B. 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 individualsí actual work activity and the organizational desire for efficiency and standardization.

Developers have applied a number of ways to incorporate collaborative technology into the organizationís 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 usersí 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 ìdepartures of the history of the work case from its prescribed (or normal) flowî [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, in describing the handling of a missing invoice, detailed how exceptions can occur and the methods that the workers used to handle them [62]. Another stream of CSCW research investigates how systems deal with exceptions. Kammer et al. discuss ways that a workflow system can adapt to a range of exceptions [63]. 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: ìAnticipate the unexpectedî [13]. The contrast between standardized workflow and exceptions is also a potential source of tension between an individualís 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 ìroutineî follow-up visit cannot always take 15 minutesó 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.

C. 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 peopleís actions are coordinated. Dourish and Bellotti describe **awareness** as ìthe understanding of the activities of others which provides a context for your own activityî [64]. Bricon-Souf and colleagues 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 [65].

The underpinnings of awareness relate to an individualsí cognitive and pre-cognitive activity. The CSCW community has described this notion through the concepts of ëfocusí and ënimbusí [66]. Focus is the explicit domain of one individualsí 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 personís focus intersects with anotherís 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 individualsí activity, or, alternatively, expanding the nimbus of another individualsí 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 controllersí activity. A redesign of the controllersí 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 peopleís 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 otherís 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 patientís 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 otherís 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 patientsí 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, ìPromote Effective Team Functioningî, and as the subgoal, ìDevelop a Working Culture in Which Communication Flows Freely Regardless of Authority Gradientî, from principle 5, ìCreate a Learning Environmentî [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.

IV. 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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