Artifacts Use in Safety Critical Information Transfer: A Preliminary Study of the Information Arena

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Highly skilled professionals in mission critical work domains communicate complicated, critical information, frequently under time pressure. For example, sustained operations require shift work, which results in hand-offs of responsibilities and need of information transfers. There is a growing interest to support their communications through advanced information technology. We observed usage of information artifacts in a pediatric intensive care unit to study information transfers to guide the design of support technology. In contrast to published studies, we examined the context of supporting environment that contains rich information sources gathered or tailored for verbal discourses. We called the supporting environment "information arena." Clinicians prepare for their personal information arena as well as the shared information arena (e.g., paper notes, charts, mobile computers). Patterns of artifact uses during discourses revealed several distinct roles of artifacts, as well as constraints on design of such artifacts. For example, artifacts in shared information arena should be easily manageable to support fluid and dynamic conversation flow. We also uncover several potential future roles for information artifacts to support information transfer.

BACKGROUND

Mission critical domains require continuous, high reliability operations in environments that are inherently unpredictable and sensitive to external events and threats. In such domains as disaster response, space missions, air transportation, military operations, industrial processing, financial transactions and hospital care, safety is achieved through layered defenses against major disasters, in particular the collaborative activities of highly skilled workers (Cook, Render, & Woods, 2000; Weick & Roberts, 1993; Shalin, 2005). The safety requirements and complexity of work domains demand elaborate, fast-paced coordination based on a seamless flow of information (Bierly III & Spencer, 1995; Roberts, Stout, & Halpern, 1994; Weick, Sutcliffe, & Obstfeld, 1999). In critical environments such as hospitals, poor information transfer across teams and specialties can lead to a range of adverse events (Donchin et al., 1995; Leape et al., 1995).

While information transfer largely occurs in physical environments shaped by tangible artifacts to support collaborative work (Xiao, 2005), the artifacts are often poorly understood. Although current computer supported cooperative work (CSCW) focuses on computer-mediated work, in safety critical domains, computers are not always the medium for work yet hold very significant roles for information transfer. In the medical domain for example, very few studies have investigated the artifacts used during medical rounds and the work environment in which medical rounds take place, (Gurses & Xiao, 2006). Therefore, we extend the distributed cognition approach (Gurses et al., 2006) to studying the role and use of artifacts for improving communication and collaborative work. This approach emphasizes the need for studying the nature and characteristics of collaborative work in detail (e.g., artifacts, the physical work environment) to understand their impact on verbal discourses.

This paper describes a preliminary descriptive study of the physical work environment in which information transfer occurs and how the environment supports multidisciplinary rounds (MDR). MDR allows care providers from different specialties to meet to communicate, coordinate patient care, make joint decisions, and manage responsibilities. MDR are critical for the safety (Young et al., 1998; Plantinga et al., 2004; Uhlig, Brown, Nason, Camelio, & Kendall, 2002) and efficiency of care (Curley, Melinek, & Speroff, 1998; Dutton et al., 2003). MDR are an ideal target for studying information transfer because of its increasing use and the increasing deployment of computerized information systems. In contrast to previous studies (Reddy, Pratt, Dourish, & Shabot, 2002), our preliminary study explored the use of artifacts for supporting information transfer to guide exploration of embedded computing technology as part of collaborative systems.

METHOD

The Information Arena

We used a model to represent information transfer occurring in physical settings involving multiple participants (Figure 1). In this model which is based on distributed cognition (Hutchins & Klausen, 1996) there may be any number of participants. The illustration below shows the example of a two person exchange (participants A and B). The goal of information transfer between A and B is denoted by the arc X. V denotes the verbal exchange between participants, S denotes exchange through shared physical artifacts (e.g. shared public display, whiteboard, computer screen), and P denotes information transfer between participants and their personal artifacts (e.g. checking the time on one's watch).

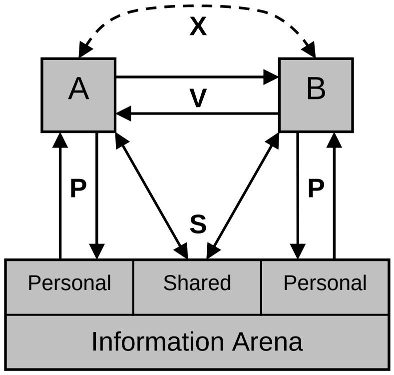

Figure 1 – A framework to understand information transfer in an artifact-rich information arena. [A, B = participants, X = information transfer, V = verbal exchange, S = exchange through shared artifacts, P = exchange with personal artifacts]

Setting

Over a two-month period, morning daily rounds and Friday cardiac specialty rounds were observed. Three data collection methods were used to study artifact use for information transfer during the pediatrics intensive care (PICU) medical rounds; field observation, audio transcription, and semi-structured group interviews. Observations were made on the content of interactions, the types of artifacts used, and time-motion data of events taking place during the round. Interview with nurse practitioners who are key participants in rounds was conducted to gain additional insight into the use of artifacts and their impact on verbal interactions throughout rounds.

Medical rounds are held to achieve four major goals; sharing patient status with medical staff, teaching and education of residents and clinicians, correction and clarification of knowledge, and the negotiating and consensus building of patient treatment goals. The rounding process consists of 3 general segments: patient status presentation, group discussion, and treatment goals development. While these 3 segments follow a general order, their specifics may intertwine depending on the rounding style of the attending physicians (or “attendings”). For example, some attendings prefer each body system to be presented and discussed in turn, while others prefer presentation of all systems followed by comprehensive discussion. We will soon see that artifacts in the information arena may also shape the process of rounds.

We will illustrate the information transfer in two examples. In Figure 2, the nurse practitioner (NP) is hidden from view (hair of NP is indicated by white circle), standing to the left of the computer in front of the cardiac surgeon (leaning on the computer). She is presenting summarized patient data to the group by reading aloud the pre-round form which she prepared earlier in the morning. Several participants can be seen simultaneously transcribing into their personal records. According to the information arena model, this can be represented by a personal exchange from the NP’s pre-round form to the NP, read aloud by NP (A), heard by participant B, and further transcribed into B’s personal notes. In another example, the cardiac surgeon (A) in Figure 3 is assisted by a 3-D radiology scan of the heart to verbally communicate a medical concept. Note that both surgeon and participant B must have shared access to the artifact.

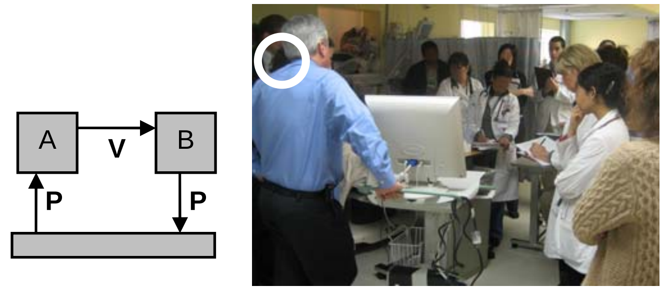

Figure 2 – Nurse practitioner (white circle) hidden from view reads aloud patient data to group of rounding participants

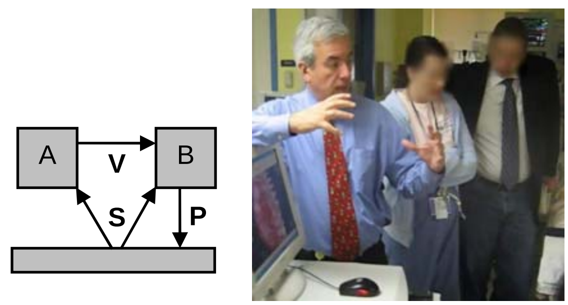

Figure 3 – Surgeon (left) teaches with support of radiology report on the computer (far left) while gesturing with hands

OBSERVATIONS AND RESULTS

Artifacts in the Information Arena

The value of information artifacts in the information arena cannot be overlooked. We observed that artifacts were used by overlapping and non-overlapping groups of individuals at specific periods during the rounds (Table 1). Additionally, these artifacts play very specific roles as contributors or receivers of data in the information transfer. The more commonly used artifacts are described in context of information arena below.

	official progress notes	computer on wheels	pre-round flowsheet	daily goals sheet	unit census printout	bedside patient charts
Attending Physician	■					
Specialty Physician		■				
Resident Physician		■	■			
Nurse Practitioner			■	■	■	
Registered Nurse						■
Medical student		■	■			

Table 1 – This table shows predominant artifact usage by type of participant role during medical rounds

Official progress notes. This form is filled out by the attending physician (attending) leading the rounds as they listen to the case presentation and scanned into the hospital patient record at a later time. It contains physical exam, body systems, and treatment plan details. Attendings were commonly observed to fill out this form while the resident or NP read off patient data from their pre-round flowsheet. Although this artifact is constructed over the course of a round, the ordering of the data fields impacts the order in which data is presented by residents.

Pre-round flowsheet form. Each cardiac patient round begins with verbal presentation of "raw values" by resident or NP assigned to the patient. This data is grouped by body systems (respiratory, cardio-vascular, etc.) and is collected into their personal pre-round from several sources including bedside charts and computerized patient records earlier in the morning. NPs indicated that the format of the pre-round form was heavily influenced by the order of data fields in the attending's official progress note. The pre-round form is arguably the primary contributor of patient "raw data" and standardized the information transfer to promote information sharing, teaching, and decision-making. The form is completed by the assigned resident, medical student or NP prior to the morning rounds and read out to the group when each round begins. The significance of this artifact is twofold; it drives the logical discussion of patient status for teaching and formulating treatment plans, and it is also the consolidation of multiple sources of patient data (computerized and paper format) around the PICU. In other words, the pre-round form has evolved to optimize discussion time and effort needed to retrieve patient data for presentation.

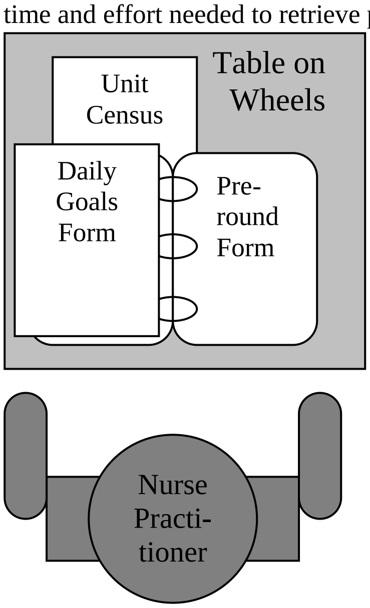

Figure 4 – Layout of nurse practitioner artifacts use

Most notably, the non-presenting NP juggled three artifacts simultaneously during rounds (Figure 4). In addition to a pre-round form to record presented information, they also utilized Unit Census printouts for unit management tasks and completed a Daily Goals sheet which was submitted to the primary care nurse as a tangible reminder of treatment goals for the day.

Computerized artifacts. Second to pre-round forms, computers were most frequently used to share diagnostic radiology reports and to retrieve lab results unavailable during pre-round preparations. Highly visual artifacts were necessary to share concepts difficult to articulate verbally (graphing of oxygen saturation levels over time or 3-D reconstruction of heart for teaching purposes). During walk rounds (group locates at patient bedside), the "computer on wheels" was regarded as a participant of the round, located at the group periphery. The use of the computer was so prevalent, on most rounds a resident or medical student would prepare the patient data on the computer in anticipation for it to be queried. The computerized artifacts exhibited a flexible visual presence in the information arena. Participants stood in front of the computer when it was not needed, and converged around it when it was needed.

Bedside charts and patient monitors. Collecting real-time patient data from the bedside, whether it is heart rate, fluid balance, or medications, was done during rounds if the "latest" data was needed for discussion or if data wasn't available when pre-round forms were being prepared.

Patterns of Information transfer with Support of Artifacts

A representative round is illustrated in Figure 5, which shows the key patterns of information transfer observed and the role of artifacts to support them. This timeline was created from time motion data of transcribed round content in Microsoft Excel, where the row heights of recorded events were scaled according to the duration of that event. A rotation of the table thus produced the figure below. This timeline has been grouped into six segments numbered one through six at the top of the figure. The segments illustrate the primary round segments of data presentation, goals discussion and clarification, and the integration of teaching sessions by the various physicians. Each is highlighted below.

Presentation of Patient Data. In this particular round, we observed three distinct data presentation segments (one, three, and five) where the resident presented patient data by reading out the pre-round form. We also see that data presentation helped to trigger other information transfer patterns. At the end of segment one, the attending contributed to data presentation by referring to the bedside charts and monitors, leading to a discussion with the surgeon on patient goals. At the end of segment three, the attending took a cue from the presented data to conduct a small teaching session. Finally, after segment five, the cardiac surgeon (who led this particular round) ends data presentation with a discussion of the goals.

Discussion of Patient Goals. Going into phase two, the cardiac surgeon requested clarification on the goals of the patient based on the data presented. This led to a high-level conversation on goals between the attending and surgeon where no artifacts were used. In these instances, knowledge was being shared and deliberated upon, which benefits all participants of the round through exposure to the rationale and knowledge negotiation process.

Teaching. In this round, we observed several teaching opportunities by the attending and cardiac surgeon (segments four and six). Teaching often occurred in context of data just presented. In most teaching instances (and in all instances in this example), teaching was done without the use of artifacts. The information transfer during teaching was achieved primarily by verbal channels where high level knowledge related to medical knowledge, policy, and procedures were communicated.

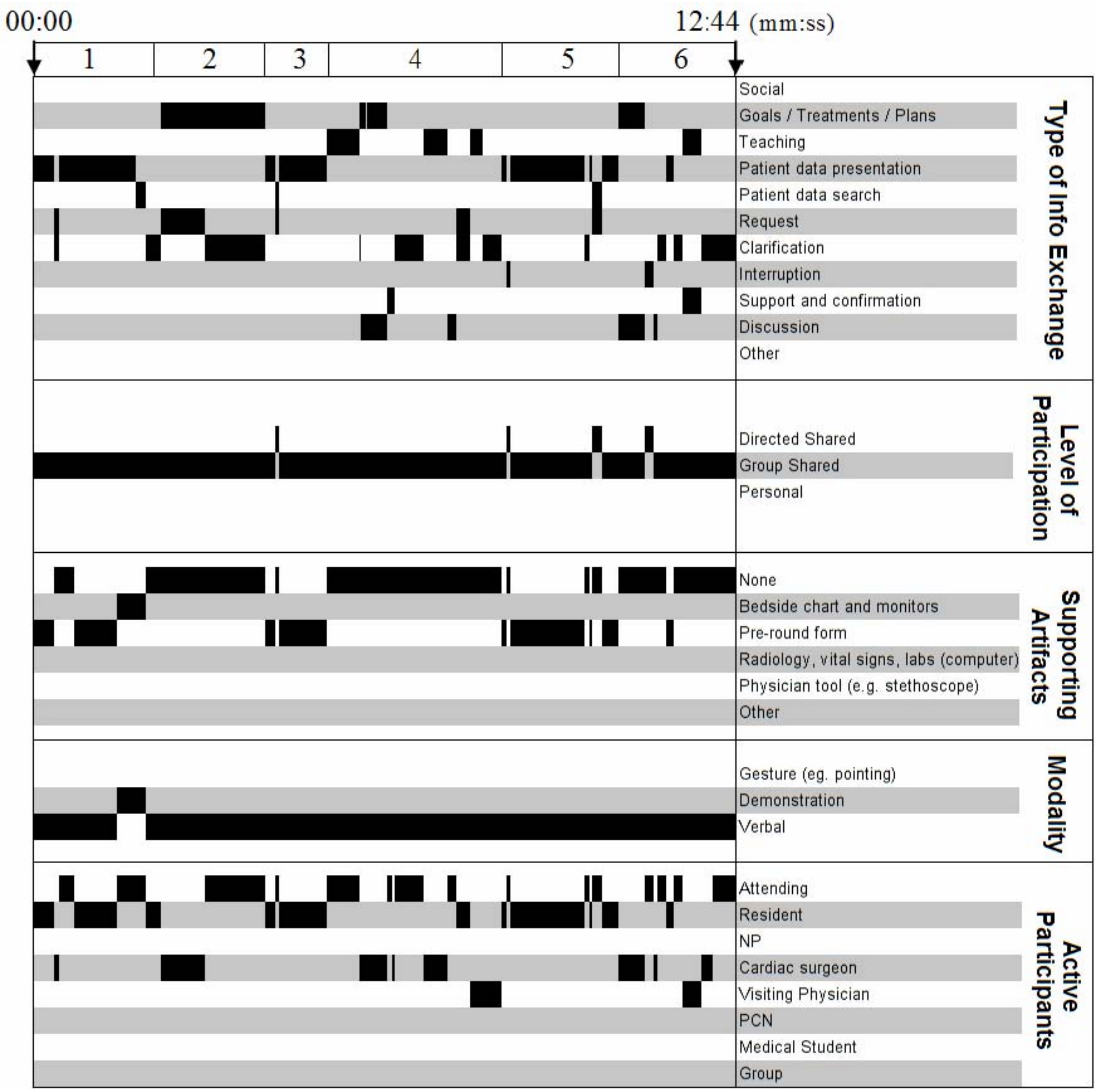

Figure 5 – Timeline of an observed patient round with corresponding coded events. Duration of round was 12 minutes, 44 seconds

DISCUSSION

When the physical environment of information transfer was considered together with verbal discourse, we identified a number of important patterns of artifact use. In all of our observations, artifacts were invariably used. Some were used for sharing, other were used for supporting their own cognition. The overall patterns were fluid and flexible, with the primary focus on unmediated, direct interaction, and several types of artifacts (paper notes, charts, information displayed on computer terminals) were used. The roles of artifacts were primarily for establishing a basis for information transfer and they were consulted most frequently during early stages of information transfer. We did observe, however, seeming unproductive recite of raw values when one person was reading off a list while others tried to integrate the information unaided.

These observations suggest some general guidelines for designing computerized tools to support information transfer. First, due to the high prevalence of verbal-only information transfer, the computerized tools should afford a flexible presence (as opposed to large, overbearing, fixed displays) such that a team could carry out their interactions unmediated and unobstructed when necessary. Second, the tools should be highly predictable and reliable, with minimal “transaction cost” in accessing. Thirdly, the tools should serve as “props” to support exchange of view points. For example, anatomic illustrations and physiology may be displayed to help convey abstract concepts during discussion.

As a methodological implication, we found the concept of information arena very useful in organizing our observation of the roles of artifacts. The concept of information arena may help to describe structures of discourses and main shaping factors of structures, such as preparatory activities, time pressure, and barriers to timely access to information. Future field and experimental research is needed to further develop the conceptual model.

Our observations reaffirmed the taxonomy as reported in Gurses et al (2006b) of patient oriented, process oriented and decision support tools. Patient-centered artifacts provided detailed information pertaining to each individual patient, such as patient medical records, progress notes, and monitoring devices in the unit. Process-oriented tools facilitated unit management (e.g., admissions, possible discharges, bed status, staffing). Process-oriented tools include paper-based rounding list that gives up-to-date summary information for each patient at a glance. The decision support tools were rarely used (e.g., handbooks) but they pointed out a challenging yet potentially highly fruitful direction for designing supporting tools (Sackett & Straus, 1998). This study of artifacts has also revealed similar characteristics inherent in boundary objects (Star, 1989), where artifacts are designed to support consolidation and negotiation of multiple actors working from heterogeneous knowledge spaces and viewpoints.

This research will deepen our understanding of information-transfer in time-critical and safety-critical periods and provide new concepts and directions for the development of computer supported cooperative work tools that capitalize on the power of information technology in artifact rich environments. This will help information and computing technology improve safety and efficiency, and it will contribute to the general understanding of the role of information tools in complex joint cognition activities.

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