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Methodological Review

Incorporating ideas from computer-supported cooperative work

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Abstract

Many information systems have failed when deployed into complex health-care settings. We believe that one cause of these failures is the difficulty in systematically accounting for the collaborative and exception-filled nature of medical work. In this methodological review paper, we highlight research from the field of computer-supported cooperative work (CSCW) that could help biomedical informaticists recognize and design around the kinds of challenges that lead to unanticipated breakdowns and eventual abandonment of their systems. The field of CSCW studies how people collaborate with each other and the role that technology plays in this collaboration for a wide variety of organizational settings. Thus, biomedical informaticists could benefit from the lessons learned by CSCW researchers. In this paper, we provide a focused review of CSCW methods and ideas—we review aspects of the field that could be applied to improve the design and deployment of medical information systems. To make our discussion concrete, we use electronic medical record systems as an example medical information system, and present three specific principles from CSCW: accounting for incentive structures, understanding workflow, and incorporating awareness.

Keywords: Software design; Collaborative work; Technology assessment; Biomedical; User-computer interface cooperative behavior; Social environment

1. Medical software systems

The design and implementation of large-scale software systems is often a complex and costly task that is essential to an organization's success. Within the healthcare industry, problems associated with deploying systems are a growing concern. Recent high-profile challenges to system implementation suggest that as a discipline, we should question whether we are applying all the appropriate methodologies to build and deploy successful information systems for clinical settings [1,2]. In this article, we argue that, as medical informatics researchers, organizational leaders, and systems developers, we would benefit from research findings and methodologies from the field of computer-supported cooperative work (CSCW). Of course, we do not claim or expect that CSCW will be a panacea for the challenges in the design and development of medical information systems. Our goal is to improve synergies between medical informatics and CSCW. Most medical information systems are targeted at users who must work collaboratively; thus, our field provides a rich domain for CSCW researchers. For medical informaticists, ideas and methodologies from CSCW should guide our research into collaboration and improve our abilities to build and deploy successful medical information systems. Rather than attempting a comprehensive review of CSCW ideas and methods, we focus on three aspects of the field that have the most promise and applicability to biomedical informatics: accounting for incentive structures, understanding workflow, and incorporating awareness.

In general, software development is expensive and susceptible to failures for a variety of reasons, ranging from poor requirements gathering to poor evaluation of

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system effectiveness [3,4]. A survey of 8000 projects in 350 US companies found that one-third of these software development projects were never completed, and one-half succeeded only partially [5]. The history of medical information systems failure is also quite extensive. Systems have failed in a wide variety of medical organizations including medical offices [6,7], hospitals [2,8,9], and ambulance-dispatching centers [10]. Researchers have argued that system failures in healthcare range from 30% to more than 50% [11,12]. We may never know the true rate of system failure in medical organization because the disincentives to publicize failure are so strong. However, we do know that system failure is a source of frustration and financial expenditure in many organizations [13].

Often, the causes of system failures cannot be explained in purely technical terms. Rather, the complex network of relationships among people in an organization strongly affects the success of a technology. These non-technical aspects include organizational and social issues, such as medical practice norms, organizational standards, small group norms and behavior, and individual user preferences [14]. In general, users play a large role in determining whether a software system will fail or succeed. In the health-care domain, these socio-technical issues dominate the success or failure of medical information systems. For example, Anderson et al. [12] state, "Despite the fact that they are technologically sound, more than half of the medical information systems fail because of user and staff resistance." To ensure success, we must examine medical information systems from a much broader perspective than is often done.

Researchers in the medical informatics community who have examined organizational and social issues related to systems development include innovators such as Bonnie Kaplan, Chuck Friedman, Joan Ash, Jim Anderson, Patricia Brennan, Carolyn Aydin, Diana Forsythe, and others [15–20]. They have focused our attention on organization and socio-technical issues concerning medical information systems. Within the American Medical Informatics Association (AMIA), the People and Organizational Issues (POI) working group has provided a forum for these researchers to exchange ideas. In addition, international researchers, such as Marc Berg and Enrico Coiera, also have highlighted these socio-technical issues [21–23]. They stressed the importance of considering different individual and organizational perspectives in designing, implementing, and deploying medical information systems. Their work incorporates both qualitative and quantitative methodologies for evaluating medical information systems that take into account not only the technical aspects of the system but also the organizational setting in which that system is embedded [24].

Clearly, these researchers have helped raise awareness about organizational and social issues to those who develop medical information systems. Our aim in this paper is to expand and extrapolate from their work, and specifically to raise awareness about a complementary body of work and literature from the CSCW community. POI researchers share many of the methodologies and assumptions of CSCW researchers and both groups study the interplay between human social systems and technical systems. However, CSCW researchers explicitly focus more on the *collaborative* nature of work that is such a critical part of medical organizations, than do most POI researchers. Furthermore, outside the POI group, medical informatics professionals, as well as researchers too often overlook the non-technical or socio-technical aspects of systems design and development that the CSCW community studies extensively.

In this article, we briefly review the field of CSCW, and outline its scope and goals. We focus specifically on three key areas of CSCW research:

- Incentive structures—How can we create systems and appropriate organizational structures to motivate users to properly use a technology?
- Workflow—How does the technology fit into the work process of its users?
- Awareness—What techniques can be used to help people be aware of and coordinate their work with others?

Although our review focuses on these three aspects of CSCW research, other areas of work within CSCW also are relevant to medical informatics. For example, there is a wealth of CSCW work on collaboratories [25–29] that are important to similar studies within medical informatics [70]. Likewise, research in CSCW also focuses on how modern technology such as mobile telephony and hand held computing affect work and workflow [30–33], and this research is critical for the study of new devices, such as wireless pagers, that are becoming a commonplace in medical care [71]. However, rather than attempting to comprehensively cover the field, we provide details on only three specific examples of concepts from CSCW research: incentive structures, workflow, and awareness.

To illustrate how these areas of CSCW research could be applied effectively to current practices, we use EMRs as an example, where we define EMRs broadly to mean any system that supports an electronic collection of an individual's health information that is used to care for that individual. We do not claim to address the entire multitude of challenges in designing and deploying successful EMRs. In particular, we do not cover questions about the appropriate *functionality* of EMRs; the recent Institute of Medicine (IOM) report thoroughly covers that topic [34]. Rather, EMRs serve only as an example to illustrate our points; the concepts and ideas from CSCW apply to many other types of medical information systems as well. The inherent collaborative nature of medical work makes it essential that we have the appropriate tools and methods to design truly collaborative medical information systems. CSCW can provide us with a framework for better understanding and supporting collaborative work in medical care.

2. CSCW: A blending of social and technical perspectives

In the early 1980s, CSCW emerged as "an interdisciplinary field that examines computer-assisted coordinated activities such as problem solving and communication carried out by a group of collaborating individuals" [35]. It explores the interactions between systems and social aggregates, such as groups and organizations. The research community is a rich blending of people that includes researchers from computer science, anthropology, sociology, and psychology. These researchers are interested in problems ranging from building collaborative systems to understanding social and organizational issues surrounding these systems. In many cases, both technically oriented and socially oriented researchers share the common goal of understanding the relationship between technical systems and the collaborative social context in which a system is embedded. They utilize these multiple perspectives to examine the design and implementation of technologies in organizational settings.

CSCW researchers are not alone in examining the design and use of information technology from a blend of social and technical perspectives. Other research disciplines have recognized the importance of social and cognitive analysis. For example, the field of human–computer interaction (HCI) has played a prominent role in exploring how people interact with technology in a variety of ways [36–38]. Similarly, the fields of human factors and cognitive systems engineering have long studied the interaction of design and human cognition [39,40]. As in CSCW, researchers in these disciplines share the notion that successful systems depend on more than optimizing the technical aspects of a design—they also depend on successfully fitting the human and social characteristics of work settings. CSCW differs from these fields in its emphasis on collaborative work settings, where social interactions and analysis are paramount.

2.1. CSCW and levels of analysis

In this article, we focus on CSCW work that emphasizes multiple perspectives with roots at different analytical levels, encompassing a range of political, institutional, organizational, small group, and individual perspectives. At the highest level, a political analysis often considers how legislative activity impacts the success and failure of systems or how collaborative systems assist government with governing activity [41]. An institutional level of analysis takes into account how human behavior is embedded in a long-term, socially constructed environment and how that environment enables, shapes, or constrains activity [42]. These long-term socially constructed environments span the range of small-scale social norms through broad cultural activity [43].

Studies that take an organizational perspective consider how relatively large groups structure and coordinate their own activities [44]. This perspective differs from an institutional one by considering the organizational frame in which human behavior is embedded as more flexible and, most likely, less long-lived than institutional frames.

A small group perspective focuses on collaborative activity where a small group often has great flexibility and choice in their procedures and coordination methods [45,46]. Small groups often exist in a larger context, such as that of an organization or institution, and often include extensive ad hoc activity. Collaboration studies that consider the individual perspective often account for cognitive activity as well as the influence of that activity on individual choice and capacity to collaborate.

As these brief descriptions attempt to convey, CSCW research engages issues at different levels of analysis with differing techniques and methods of study. These different perspectives provide important analytical insight and inform aspects of future systems design that cover a range of complex collaborative behavior. By looking at systems from these multiple perspectives and across multiple settings, CSCW researchers have developed general models and insights that could prove useful for medical information systems. Although Kaplan et al. [16] used similar levels to discuss where informatics applications are used, we carry the analysis of these levels one step further by both including examples of how the levels can be used to analyze medical information systems, focusing on EMRs, and relating them to findings from the CSCW literature.

2.2. CSCW Methodology

Much of the research in CSCW is based on ethnographic methods for investigating organizational and technological settings (e.g. [47–49]). These methods include qualitative data collection through observation, participant observation, and semi-structured interviews, as well as analysis using a grounded theory approach [50–52]. These methods allow the researcher to understand a complex phenomenon deeply and to develop a rich analytical description of that phenomenon as part of an iterative cycle of observation and analysis. Such methods have proven to be particularly useful in situations where multifaceted interdependencies make it difficult to separate the independent and dependent variables, such as those in complex work settings where technical, organizational, and social factors intersect (e.g. [45,46,53]).

In addition, CSCW researchers recently have been taking a technomethodological approach for the design and development of collaborative technologies [54,55]. This methodology promotes combining the analytical and abstractive power behind technology design with the situated knowledge gained from a type of sociological inquiry approach called ethnomethodology [56]. This explicit inclusion of design as a part of the methodology helps CSCW researchers move beyond only descriptions of failures or successes and into the design and development of new and useful systems for collaborative environments. This technomethodological approach provides a prime example of how CSCW work blends both the social and technical perspectives. The methodologies we mentioned briefly in this section should prove helpful in analyzing and designing for the complex and collaborative medical work settings.

3. Reconsidering the EMR from CSCW perspectives

The EMR is a good example of a collaborative technology; multiple people use the EMR in different ways to accomplish the shared goal of effective and efficient patient care. EMR systems are also examples of large, complex software systems, and as such, they fail more often than one would like. Medical informatics researchers have uncovered many barriers to EMR adoption [57], but we believe additional attention is needed on issues surrounding the EMR as a *collaborative* technology. Our hope is that reconsidering the EMR from CSCW perspectives will provide examples of valuable insights that could lead to more successful development and deployment of medical information systems in general.

A number of CSCW researchers have studied the patient record as a collaborative technology, in either its electronic or paper form. Berg and Bowker [21] argue that the patient record serves as a coordination mechanism between health-care workers. The physician can give orders concerning the patient via the patient record. In turn, the nurses' note information in the record that helps the physician decide what to do next for the patient. Thus, Berg and Bowker concluded that the patient record is essential for coordinating the interaction among health-care providers. In a study of EMRs in doctors' offices, Heath and Luff [6] discuss the patient record as a form of asynchronous collaboration that provides a mechanism for information sharing between doctors. For example, one physician would write the diagnosis of the patient in the record. At a later point, when that patient went to another physician, the second physician would read what the first wrote to help in her decisions regarding the patient's care. Although the EMR can serve as an important communication conduit between physicians, Engestrom et al. [58] specifically discuss the role that work pressures place on physicians to prevent them from fully utilizing the EMR as a true communication mechanism. The insight that the EMR plays an important communication and workflow role has been recognized by some but not all EMR developers [59]. Nonetheless, this aspect of the EMR could still be enhanced to create incentives among clinicians for its adoption.

In the following sections, we examine how three aspects of CSCW research could improve EMR design, deployment, and use. We start by exploring *incentive structures* at the institutional, organizational, and small-group levels, and examine how these levels help us understand successful EMR adoption. Second, we reflect on the issue of *workflow* and apply another example of organizational analysis that considers the tension between routine activity and the exceptions that occur in everyday work. Third, we consider how individuals get value from collaborative systems through *awareness mechanisms*, and how political perspectives play a role in the options available for providing such awareness mechanisms. For illustrative purposes, we focus on insights that can be derived from existing CSCW research for only EMRs. In addition, these same insights are likely to be fruitful for most medical information systems.

3.1. Incentive structures

A major problem in adoption of workplace technologies is getting employees to use the systems as intended [53]. It is not enough to have technology adopted into the workplace; the technology must be adopted appropriately. In organizations, the institutional infrastructure is just as important as the technical infrastructure. A key component of the institutional infrastructure is the set of incentive structures that the organization has to motivate its employees to use the technology appropriately.

Medical informatics researchers have identified several incentives for adopting an EMR at the *institutional* level [60]:

- Better access to care
- Better quality of care
- Lower cost of health care
- Lower administrative costs
- Improved practice management
- Improved physician training

These incentives operate at the institutional level because they derive from the norms and culture of providing appropriate, cost-effective healthcare. As such, the behavior of organizations, such as hospitals or clinics, and the behavior of their small groups and individual members are embedded in social structures that reinforce these institutional incentives.

Within health-care organizations, EMRs have a great deal of potential for helping achieve the goals outlined above. However, although there are institutional incentives for adopting this technology, the members of that institution, who are also members of small groups, such as physicians, nurses, and pharmacists, are the ones who will use the EMR. Thus, incentives at the group and individual level for using the system must also exist. For example, having physicians enter their own notes has a financial incentive to the institution in terms of saving transcription costs, but it also acts as a disincentive to the physicians who are unlikely to work as efficiently. The greater benefit to the institution usually creates an insufficient incentive to the clinicians; thus, to maximize adoption, direct incentives (e.g., time or effort savings in some other part of the daily work) must be provided for the clinicians as well. It is important for designers and managers to account for these multiple perspectives when considering incentive structures for the adoption of new systems.

CSCW researchers have discovered that many technologies have not been appropriately tied to incentive structures at multiple levels in the institution, and that this oversight led to adoption problems and eventual failures. In many cases, multiple and diverse incentives exist, reflecting different groups and interests that compete with each other and influence overall system success. A classic CSCW study illustrates this complex mix of incentives. In this study, Orlikowski [53] used ethnographic techniques to discover and describe both incentives and disincentives at the institutional, organizational, and group levels for using an application, Lotus Notes, to share information within a consulting organization. The study highlighted the divergent incentives for different hierarchical positions in this consulting organization—in particular, the differences between senior partners in the organization and more junior members. From a junior member's perspective, the institutional characteristics of consulting emphasize competition among individuals and discourage information sharing. However, once an individual has reached the rank of partner, the competition for promotion decreases, and more collegial information sharing becomes the norm. Within the particular consulting organization, a drive for external competitive advantage pervades the organization, and this drive leads to a desire to have an efficient and free flow of information. Thus, the senior partners, responding to organizational incentives, believed that the information sharing attributes of Lotus Notes would allow employees to work much more effectively and efficiently. In contrast, the incentives for junior consultants were at the institutional level, and aligned with those of the consulting discipline. Thus, in this case, the incentives of the different hierarchical groups competed with each other. The upper management's incentives for adopting the system interacted with the lower level employees' disincentives to adopt the system and prevented appropriate use of the technology.

EMRs face similar sorts of problems. The use of EMRs is embedded in the institutional frame of health care, but must also be effective for a specific group within an organization. For example, nurses interact with the patient record as often as the physicians do. However, since they use the EMR differently than physicians, their incentives will also differ. For instance, nurses often need prospective information about when medication needs to be administered to a patient. Therefore, an EMR that provides this information in an easily accessible manner will create an incentive for nurses to use the system [46]. It is unreasonable to speculate, without appropriate data, what incentives or rewards are important for health-care workers in particular settings. The field of CSCW does not offer a panacea for creating appropriate incentives for particular settings. Rather, it highlights the importance of considering incentive structures for different groups of users at different levels of analysis (small groups, individuals or institutions). For managers and designers of EMRs, the lesson is to understand the incentives that different groups have for using a particular technology and to recognize that these incentive structures are crucial for adoption and successful use of a new system.

Other incentives cross through organizational and small group levels of analysis. One common incentive (or disincentive) is the disparity between who does the work in a collaborative technology system and who receives the benefit. For EMRs, this situation may occur for one such group of users: nurses. In many cases, nurses enter most of the information into an EMR. Yet these systems may not provide them with direct benefits in their primary work activities of patient care. If a group of primary users do not believe that they are gaining benefit from the system, or worse, think that others benefit more than they do from their work, or even worse yet, feel that they personally are incurring a cost from using the system, then it will be difficult to motivate them to use this system. The mismatch between who does the work and who gains the benefits can lead to system failures. In a seminal paper on groupware applications, Grudin [14] suggests that a solution is "to design, along with the technology, processes for using it that creates benefits for all group members." Thus, the proper organizational and small group incentives must be created to motivate users to adopt the technology.

In a variety of settings, CSCW researchers have used ethnographic methods to find that incentive structures play an important role in system success or failure. Their findings tying successful system implementation to proper incentive and rewards structures have a direct correlation to many of the adoption problems facing the EMR and similar medical information systems today.

Thus, the community could benefit from examining related CSCW literature and focusing on the issues of institutional and small group incentives for technologies.

3.2. Workflow

Workflow reflects the processes that an organization has created to coordinate the activities of different individuals, to ensure the successful completion of work, and to improve the overall efficiency of workers. Key features of workflow, such as standardized operating procedures and forms, influence the character of coordinated activity. The prominent role that these standardized procedures play in coordinating individual activities makes the concept of workflow both popular in organizations and enticing to systems designers. However, because work is not completely routine, a subtle tension exists between an individuals' actual work activity and the organizational desire for efficiency and standardization.

Developers have applied a number of ways to incorporate collaborative technology into the organization's workflow successfully. At one extreme, developers carefully design the application to fit the specific work practices of its users. Under this model, users do not change their work practices at all, because the technology accommodates their specific needs and work styles. The alternative extreme is to reshape the processes of the organization around the new application. For this approach to be successful, the users' must change their work habits to fit the introduced technology. In this model, the technology is so important that the users do all they can to incorporate the technology into their work by whatever means necessary, which includes changing the way they work. Although both extremes have occurred in collaborative technology adoption, most applications fall in a middle ground: a mixture of supporting some existing work practices and attempting to change others.

In medical care, the work environment is a particularly complex mixture of routine and exceptional events. Although clinicians generally follow standards and a prescribed plan of care, they must also deal with exceptions on a daily basis. This exception-filled nature of the work makes it difficult to build formal workflow models. For example, in his description of physician and nurse interactions, Berg points out [22]:

> 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.

CSCW findings support the idea that much of the activity in the workplace deals with exceptions. In an organizational sense, exceptions can be viewed as "departures of the history of the work case from its prescribed (or normal) flow" [61]. The irregular and unpredictable nature of exceptions makes them difficult to understand fully. Yet, because they occur frequently, exceptions become part of the normal workflow and must be dealt with in system design. People intuitively handle exceptions using prior knowledge or experience, but systems have considerably more difficultly managing this problem. It is much harder to design a system that handles frequent exceptions than to design a system based on standardized workflow. The CSCW community has studied exceptions extensively and can provide insights into both how to study exceptions and how to incorporate those results into system design. For example, Suchman [62], in describing the handling of a missing invoice, detailed how exceptions can occur and the methods that the workers used to handle them. Another stream of CSCW research investigates how systems deal with exceptions. Kammer et al. [63] discuss ways that a workflow system can adapt to a range of exceptions. They argue that, although it is a difficult problem, dealing with exceptions is easier once it is understood what the exceptions are and how they influence the workflow.

Much of current medical workflow modeling is derived from a fairly rigid view of work that is not usually designed to flexibly handle exceptions. Yet, the exceptions in workflow often provide the greatest challenges in patient care and management and the greatest potential for errors. The IOM recognized this challenge in its report on errors by listing as principle #4: "Anticipate the unexpected" [13]. The contrast between standardized workflow and exceptions is also a potential source of tension between an individual's work activity and the organizational level desire for efficiency and standardization. For example, an organization may impose guidelines and standard order sets, and provide technology for supporting these, but may fail to take into account exceptions. For example, a "routine" follow-up visit cannot always take 15 min—it can be much longer depending on the clinical context, e.g., the healthy diabetic in good control vs. the depressed schizophrenic alcoholic diabetic in poor control. Attempts at higher organizational levels to hold providers to standard workflow constraints have resulted in increasing individual dissatisfaction, illustrating both the importance of workflow understanding and of conflicting incentives at multiple organizational levels. Thus, rather than simply building information and decision support systems that adhere to standard workflow guidelines, we must consider the exceptions of medical work, and the CSCW community is a good place to turn to for insights in this area.

3.3. Awareness

Investigations of 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 people's actions are coordinated. Dourish and Bellotti [64] describe **awareness** as "the understanding of the activities of others which provides a context for your own activity." Bricon-Souf and colleagues [65] 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.

The underpinnings of awareness relate to an individuals' cognitive and pre-cognitive activity. The CSCW community has described this notion through the concepts of 'focus' and 'nimbus' [66]. Focus is the explicit domain of one individuals' activity. A focus can be very narrow or somewhat broad. Nimbus is the behavior, display, or activity that emanates out from an individuals activity. When one person's focus intersects with another's nimbus we say that one person becomes aware of another. The relationship between focus and nimbus is not reciprocal. For two people acting in some physical space or some collaborative activity, one person may be aware of the other, but not vice versa. Thus, for example, the focus of a surgeon can be narrowed to the operative field; whereas, the focus of the anesthesiologist might be the overall physiologic state of the patient under anesthesia. The surgeon might influence the cardiac output of the patient, and thus, his nimbus would intersect the focus of the anesthesiologist, who becomes aware of the surgeon but not vice versa.

Awareness is often taken for granted as an aspect of any collaborative work setting. The activities that convey awareness, by increasing the potential focus of one individuals' activity, or, alternatively, expanding the nimbus of another individuals' activity, have direct consequences for the design of collaborative systems.

One example comes from studies of air traffic controllers [47,67]. For many years, controllers would rely on small slips of paper to signal the amount of traffic being monitored, the priority for individual aircraft, as well as the potential problems. The activity of manipulating a control slip effectively expanded the nimbus of the controller who monitored that aircraft. In addition, the physical transfer of a slip from one controller to another represented an explicit point of focus for coordinating two controllers' activity. A redesign of the controllers' workspace tried to remove reliance on the slips of paper. Studies of the new paperless system demonstrated that the new system could not reproduce the awareness and coordination provided by annotating, manipulating, and exchanging the slips of paper. The notion of awareness and awareness support in collaborative systems greatly influence people's ability to work effectively.

For our EMR example, the ostensible purpose of the system is to record information about the patient. However, we found in a previous study that users often were not looking for information about the patient per se, but rather for information about the activities of other health-care workers regarding that patient [46]. The traditional, paper process ensures that clinicians stay aware of each other's activities and priorities through interactions, such as conversations as they review data or place orders at the bedside. These interactions both raise awareness and provide incentives for members of the team to interact in important ways. Without such interactions, it would be difficult for the physician to ascertain which patients are of most concern to the nurse, or for the nurse to know which orders are the most important. In addition, the paper process ensures that patients and clinicians interact. For example, clinicians could become peripherally aware of a patient's anxiety or general health state when they review the patient record at the bedside. Others have observed similar coordinating phenomenon in health-care settings [68,69].

Good software designers could include mechanisms to support awareness and interaction in EMRs, but they first need to understand the necessity of such mechanisms in the context of health-care work. Medical information systems, such as EMRs, are not simply repositories of patient data but, rather, are an integral part of the collaboration among health-care workers. EMRs provide not only valuable patient-care information but also keep health-care workers informed about each other's activities, allowing them to coordinate their work effectively. However, these mechanisms are not produced solely by the system or 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 be used as a coordinating mechanism.

The political level of analysis also reveals insights regarding the incorporation of awareness mechanisms. HIPAA regulations to increase patient privacy and security now dictate restrictions on mechanisms that we can use to maintain awareness. Previous awareness mechanisms, such as white boards with patients' names, medical conditions, and responsible health-care personnel, can no longer be used in publicly visible locations. Although these same regulations also place limits on EMR use, it could be designed to provide some of that lost sense of awareness. One can think of a virtual white board on which the interns could summarize clinical information on their patients, independent of location. In contrast, the nurse managers could summarize resource utilization information on all the patients for a unit to help with staffing decisions for the upcoming shift. Designers are likely to think of these added features only if they understand both the need for team members to maintain this level of awareness and the details of what information is needed, when, how, and for whom. Explicitly recognizing and accounting for this political perspective is clearly necessary for successful systems.

Based on experience in computer-assisted collaborative work in other domains, the concept of awareness needs to be considered in the design of collaborative medical information systems, such as EMRs. Unfortunately, there are limited studies looking directly at the importance of awareness in the health-care setting. Indirect evidence from the medical errors literature suggests that lack of communication and awareness across the multiple providers in the healthcare setting contributes to medical errors. For example, awareness is an implicit key factor in the IOM report on error, both in its third principle, "Promote Effective Team Functioning," and as the subgoal, "Develop a Working Culture in Which Communication Flows Freely Regardless of Authority Gradient," from principle 5, "Create a Learning Environment" [13]. Thus, the CSCW concept of awareness is both one of the least studied and potentially one of the most important concepts for developers and designers of complex medical information systems.

4. Conclusion

Because medical work involves teams of people working together to care for patients, medical information systems need to support collaboration among these many individuals who have different roles and work incentives. This concept is not new to medical informaticists, and research has led to many successful advances in EMRs and other collaborative medical information systems. However, addressing these complex socio-technical issues still presents unresolved challenges, and we need to cast a wide net for insights on improving our ability to design and deploy successful systems. In particular, there is a growing body of literature from the field of CSCW that discusses these issues but has not been broadly applied to medical informatics. Three main, highly competitive, peer-reviewed conferences focus exclusively on CSCW issues. The Association for Computing Machinery (ACM) sponsors two of these conferences: Computer-Supported Cooperative Work (CSCW) and Groupware (GROUP). In addition, the European Conference on Computer-Supported Cooperative Work (ECSCW) provides a mainly European viewpoint. The annual ACM-sponsored Conference on Human Factors in Computing Systems (CHI) often includes many papers discussing these issues too. Outside of conferences, the Journal of CSCW provides a forum for many publications on this topic.

To provide concrete examples of CSCW ideas, we discussed three popular CSCW principles: accounting for incentive structures, understanding workflow, and incorporating awareness. Using EMR systems as an example, we illustrated how these principles could be useful to improve the next generation of medical information systems. In fact, these principles can be combined to help guide the design of such systems. For example, to design EMR systems with greater incentives for use, one should consider the collaborative and exception-filled nature of clinical work. Because exceptions cause great disruptions in clinical workflow, users would have an incentive to adopt a system that responds appropriately when exceptions arise. Likewise, because collaboration with others is such a central feature of clinical work, systems that are designed to support collaboration explicitly and appropriately will have a built-in incentive for adoption.

The three principles we discussed represent only a partial review of the ideas that can be adapted from the CSCW community. CSCW researchers offer many other potential insights, from methodologies for studying groups and informing system design, to insights on the successes and failures in system adoption. In describing and reviewing a portion of the CSCW field, part of our goal was to help create a synergy between medical informatics and CSCW, resulting in productive teams of CSCW researchers, medical informaticists, health-care providers, patients, and other stakeholders in health care. We hope that these teams will use both the methodologies and findings from our paper and the referenced CSCW resources to study, produce, and deploy quality medical information systems that succeed.

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