Improving Safety through the Cognitive Design of the Collaborative Computer–Based Patient Record

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Abstract
Physical information objects such as paper–based patient records, laboratory forms, and patient identification cards are abundant in clinical settings. In this paper, we discuss some roles these everyday objects have in supporting cognition and collaboration and suggest implications for the design of the computer–based patient record. Based on a study of distributed cognition in an emergency room setting, we show how such artifacts are used in practice to support memory tasks, how they function as triggers of action, and their roles in supporting team communication. It is concluded that to avoid excessive cognitive load on clinicians, it is important to acknowledge the roles everyday workplace objects have for cognition and collaboration in the design of clinical information systems.

INTRODUCTION

Improving safety of medical practices is an important goal in the design of clinical computer systems. This requirement particularly applies to cognitively–demanding and high–tempo undertakings such as work in emergency rooms and in the intensive–care units. For example, in the flow of work clinicians must remember and assess the specific medical condition of many patients. Furthermore, they need to maintain awareness and monitor progress of the overall clinical situation. Technologies that aim to support such demanding workplaces must account for the cognitive workload on the users of the tools [1].

Recent workplace studies have reported on how professionals take advantage of *everyday objects* in different ways to cope with the excessive cognitive load [2,3,4,5]. Artifacts in the material environment such as papers and sticker–notes act as external memories, support attention, and structure perception. These studies suggest that in having these supporting structures, we can reduce the time and memory demands of tasks down resulting in higher *reliability* of actions. Our previous research on medical practices show that clinicians frequently use paper–based records and other pervasive workplace objects to improve cognitive performance and to support teamwork [6].

Today, computers are transforming clinical practice. However, the roles physical objects have in supporting cognitive processes are seldom addressed in the design of the new tools aimed to substitute the old ones [7]. We believe that failing to acknowledge in design the invisible roles the basic workplace objects have in supporting cognition and collaboration threatens to introduce medical error and ultimately risk patient safety. For example, one class of cognitive errors that inappropriately designed systems risk to introduce is omissions; not doing something due to problems in memory recall [8].

Few empirical studies have addressed the roles the traditional workplace objects have in clinical practice. Notable exceptions are the work of Berg [9], Heath et. al. [10], and Lundberg et. al. [11] . In addition, characteristic of many of these studies is that they rarely draw any design considerations, which make it difficult for system developers to take advantage of the results. Our research aims to understand the rich multifaceted roles the physical workplace objects have in clinical work to appropriately approach the design of computer systems.

The goal of this paper is twofold. First, based on an empirical workplace study, it aims to exemplify how clinicians offload cognitive tasks to the environment. Second, drawing from the study, the paper provides a set of design suggestions aimed at developers of clinical computer systems, in particular, developers of the secure computer–based patient record (CPR) [12] and data collection systems.

BACKGROUND

Systemic error and supporting structures
Recent research has recognized the role of the *operational context* in which practitioners work as an influencing factor in a large number of organizational accidents [13, 14]. From this *systems perspective*, human performance is conditioned by the requirements of the monitored process and the resources and constraints that are part of the working environment [15]. These contexts include both the physical and cognitive resources available to practitioners as they deal with work [7].

Part of these systems (i.e., the operational context consisting of people and their tools) are physical workplace objects like paper–based patient, laboratory forms, rolodexes, shelves and sticker–notes; still omnipresent equipment in today's clinics. However, today there is a strong trend to *substitute* these physical objects for the computer medium. Researchers have also stated the vision of the paperless clinic. For example, large efforts are going into the design and development of the computer–based patient record [12]. Essentially, this work aims to approach known practical problems in clinical work such as retrieving the patient record when it is needed.

However, it is not clear how we should go from paper–based to computer–based medical practices, because the paper objects are intertwined and highly coupled in the system of activities. Cook and Woods discussed the *substitution problem* stating that it is not possible to substitute one medium for another without transforming work in fundamental ways [7]. Such "clumsy automation" often interacts with the system in unforeseen ways that create new burdens on practitioners rather than supporting them. Dix argued that without an understanding of what roles the artifacts play in business processes it is easy to redesign the processes and unintentionally loosing some important roles of artifacts [5].

Our workplace studies of cognitive practices have shown that everyday workplace objects are important in supporting cognition and collaboration in clinical work [6]. We have observed that workplace objects like the paper–based medical records, paper–based forms, and sticker–notes are used to support several cognitive processes. Our belief is that a better understanding of how these artifacts are used in supporting clinical cognition and collaboration, enables us to more appropriately approach the design of clinical computer systems like the CPR.

Clinical Cognitive Systems and cognitive tools
Recent developments within cognitive science examine cognition from a *systems perspective*. In this view, individual cognition is determined and influenced by the *social*, *organizational*, and *material* aspects in which the activities take place [3,16,17]. We follow Hutchins' approach to distributed cognition [2] where cognition is seen as processes that emerge among people, and between people and their tools. Thus, we see clinical cognition to be distributed cognitive processes that take place among clinicians and among clinicians and their tools. We call these systems Clinical Cognitive Systems [6].

Fundamental in this approach is that individual cognition is always *aided and structured* by mental and physical tools. A basic example on how physical artifacts support cognition is the written note on a piece of paper. It supports memory tasks of individuals comprising a more robust *memory system* than the individual mind alone [18,19]. In this paper are we interested in how people *place out artifacts in space* to convey meaning [20] and support memory [4]. For example, to track work–in–progress one can place things in space that reflect the sequence in which tasks are to be carried out. Furthermore, from a collaborative work point of view, such physical arrangements of artifacts are important. They can be seen as *coordination mechanisms*; structures used to align collaborative work efforts [21]. For example, in collaborative work setting, actors frequently place out things in the environments for others to act on.

In this regard, artifacts function both as *memory cues* and draws *attention* to tasks to be carried out. In the remainder of this paper, we show how clinicians created such a collaboration mechanism out of already existing paper–based patient records by spatially arranging them on a desk.

METHODS

Workplace study
The empirical study was carried out in an emergency room setting in a 250 bed hospital located in Sweden. We used participatory observation methods, following physicians, nurses, and nurse's aids in day and night shifts. The period of data collection was one–person month. In addition, we tracked the flow of patient records in the system to study how these were used in different ways. In particular, we studied artifact–use and efforts of coordination. In the later phase of the study, we adopted the distributed cognitive perspective and focused on interaction with the patient folders and how they were used to support cognitive and collaborative tasks. Because video recording was prohibited due to confidentiality reasons, we had to rely on observation methods for tracking interaction (i.e., taking fieldnotes).

RESULTS

Arrangement of patient folders
To track work–in–progress, clinicians arranged spatially *patient folders* on a desk. Figure 1 shows the desk and its folders. Each folder contained standard forms for recording drugs administered to patients (used by nurses), forms used by physicians for note taking, and the patient's medical record. In principle, clinicians accumulated each piece of information concerning their patients in the corresponding folder.

The specific position of a folder within the arrangement signified the patient's clinical status, priority, and progress through the different clinical activities. Thus, the two columns represented the sequence of patients to be processed by the team.

The head nurse was responsible for triage. This work was reflected in the right column (i.e., positions 1 to 2). Folders placed at position 1 represented newly arrived patients with a less serious condition. Folders placed in position 2 denoted patients that needed urgent attention by a physician. After physicians had examined a patient, they placed the corresponding folder in position 3. Placing the folder in this position indicated to nurses that additional actions was needed on their part. Subsequently, when information had arrived, such as a laboratory result, nurses placed that document clearly visible in the folder for the physicians to see and placed the folder at position 4 to hand over the task to physicians.
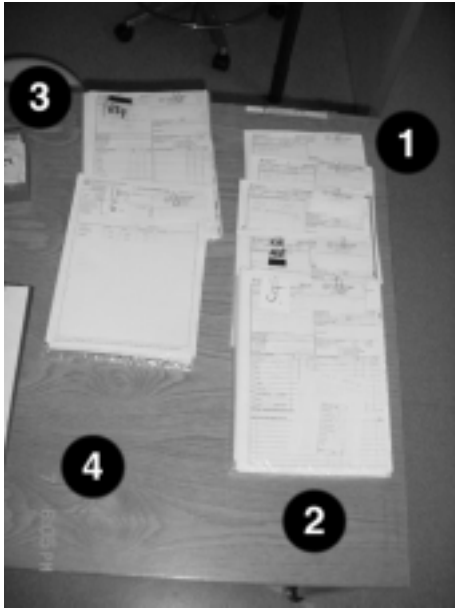
FIGURE 1. The spatial arrangement of patient folders on the desk represents the current clinical situation.

Highlighting strategies that direct attention
Clinicians worked intensely to maintain the spatial arrangement keeping it updated. In addition, nurses *sorted* the papers in the folders so that the most important information was directly visible to physicians. In a similar approach, nurses frequently placed sticker–notes visible to *highlight* important information to team members.

Cognitive functions
From a cognitive standpoint, the arrangement of folders on the desk provided several important functions. First, the entire arrangement is a *shared public display* representing the *current clinical situation* for the team (i.e., a structure that always displayed the current problem state). In addition, it is clearly a coordination mechanism, because it supported the alignment of task carried out by the team.

The two columns represented the sequence of patients to be processed by the team. Because information was updated and represented explicitly, there was no need, for example, to remember that sequence because it was already represented in the arrangement. In addition, such displays provide a good overview of the situation. Simply by *seeing* it, clinicians could estimate the amount of patients they were currently processing and set in the appropriate resources.

Clinicians communication through the placement of folders to handover tasks is imperative in collaborative work. Such *feedback systems* are important as cues to initiate action, and to know that someone has the responsibility for the task.

Furthermore, clinicians sorting of papers in the folders and their use of sticker–notes to highlight information were important. These approaches cued out the unimportant task and directed physicians to the more important task [c.f., 4, 22]. However, a constant rearranging and maintenance of the physical arrangement was necessary to maintain an awareness of the overall clinical situation.

Design implications
Overall, it is difficult to provide general design suggestions from a specific workplace study that can be transferred adequately to other settings. The following design suggestions are basic attempts to maintain some of the roles of paper in a computer application. However, although basic, we believe that these approaches are important and powerful from a cognitive and collaborative standpoint. Unfortunately, we seldom see them in practical computer applications.

- *View the CPR as a collaborative tool*

In this study, several professions used the patient folders for several purposes. Clinicians placed all available information about a patient in the corresponding folder; both temporary data–collection forms, the patient record, and additional notes. Having all information on a patient at one place helped physicians to recreate the context on a specific patient. In parallel, clinicians used the folders as collaborative tools to convey a shared meaning and to communicate in the team.

- *Public displays and natural coordination mechanisms*

Clinicians created a public display of the patient folders that represented the current state and supported coordination. We believe it is important to support or replicate these collaborative practices also in the design of the CPR. The goal is to let practitioners create their own *local* representations of their work dynamically as an integrated part of their work.

Naturally, a basic design approach to support these practices is to provide a user interface that allows users to place and arrange the case folders on a desktop. Figure 2 shows an example on how we approached this problem in a groupware system for case management we developed in a related research project [23]. Alternatively, if one develops for mobile devices, one can leave out this desktop arrangement, allowing users to place the mobile device in space to convey meaning and to create representations of their work.

- *Sticker–notes and annotation to support group attentional dynamics*

It was found important to highlight information for team members to maintain *awareness* and *direct attention* to significant information and tasks to be carried out. To support such *group attentional systems*, naturally, it is possible allow users to place sticker–notes on folders and at other places in a system. Other approaches to support practitioners in their efforts to communicate in a team is to allow annotations to be made on forms.
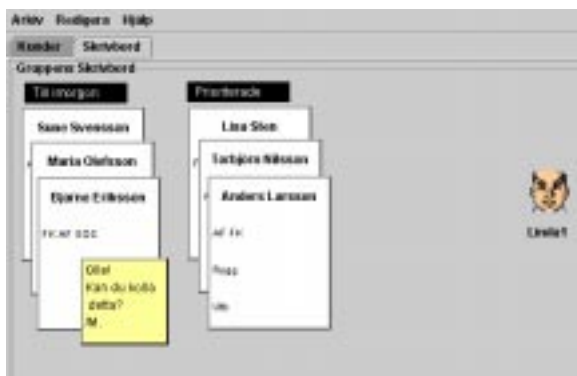
FIGURE 2. Patent folders are placed out on a virtual desktop to replicate the physical desk system.

In the groupware system, we added support for sticker–notes and annotations. Figure 3 shows example on how highlighting in a group can be supported by means of sticker–notes and pen–based annotations.

- *Sorting and visualization as means to maintain awareness and representation state*

We observed how clinicians sorted forms to keep the most relevant information clearly visible and up to date. In the paper–system, they did this by placing forms and notes uppermost in the folders. Unfortunately, most graphical user interface implementations provide little or no support for the dynamic handling and sorting of documents. However, one approach could be to allow users of the systems to drag–and–drop tabs to reflect the relevance of the information in the tab.

DISCUSSION

In order to maintain and improve clinical safety, we described how clinicians used everyday workplace object to support cognition and collaboration by, e.g., placing out the objects on a desk. Highly mobile "low tech" artifacts such as paper sheets and their folders are powerful tools because they let practitioners approach local problem and create their own solutions to problems. In our case, they created a cognitive tool to approach the excessive cognitive load. In this regard, the inabilities of paper objects become a strength. However, practitioners and designers seldom acknowledge how such tools support work because they function well and are invisible in work [24].

We believe that paper–based medical practices will pervade because of its *complementing* properties to the computer medium. These technologies will probably go hand in hand in the future, even thought some properties of paper certainly will be replicated in many mobile devices. Thus, the paperless clinic may be an unfortunate vision which misdirects designers of clinical computer systems.
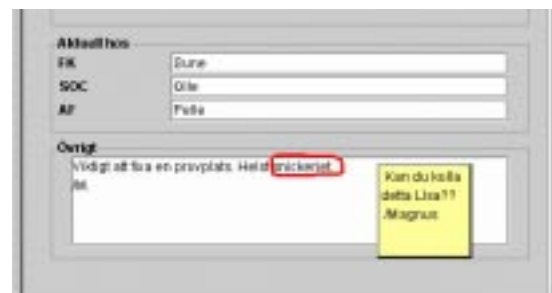

FIGURE 3. Two basic approaches to support memory and direct attention in a collaborative computer-based patient record.

Serious approaches to the design of clinical computer systems must acknowledge that technologies have different properties, and that the appropriate approach is the *integration* of these technologies into a functional whole.

Naturally, there are problems with paper that are advantageous to approach. For example, paper objects do provide limited memory aid supporting data collection such as pop–down menus with predefined values. Designing for mobile devices is promising in imitating papers' properties and to improve data collection. However, designing for mobile devices still requires that one take into account the cognitive and collaborative functions of paper. For example, we believe it is important to provide shared public displays that represent patients to process for the team.

Recent developments within Ubiquitous and Pervasive Computing seem promising for future design of the CPR, because they also could take the physicality of clinical practice into consideration. In addition, technologies such as electronic paper are interesting. Nonetheless, the overall goal should be to develop tools that combine the best properties of paper and computer to maintain the important cognitive functions in the operational physical systems.

CONCLUSION

We have analyzed collaborative work in an emergency room from the standpoint of distributed cognition. The study aimed at proposing design suggestions from the study to direct the design of CPRs and data collection systems. We found that clinicians used everyday workplace objects, such as the paper–based patient record, laboratory forms, and notes in different ways to support cognition and collaboration in the team. These physical objects were spatially arranged by clinicians to create coordination mechanisms to support collaboration, they triggered action, and were used to support memory tasks. Furthermore, they were used to direct attention to the important tasks. We conclude that it is important to consider how clinicians use everyday objects such as the paper–based patient record to support cognitive and collaborative tasks. Otherwise, we risk safety by introducing new cognitive burdens on the users of the computer systems.

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