to the development of software systems is the high cost associated with finding and fixing errors. The further in the developmental cycle that a software error is discovered, the more expensive it is to fix error. Through a series of empirical studies, researchers have discovered that it is almost two hundred times more expensive to fix the error in the maintenance phase of system development than it would have been to detect the problem during the requirements phase [8, 9]. Therefore, accurate requirements gathering and analysis are vital to low-cost system development.

Over the years, researchers have utilized various methods to gather and analyze requirements. In this section, we first discuss "traditional" requirements analysis methods. We then highlight two underlying assumptions of these methods and why they are problematic for collaborative medical work. Finally, we present an example of a clinical system built based on these assumptions that failed.

2.1 Traditional Requirements Analysis Methods

In examining requirements, Jackson asserts, "The traditional practice in software development has been to ignore the application domain and focus attention on the machine" [10]. Although most software engineers are now more sensitive to the importance of closely examining the work surrounding the system, there are still many who use "traditional" methods to gather and analyze requirements to design a system. For instance, the STARTS Handbook [11], a guide to software industrial good practice, presents techniques for requirements analysis. The requirements analysis methods presented in STARTS focuses on system functions. In his critique of the requirement analysis in STARTS, McDermid argues that the process for gathering requirements begins at the wrong place by focusing on the "presupposed" system boundaries instead of trying to understand the users needs or objectives [12]. By creating system "boundaries" before truly learning what the user needs, these methods privilege system functionality over the actual work of the users. Underlying these methods are a set of assumptions about the system and the work of the users.

2.2 Underlying Assumptions

It is often difficult to elicit clear and precise requirements [13]. To simplify the requirements specification process, a set of underlying assumptions have driven "traditional" requirements gathering and analysis in many software projects. We discuss two of these assumptions: that requirements should be formulated in terms of technical challenges, and that requirements can formalize work as routine.

As part of the design process, requirements need to provide information to the developers about what features the system should contain. Thus, many designers make the first assumption that requirements analysis should focus predominantly on the technical features and constraints of the system. This assumption would have validity if clinical systems were only used as repositories for patient information. However, the collaborative nature of medical work [14-16] undermines this assumption in analyzing requirements for clinical systems, because it embeds information access within a richer and more varied system of work practice. To provide appropriate patient care, health care workers interact frequently with each other; for example, nurses, pharmacists, and physicians interact about a patient's medication decisions. However, if system designers viewed medication administration solely as an information processing event, and not a collaborative and dynamic activity, they would not incorporate the features necessary in the system to support the interactions among physicians, nurses, and pharmacists (some of which we will outline shortly). Weakening collaboration amongst health care workers such as physicians and nurses can result in poor patient outcomes [14, 17]. The critical issue here is that collaboration is often implicit in the work of health care professionals. During requirements gathering, designers must broaden their focus from the technical system to include the work in order to capture these interactions.

The second assumption is that requirements analysis can capture users' work as a formal, routinized process and can present a single, unambiguous view of the work. Although this assumption might hold in a relatively predictable work environment, such as banking or shop-floor automation, a formal workflow model of medical care is difficult to build because medical work is an unpredictable combination of routine and exceptions [18, 19]. Berg [20] describes this complication when discussing physician and nurse interaction:

> According to formal workflow depictions of medical work, for example, doctors instruct nurses about the medication to administer, when, what dosage and via what routes; nurses then act upon this instruction and administer the appropriate drug. In practice, however, boundaries between tasks and roles are not so tightly drawn. Nurses often suggest the right dosage to the resident, or may already administer the basic medication before the doctor has formally entered the request in the record (p. 245).

Further, although patient care is the central focus, physicians, nurses, and pharmacists have their own work to do; their motivations, and concerns are quite different [21]. Because patient care is a collaborative process, these motivations and concerns can be at odds during the work and need to be reconciled on a case-by-case basis. Therefore, presenting an unambiguous, formal, predictable view of collaborative medical work is a difficult if not an almost impossible task.

2.3 Example of a Failed Clinical System

Heath and Luff's [5] study of a failed medical record system, VAMP, highlights the problems with making traditional requirements analysis assumptions in the clinical health care domain. The designers wanted to substitute VAMP for the paper documentation used by physicians during patient consultation. However, their attempts to formalize aspects of the physicians' activity failed to accurately represent their work. For instance, the paper documentation allowed the physicians the freedom to be ambiguous when writing a diagnosis or an assessment of a complaint when they were unsure of the patient's condition. The designers removed this freedom by formalizing the diagnosis and assessment choices and forcing the physicians to choose from a pre-specified list when using VAMP. This sort of mismatch between practice and technology caused the physicians to reject the system. As Heath and Luff state:

> In a sense, the design of the system reflects a rigorous, but limited, requirements analysis…The relevant classes and categories have been identified, but the practices through which the document is written, read, and used within the consultation have been largely ignored. By ignoring these practices, the design not only discounts the indigenous rationality oriented to by the doctors themselves in the producing and reading of the records, but fails to recognise that such practices are themselves inextricably embedded in the day to day constraints of in situ medical work (p. 360).

The designers assumed that by formalizing the work they could create a system that would both increase a physician's productivity and be simple to use. However, their focus on the system (e.g., diagnostic classes and categories) and not the actual work of the physicians lead to the ultimate rejection of the system.

On the basis of experiences like this, we argue that designers should approach requirements from a *sociotechnical* perspective that sees technology and practice as interrelated. In the next section, we describe in greater detail this type of requirement analysis.

3. Sociotechnical Requirements Analysis

Clearly, we are not the first to discuss the importance of sociotechnical requirements in system design. Yet, traditional requirements analysis is still predominant in medical informatics system design and only a few researchers (e.g. [5, 15, 20]) have started to investigate the applicability of sociotechnical requirements analysis in the clinical health-care domain. In this section we provide some background to sociotechnical requirements analysis and discuss its relevance for the system design in the clinical health-care domain.

3.1 Background

From a sociotechnical perspective, it is impossible to separate the organizational or social issues from the technical issues. Instead, the organization and the technology are interwoven to form a sociotechnical system [22]. Where traditional requirements analysis focuses on what the technology should do (i.e. in terms of its functionality), sociotechnical analysis looks at how the technology will be incorporated into work activities. This type of analysis is based on the observation that implementing a successful technology requires a thorough understanding of the organizational context, such as the organization's structure, work, and employees. For example, Travers [3] examined the implementation of the same CPRS technology in two different pediatric offices (A & B). Although the information needs were the same in each office, the CPRS was adopted in office A but not in B. The different outcomes were accounted for not by technology differences but rather by the differences in the work practices and social organization of the two offices. Travers noted that because the staff in office A had a cooperative spirit, they were more open to the introduction of new technology than the staff in the less cooperative office B; Office A staff had greater resources to draw upon in adapting to the new system. The success of the technology depended on the social structure in which it was embedded.

A growing number of researchers have focused on sociotechnical requirements analysis as a means of dealing with the limitation of the underlying assumptions of traditional requirements analysis [7, 23]. Researchers have focused on sociotechnical requirements in a number of different organizational systems: air traffic control [24, 25], underground subway control system [26], and financial systems [27]. In gathering and analyzing sociotechnical requirements for these systems, researchers have utilized ethnographic techniques. These techniques are used to observe users in their actual work settings carrying out their day-to-day work activities. Sommerville [28] describes two types of requirements that ethnographic techniques are particularly effective at gathering:

> 1) Requirements that are derived from the way in which people actually work rather than the way in which process definitions say they ought to work.
> 2) Requirements that are derived from cooperation and awareness of other people's activities. (p. 136)

Because sociotechnical requirements are embedded in the work activities of individuals, ethnographic techniques provide one way of observing and extracting these requirements from the work [5, 20, 25-27, 29-31].

3.2 Clinical Systems Design

Sociotechnical requirements analysis should play a prominent role in the design of clinical systems such as a CPRS because of the collaborative and highly institutionalized nature of social practices in the medical domain. The patient record – as a repository of collected data, observations, and plans – is central to collaboration in medical work. Health care workers routinely use the record to exchange patient care information. For instance, physicians read nursing observations about the patient in the record and write orders for nurses to carry out. Therapists often read both nursing and physician notes before writing a therapy plan. So, in designing a CPRS, we need to be sensitive to the collaborative activity of its various users; introducing a new component, whether it be technical (e.g. a module) or social (e.g. a convention), impacts the collaborative process. Sociotechnical requirements analysis helps us to design clinical health care systems that integrate well with other organizational components.

Besides collaboration, medical environments also have strongly institutionalized social practices that complicate the task of requirements analysis. For instance, the medical staff in hospitals has an extensive veto power over most hospital decisions that affect clinical care. This veto power is not formalized in any hospital policy but is nonetheless rigidly enforced because the physicians view themselves as responsible for patient care. Goddard [6] also identified lack of physician support as one reason for their organization's CPRS implementation failure. A hospital will be reluctant to implement a clinical information system that the medical staff opposes, even if the system can provide tangible benefits to the organization. Similarly, the roles and responsibilities of different health care workers are further institutionalized social practices. These roles and responsibilities affect how they view the usefulness of a technology. For example, a nurse who wants detailed information about certain aspects of patient care would have different expectations of a system than a physician who wants only brief patient care information. By expanding our focus to the health-care organization, sociotechnical requirements analysis techniques allow us to understand how social practices of nurses, physicians, and other health-care workers impact system design.

In the next section, we expand on our discussion of sociotechnical requirements analysis by presenting real-world examples of two sociotechnical requirements found in a field study of a CPRS in an intensive care unit of a hospital.

4. CareVue: Sociotechnical Requirements from a Successful Clinical System Adoption

One way to gain a better understanding of sociotechnical requirements that designers should consider when developing future systems is to examine similar systems that were successfully adopted. We studied the use of CareVue (CV), a computerized patient record system that has been used in an intensive care unit for more than nine years [32]. In this section, we present our research site and methods. We also provide a brief example of how CV supports collaboration amongst various health care workers during the medication administration process.

4.1 Research Site and Methods

The surgical intensive care unit (SICU), where we conducted our fieldwork, is one of nine intensive care units of a large urban teaching hospital. The SICU is a 20-bed unit equipped with sophisticated equipment including a fully computerized patient record system. The research team had access to the SICU staff including physicians, nurses, and pharmacists. In addition, we observed and interviewed the CPRS technical team members from the hospital's information systems department. The first author observed work in the SICU for approximately seven months during 2000 to 2001. He collected data through 30 semi-formal interviews, as well as a number of informal interviews, and observations. The semi-formal interviews were taped and transcribed. The research team had access to the CPRS application and internal communications, including written policies, procedures, and meeting notes.

Information technology plays a crucial role in the SICU. CV mediates much of the work among the physicians, nurses, and pharmacists. Almost all patient information is in the computerized record. Because the patient's bedside monitoring systems are linked to CV, physiological data such as temperature, blood pressure, heart rate, and fluid levels are downloaded automatically into the patient's CV record. The record also contains medication information, progress notes, and laboratory results. Nurses enter most of the data that is not automatically downloaded into CV.

Physicians largely use CV to monitor the patient's status and to find needed patient information. Pharmacists are interested in ensuring that the patient is receiving the appropriate medication and that all the information related to the patient's medication is correct.

4.2 Medication Administration

Ordering and administering medication requires collaboration between physicians, nurses, and pharmacists. In routine situations, most surgeons use a standard set of drugs. However, for complex cases, nurses and pharmacists often provide information that help physicians tailor the prescription. Because nurses are constantly by the bedside, they can inform physicians about the patient's physical and mental state. This information helps physicians to decide whether a current drug and dosage are appropriate. If physicians need to prescribe a drug for a problem with which they are not familiar, pharmacists can provide a list of appropriate medications.

Nurses must collaborate directly with both physicians and pharmacists. When ordered to give an unfamiliar drug, nurses commonly ask the physician why it is being given, especially when the drug causes discomfort or pain to the patient. Most physicians want the nurse to understand the plan of care and will answer such questions

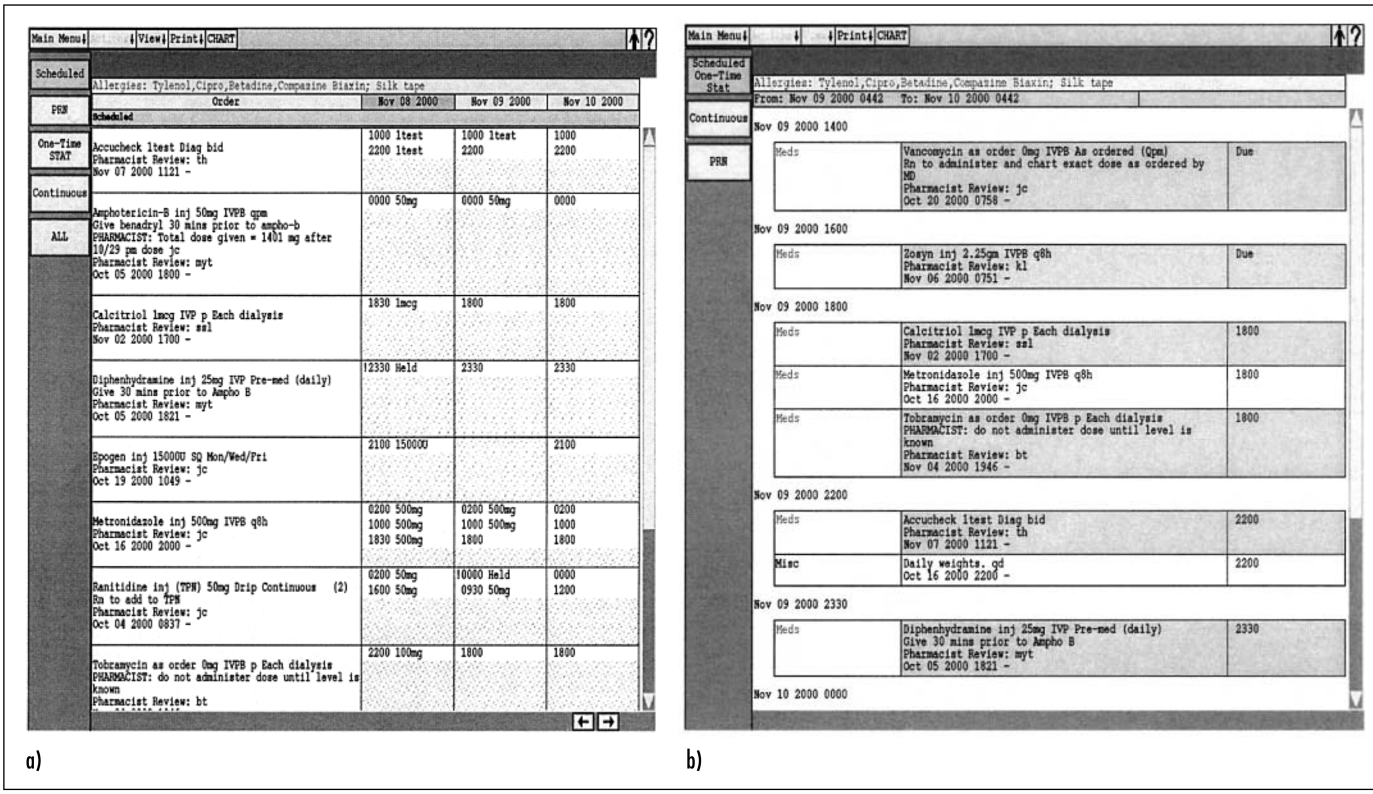

Fig. 1 Different representations of medication information: a) Pharmacists use the Medication Administration Record (MAR) to provide them with the more detailed information on each medication. b) Nurses use the Medication Worklist to keep track of their medication administration work activities.

readily. The nurses also ask the pharmacist questions concerning the medication and dosage administration. For certain kinds of drugs, such as pain relievers, it is the nurse who observes the patient's response most directly, and whose opinion is usually given high regard by physicians for subsequent pain medication orders.

CV plays an important role in supporting this collaborative process of medication administration. The central element that CV provides is the Medication Administration Record, or MAR (Figure 1a). The MAR coordinates both the prescription and administration of medication. When the physician writes a medication order, a nurse or pharmacist enters the order into the MAR, recording the details of the prescribed medication. Although the MAR provides the detailed information necessary for the pharmacists, it provides too much detail for the nurses to efficiently plan their medication administration activities for a shift. Consequently, to administer medications effectively and on-time, nurses use another „view" of the MAR, the Medication Worklist (Figure 1b), which provides a time-ordered list of dosages, and administration times for all drugs due to be administered on the current nursing shift. The nurses use this Worklist to plan their medication administration activities for each of their patients.

Each group uses the system to view a patient's medication information, although in different ways. For example, pharmacists check the appropriateness of the medication based on the patient's condition. If they do not believe that the drug is appropriate, they will offer the physician advice about alternative medications. Physicians may consider the pharmacists' recommendations when making their final medication decision, based on the information that CV provides them concerning the patient's response to previous treatments.

5. Two Sociotechnical Requirements for Collaborative Work

As we examined the medication administration process more closely, we discovered that certain features of the work are well supported by CV. Based on our observations, we describe two sociotechnical requirements that are embedded in the collaborative work of medication administration. These requirements, awareness and coordination, are closely related to each other; for effective collaboration, individuals must be able to maintain an awareness of each other's work activities and coordinate their diverse activities.

5.1 Awareness of Work Activities

The ostensible purpose of a CPRS such as CV is to record information about the patient. However, we found that the issue of

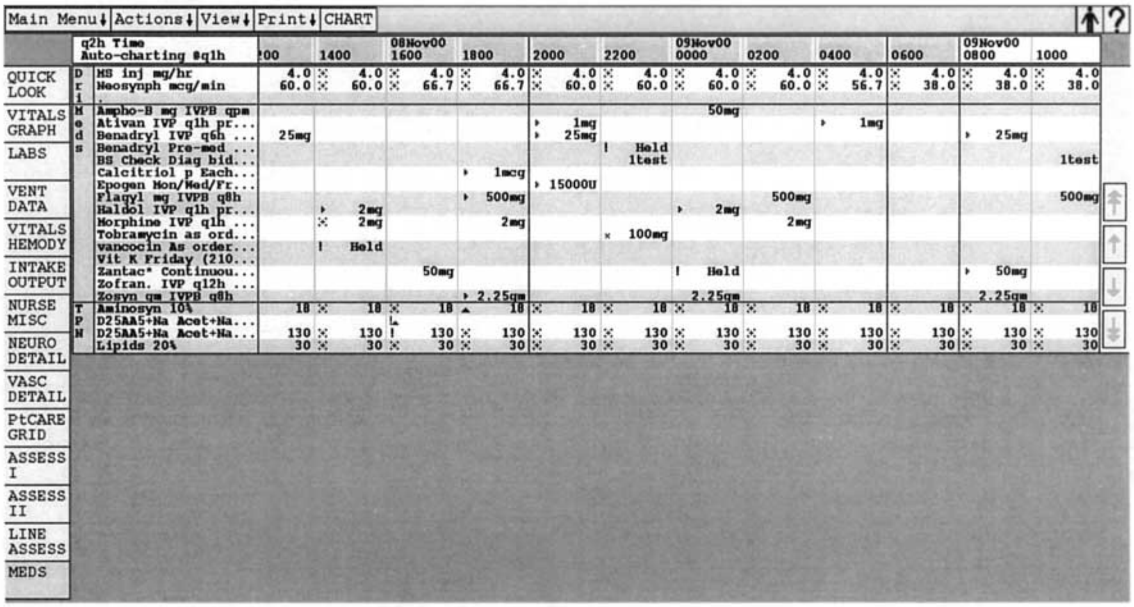

Fig. 2 CareVue flowsheet's MEDS section: The ICU staff, especially physicians, use the MEDS section to quickly check on patient medications.

concern to CV users in many cases was not information about the patient per se, but information about the activities of other health care workers over that patient. This phenomenon is well-observed in studies of cooperative work mediated by computer technology [18, 29].

Investigations of collaborative work show that collaboration improves when people can actively produce and maintain an idea of what is going on around them. Maintaining this "awareness" of ongoing action helps ensure that their actions are coordinated. Dourish and Bellotti [33] describe awareness as "the understanding of the activities of others which provides a context for your own activity". Bricon-Souf and colleagues [34] argue that one way to support successful collaboration is to share information about users' work activities because individuals can more efficiently coordinate their work if they know about one another's activities.

CV supports such awareness and plays an integral role in the collaboration amongst physicians, nurses, and pharmacists during the medication administration process by providing knowledge to each group of the other's work activities. For example, physicians use CV to monitor the patient's status and to find needed patient information. Because physicians are concerned with the patient's overall medical condition, they are not always interested in reading the detailed information provided in the MAR. Instead, they use the CV Flowsheet (specifically, the MEDS sub-section) to provide them with summarized drug, dosage, and time administration information (Figure 2). The information is presented in a time-oriented fashion so that physicians can quickly scan the data from left to right to see when the patient has received her medication. They use this information to monitor the patient's medications as well as to ensure that the nurses are administering the medication as ordered. If the physician spots any discrepancies, such as wrong dosage information, she can then contact the nurse to investigate the problem. The Flowsheet allows physicians to maintain an awareness of nursing action and to make sure that the nurses are administering medication properly.

Although physicians prefer the Flowsheet, pharmacists and nurses regularly use the MAR. An important component of medication administration is the prevention of medication error. To minimize opportunities for medication error in the SICU, the pharmacist vets all the medication orders. When a pharmacist has approved a medication, he adds his electronic signature that is visible to the nurse next to the order in the MAR. The nurse then knows that the pharmacist has checked the drug for appropriateness, route, and dosage. This form of awareness is used to reduce possible medication errors. Finally, the MAR's visual interface provides considerable information to its users. Discontinued medications are displayed in light gray at the bottom of the screen. Nurses, pharmacists, and even physicians quickly glancing at the screen can distinguish active from non-active drugs. If someone spots a discrepancy, she can bring it to the attention of other team members. Thus, from a sociotechnical perspective, CV serves as more than just a repository of patient information; it also provides people with a view of each other's activity.

Awareness is rooted in the workpractices of health care workers. Many times, it is maintained without the aid of any technology. However, in the fast-moving medical environment, technology can play an important role supporting health care workers knowledge of each other's activities. Therefore, incorporating the proper structure and type of information in the system is important for building awareness. By using sociotechnical requirements analysis, we can gain a better understanding of how the interaction of the technology with user workpractices creates awareness mechanisms.

5.2 Coordination of Work Activities

Although awareness is important for collaboration, it is, by itself, not sufficient to allow people to carry out collaborative activities. Collaboration also requires people to interpret each other's actions in order to *coordinate* their mutual activities. Coordination is one of the achievements that awareness supports.

Berg and Bowker [35] explore some of the ways that health care workers employ the medical record as a coordinating device, using it to communicate directly and indirectly and to ensure that their activities mesh effectively. For instance, the physician writes a patient order in the medical record that is read by the nurse. In turn, the nurses write patient information in the record, which helps physicians decide what to do next for the patient. Without using the patient record to coordinate their activities, physicians and nurses would have difficulty collaborating on patient care issues. Coordination is an important feature of collaboration that is only noticed when it fails [36].

One mechanism for coordinating work is through a shared understanding of each other's work practices. Such a shared understanding encompasses a more detailed knowledge of each other's practices that is not provided by simple awareness. However, in a heterogeneous work environment, such as an SICU, physicians, nurses, and pharmacists' activities and knowledge are quite diverse. This diversity makes collaboration difficult because, in many ways, each group has only a superficial understanding of the other groups' work practices. CV's presentation of information provides a clue on how to deal with the coordination problem in a diverse work environment. Through its multiple screens (Flowsheet, MAR, Medication Worklist), CV provides different views of the same information; these different views are oriented to the specific needs of the different groups who use them. For example, physicians want the brief information provided by the Flowsheet. In contrast, pharmacists and nurses are concerned with the actual process of medication administration and hence, want the more detailed information provided in the MAR and Medication Worklist. However, the need for these different views is balanced by the need for shared information. It is not enough for the views to be different, but they must be different views of *identical* underlying information. It is through the sharing of this information that coordination is achieved. Furthermore, all the views are synchronized to reflect changes made to the underlying information by a user. For example, if a pharmacist puts a hold on a medication in the MAR, that same information is also available in the Flowsheet and in the nurses' Medication Worklist. CV's presentation of the same information through different views allows physicians, nurses, and pharmacists to coordinate their diverse patient care activities.

Rapid and effective coordination amongst health care workers is required for managing severely ill patients. However, the sometimes diverse work activities and concerns of health care workers can impact patient care coordination. By providing mechanisms allowing individuals to coordinate their activities, clinical systems can play an essential role in improving the quality of patient care.

6. Sociotechnical Requirements Analysis for Clinical System Design

In our discussion of medication administration, we highlighted two sociotechnical requirements that emerged from our field observations. Although we specifically examined a computerized patient record system, our observations suggest some two general implications for clinical system design.

First, traditional requirements analysis is insufficient to address the needs of clinical system designers. Instead, we must reexamine requirements from a much broader sociotechnical perspective that takes into account the highly collaborative, diverse work typical in clinical health care. Traditional analysis with its emphasis on the technology often misses crucial features of the complex work environments in which the technology is implemented. It is only through closely examining the work that designers can develop clinical systems that fully support the needs of its users. Viewing requirements from a sociotechnical perspective allows designers to gather a much richer description of the environment surrounding the computer system. However, examining and understanding individuals' work is a non-trivial task. We believe that the ethnographic techniques we utilized in our field study can play an important role in eliciting sociotechnical requirements useful for the design of clinical systems. As we discussed in section three, ethnographic techniques have been used successfully in other domains for requirements gathering and analysis. Similarly, clinical systems' design can also benefit from these techniques.

Second, clinical systems are not simply information repositories of patient data but rather are an integral part in the collaboration amongst health care workers. Our field study described how a CPRS is used for dual purposes. It provides not only valuable patient care data but also keeps health care workers informed about each other's activities allowing them to coordinate their work more effectively. However, these mechanisms are not produced solely by the system nor by the practices of the users. Rather, it is the practices combined with the technical features of the system that allows patient care data to also be used as a coordinating mechanism. Sociotechnical requirements analysis, with its emphasis on the interplay between social and technical issues, highlights the coordinative role played by this same information. Supporting one without the other impairs the collective delivery of health care services.

Sociotechnical requirements analysis is not a solution for all the problems facing clinical system design and does not always necessarily lead to a better set of requirements for the system. Yet, its focus on the intertwining of the organization and technology, and its insights into the work of the users will improve our chances for understanding what is essential for the design of successful clinical systems.

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References

1. Robertson S, Robertson J. Mastering the requirements process. Menlo Park: ACM Press, 1999.
2. The Standish Group. The Chaos Report. [Online]. 1994 [cited 2001]. Available from URL: http://www.pm2go.com/sample_research/chaos_1994_1.asp.
3. Travers DA, Downs SM. Comparing user acceptance of a computer system in two pediatric offices: a qualitative study. Proc AMIA Symp 2000: 853-7.
4. Barley SR. Technology as an occasion for structuring: evidence from observations of CT scanners and the social order of radiology departments. Administrative Science Quarterly, 1986; 31: 78-108.
5. Heath C, Luff P. Documents and professional practice, 'bad' organisational reasons for 'good' clinical records. ACM Conference on Computer-Supported Cooperative Work, 1996: 354-63.
6. Goddard BL. Termination of a Contract to Implement an Enterprise Electronic Medical Record System. J Am Med Inf Assoc 2000; 7: 564-8.
7. Jirotka M, Goguen J. Requirements engineering, social and technical Issues. San Diego: Academic Press Limited; 1994.
8. Daley, E. Management of software development. IEEE Transactions on Software Engineering 1997; 3: 229-42.
9. Boehm BW. Software Engineering. IEEE Transactions on Software Engineering 1976; 1: 1226-41.
10. Jackson M. Software requirements and specifications. Menlo Park: Addison-Wesley; 1999.
11. NCC. The STARTS Purchasers' Handbook. UK: NCC; 1989.
12. McDermid JA. Requirements analysis: Orthodoxy, fundamentalism, and heresy. In: M. Jirotka M, Gougen J, editors. Requirements engineering, social and technical issues, San Diego: Academic Press; 1994, pp. 17-40.
13. Gougen JA, Linde C. Techniques for requirements elicitation. IEEE Conference on Requirements Engineering, 1999: 152-64.
14. Baggs JG. Intensive care unit use and collaboration between nurses and physicians. Heart Lung 1989; 18: 332-8.
15. Berg M. Patient care information systems and health care work: a sociotechnical approach. Int J Med Inf 1999; 55: 87-101.
16. Forsythe DE, Buchanan BG, Osheroff JA, Miller RA. Expanding the concept of medical information, an observational study of physicians' information needs. Computers and Biomedical Research 1992; 25: 181-200.
17. Baggs JG, Schmitt MH, Mushlin AI, Mitchell PH, Eldredge DH, Oakes D, Hutson AD. Association between nurse-physician collaboration and patient outcomes in three intensive care units. Crit Care Med 1999; 27: 1991-8.
18. Symon G, Long K, Ellis J. The Coordination of work activities: cooperation and conflict in a hospital context. Comp Supp Coop Work 1996; 5: 1-31.
19. Katzenberg B, Pickard F, McDermott J. Computer support for clinical practice: embedding and evolving protocols of care. ACM Conference on Computer Supported Cooperative Work 1996.
20. Berg, M, Langenberg C, vd Berg , Kwakkernaat JK. Considerations for sociotechnical design, experiences with an electronic patient record in a clinical context. Int J Med Inf 1998; 52: 243-51.
21. Strauss A, Fagerhaugh S, Suczek B, Wiener C. Social organization of medical work. Chicago: University of Chicago Press; 1985.
22. Bikson T, Eveland J. Groupware implementation, reinvention in the sociotechnical frame. ACM Conference on Computer Supported Cooperative Work 1996: 428-37.
23. Viller S, Sommerville I. Social analysis in the requirements engineering process: from ethnography to method. IEEE Conference on Requirements Engineering 1999: 6-13.
24. Sommerville I., Rodden T, Sawyer P, Bentley R, Twidale M. Integrating ethnography into the requirements engineering process. Requirements Engineering 1992: 165-73.
25. Bentley R, Hughes JA, Randall D, Rodden T, Sawyer P, Shapiro D, Summerville I. Ethnographically-informed systems design for air traffic control. ACM Conference on Computer Supported Cooperative Work 1992: 123-29.
26. Heath C, Luff P. Collaboration and control: crisis management and multimedia technology in London Underground line control rooms. Comp Supp Coop Work 1992; 1: 69-118.
27. Hughes J, King V, Rodden T, Anderson H. Moving out of the control room, ethnography in system design. ACM Conference on Computer Supported Cooperative Work 1994: 429-39.
28. Sommerville I. Software engineering. San Francisco: Addison-Wesley; 2001.
29. Berg M. Accumulating and coordinating, occasions for information technologies in medical work. Journal of Computer Supported Cooperative Work 1999; 8: 373-401.
30. Forsythe DE. Using ethnography to investigate life scientists' information needs. Bulletin of Medical Library Association 1998; 86: 402-9.
31. Hughes JA, Randall D, Shapiro D. Faltering from ethnography to design. ACM Conference on Computer Supported Cooperative Work 1992: 115-22.
32. Shabot, MM. The HP CareVue clinical information system. International Journal of Clinical Monitoring Computing 1997; 14: 177-84.
33. Dourish P, Bellotti V. Awareness and Coordination in Shared Workspaces. ACM Conference on Computer Supported Cooperative Work 1992: 107-14.
34. Bricon-Souf N, Renard JM, Beuscart R. Dynamic workflow model for complex activity in intensive care unit. Medinfo 1998; 9: 227-31.
35. Berg M, Bowker G. The multiple bodies of the medical record, toward a sociology of an artifact. The Sociological Quarterly 1997; 38: 511-35.
36. Malone TW, Crowston K. The interdisciplinary study of coordination. ACM Computing Surveys 1994; 26: 87-119.

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