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DESIGNING FOR COGNITIVE ARTIFACTS AND ACTIVITIES IN CLINICAL CARE

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ABSTRACT:

This paper concerns the early phase of fundamental research for designing information technology (IT) systems in clinical environments by constructing activity modeling based on ethnographic research in contexts of use. From *interaction design* and *information design* perspectives, this study focuses on understanding the activities of clinical staff in Cardiac Catheterization Laboratory ('Cath Lab'). The Cath Lab activity system includes several cognitive artifacts that help clinicians in their work by organizing complex information. All Cath Lab team members work to achieve shared goals which are basically for patient safety and quality initiatives. Re-designing information systems in clinical care to achieve user-centered design requires a new look at existing interface design in the real-time contexts of activities and actors. This study has been carried out by a team of six graduate design students from February to May 2007 in a major metropolitan research hospital in the United States.

Keywords

Healthcare information systems, cognitive artifacts, interaction design

1. INTRODUCTION

Cardiologists, nurses and technicians require professional knowledge and cooperative performance toward each other and with specialized equipment. They must enter various data into IT reporting tools both during the clinical procedures and afterward. As a collective of *cognitive artifacts*, the Cath Lab system as a whole helps clinicians in their work by organizing complex information. The research aims for knowledge for designing information systems and communication, work and data flows that support Cath Lab team members during the procedure and that subsequently support the circulation of Cath Lab data throughout distributed cardiovascular and hospital information systems (CVIS, HIS) and emerging electronic patient records (EPR) to hospital staff responsible for diverse clinical, research, quality assurance and administrative purposes. Altogether, these highly cognitive distributed processes give rise to demands for design for well-organized information system interfaces. Re-designing clinical information systems to achieve user-centered design requires 'fresh eyes' from outside of medical informatics to re-think established system-centered design paradigms.

Distributed cognition is a useful approach for designing socio-technical aspects of cognition by putting emphasis on the individual in the context of his/her environment and collective activity (Hutchins, 1995). This cognitive theory perspective regards a system as a set of representations and models for the interchange of information between the representations. In addition, artifacts are used to distribute cognition in various ways. *Cognitive artifacts* can either be in the cognitive space of practitioners or external representations available in context, in this study in a clinical environment. Each artifact plays a unique role in communicating and holding information related with status-in-time and processes that need to be performed. This approach enables us to visualize how clinical staff access, interpret and use digital information and other artifacts in their collaborative practices.

This user-centered research aims to support practitioners by addressing difficulties in using IT systems in Cath Labs. The study follows an ethnographic research approach including video recording, field notes documentation, and artifact analysis. The interactions between artifacts and activities that are carried out by clinical team members are evaluated by observing and modeling Cath Lab processes through analysis of Cath Lab data at points of entry and points of use. Our primary research focus concerns relationships between practitioners' activities, their interactions with cognitive and physical artifacts, and interactions between artifacts in the Cath Lab IT system. The goal of the research is to develop design concepts based on modeling the relationships between practitioners, cognitive artifacts and IT system interfaces.

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2. UNDERSTANDING THE NATURE OF CLINICAL CARE

Clinical care consists of complex, time-critical, distributed, regulated, knowledge-dependent and collaborative activities. Therefore, clinical practitioners must cooperate in carrying out clinical care in time-dependent work processes according to their roles. Cardiac catheterization is a procedure for diagnosis and treatment (interventions) for heart conditions by using catheters instead of heart surgery. Cardiac Cath Lab teams perform high-risk complex coronary and vascular cases. A Cath Lab includes fully equipped operation rooms and control rooms where angiography and hemodynamic studies are performed. Typically, one or two cardiologists, two nurses, and a technician comprise the core team in a Cath Lab. In the first two Cath Labs observed in the research, cardiology fellows, nurses-in-training and observers from specialized equipment vendors were also present. Information Technology (IT) systems are essential in healthcare to meet multiple purposes: To help the staff communicate and work efficiently, to assure the safety of patients through critical information-sharing, to meet practice standards and continuously improve quality of service, to enable clinical research, to manage costs of staffing and supplies, and to control timeliness of insurance claims for cost-capture. Well-known benefits attributed to IT systems in healthcare include the value of one-time data entry, faster data retrieval, reduction in time spent searching for patient information, and eventual replacement of paper charts by electronic patient records (Brown, 2005).

Collaboration: Multiple actors with different roles and skill sets
In this study, a Cath Lab team comprises four to six practitioners: the attending cardiologist, a second cardiologist who may be a cardiology fellow, two nurses, and a technician. Before, during and after the procedure they cooperate with each other sharing goals, knowledge and information to provide high quality service for the patient through their collaboration and coordination of their workflow. The work and roles are allotted by individual knowledge and discipline as well as resource availability.

Reliance on IT systems
As the Cath procedure is carried out in combination with other diagnostic tests such as angiography, different kinds of IT systems are used at the same time before, during, and after the procedure (see Figure 1). Due to the complexity of the collective 'IT system' as a family of specialized information and imaging systems and specialized diagnostic and interventional technologies, highly skilled staffs are needed to operate complicated equipment. The practitioners in the Cath Lab rely extensively on IT applications for recording and graphically displaying vital signs and lab results of patients, measuring hemodynamic data during the Cath procedure, reviewing electrocardiograms and arrhythmia monitoring, measuring

echocardiograms, and sophisticated digital image processing and storage of a wide range of diagnostic images of the heart.
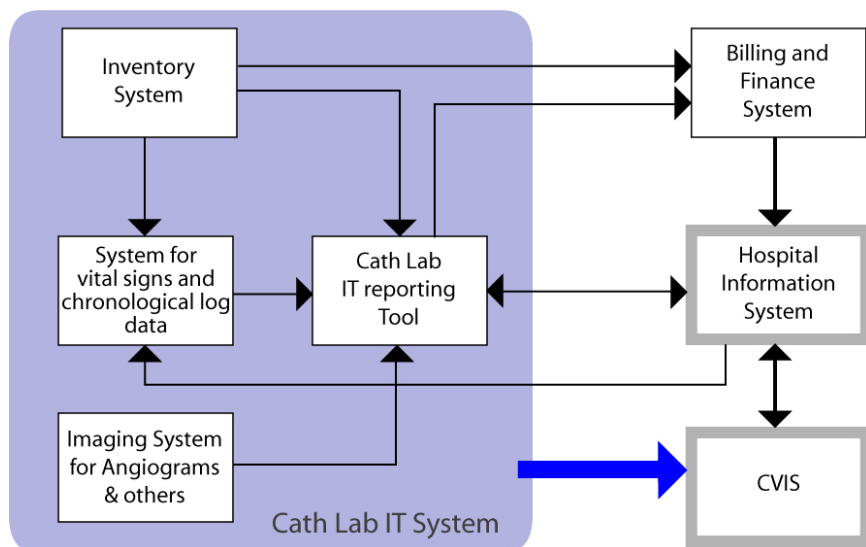

Figure1. Cath Lab IT System

Time demands

The Cath procedure should be performed in a timely manner following the appropriate process. Timely action and timing are directly related to the patient safety. Providing appropriate treatment is also correlated with the productivity of the Cath Lab, increasing benefit to the hospital.

Context dependencies and interdependencies

By the difficulties or complexity of the procedure or patient's condition or anatomical difference, the procedure will be different case by case. Suchman highlighted the view that every action is determined by their material and social circumstances. The basic premise of *situated action* is that "That what traditional behavioral sciences take to be cognitive phenomena have an essential relationship to a publicly available, collaborative organized world of artifacts and actions. And that the significance of artifacts and actions and the methods by which their significance is conveyed, have an essential relationship to their particular, concrete circumstances" (Suchman, 1987: 50).

3. RESEARCH APPROACH AND METHODS

3.1. ETHNOGRAPHIC UNDERSTANDINGS IN DESIGN RESEARCH

Ethnography has long been used in social science research studies that seek understandings of the life worlds and activities of social groups and communities from within their contexts rather than by imposition of *a priori* categories or by interpretation from fixed assumptions. In anthropology and sociology traditions of ethnographic research, researchers immerse themselves in the environment of people's lives, often but not always engaging in participant observation in daily routines. Through careful observations over time, environments, people, artifacts and activities are analyzed across many instances of interactions. Ethnographic methods are especially useful for revealing how people work with and interact with artifacts. In these ways, insights from ethnographic research can inspire and trigger the generation of concepts and implications for designers (see Hughes et al., 1995), by showing how breakdowns or malfunctions occur in everyday situations and what people do to repair and work around these or improvise new ways of working. Such detailed and grounded understandings provide a basis for insights into how existing social practices are changing that may open onto emergence of new patterns and possibilities for design.

Suchman (1983, 1987, 2007), Wynn (1979, 1991), Blomberg et al. (1993) and others were among the earliest anthropologists in the United States to undertake studies of work, practices and technology that were the object of computer science, systems design and technology design in the late 1970s and 1980s. Suchman (1983) addressed the ways that existing office technologies were designed in comparison to how people actually worked. By observing people doing office work in context, she found big misunderstandings between how people work in real situations as they unfold and how people were made to work with the office technologies that were provided. Suchman proposed that designers should observe the users' actual work practice to create better systems. In *Plans and Situated Actions* (1987), Suchman effectively demonstrated how focusing on the unique details of an actor's particular situation can be greatly beneficial for computer systems and technology design (also see Suchman, 2007). In a discussion of how ethnography was taken up in design, Wasson (2000) points out that ethnography became compelling to designers because it introduced a new way to include "the actors." Through ethnographic research methods, designers can learn how the products they designed are used in reality.

Employing ethnographic methods in interaction design, in this research, in order to have better understanding of the use of IT systems in Cath Labs, we can identify the kinds of elements of an IT system that need to be augmented, reorganized or eliminated. The design of IT reporting systems is crucial to the intricate communication, coordination and collaboration required in critical care environments. The specialized Cath Lab IT reporting tool must be understood as more than 'a system'; it is one of several information systems that collectively comprise the 'Cath Lab IT system' (see Figure1). From the early ethnographic field research, we understand that integration between the parallel and partially integrated

family of information and imaging systems that support Cath Lab teams and clinical and administrative needs for Cath Lab data throughout the hospital that represent one of the challenges that need to be taken into iterative design of effective Cath Lab IT reporting tools considered in their real-time use by cardiologists in Cath Lab teams.

3.1.1. FIELD OBSERVATION AND INFORMAL INTERVIEWS

To understand the context of Cath Lab work and activities, field observations were carried out from February to May 2007 in a major metropolitan research hospital in the United States. Site visits and additional observations were conducted at two additional Cath Labs in two other hospitals. Direct field observation is supported by photographic documentation of the surroundings and the actors-in-action. Video recording documented the interface of the IT reporting tool-in-use during cardiologists' documentation of the Cath Lab procedure report (see 2.1.4).

Two simple frameworks that are often employed in design research were used to guide the observational research and to organize findings from the field research for initial generation of insights from observations: (1) thinking about the journey of different actors' experiences and (2) consistently thinking about activities, contexts, interactions, artifacts and roles of the team members. Observations regarding interactions with cognitive artifacts organized temporally by the journey framework and categorized by the framework are presented in Table 1, section 4. The categories of the framework are defined below.

Activities are goal-oriented sets of actions which practitioners want to accomplish. These include a group's shared goals and policies (in this case, policies of the hospital).

Contexts include the entire set of spaces where Cath procedures take place with focus on the operating room and control room. The holding room was not observed in the initial study.

Interactions are observed between an individual actor in the Cath Lab and other actors and/or artifacts such as IT systems, paper-based records, patient charts, images, specialized equipment, and so on.

Artifacts are regarded as all tools, technologies, systems, and communicative means that practitioners use for achieving their goals during the procedure. In this study the IT system is the central cognitive artifact for our observation and analysis.

Actors are the practitioners that take part in Cath procedures: Cardiologists, cardiology fellows, nurses and technicians are the main actors in this research. The patterns and actions of their work are differentiated by their roles.

3.1.2. UNDERSTANDING CATH LAB CONTEXT

The work area of the Cath Lab is divided into three spaces: the operating room, control room, and holding rooms. The Cath Lab team members perform different roles depending on their activities by environment. Every patient undergoing a procedure in the Cath Lab is evaluated beforehand by a cardiologist who reviews the chart and conducts a brief interview and examination. These activities are performed in the holding room. Meanwhile, the nurses and other staff prepare for the procedure in the operating room and the technician gets ready by entering patient information that needs to go into the reporting system for the chronological log of the procedure in the control room. The operating room must be maintained as sterile by all Cath Lab team members and observers.
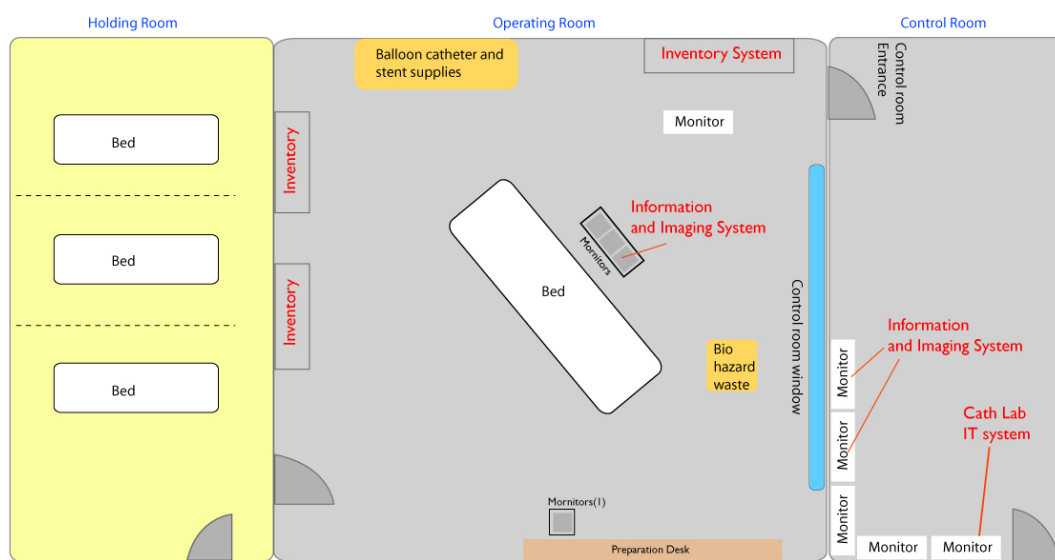

Figure 2. Floor Plan of a Cardiac Cath Lab

3.1.3. JOURNEY: ACTIVITIES AND ACTORS

Actors in the Cath Lab -- cardiologists, nurses, technicians, and the patient -- are located in the environments of holding rooms, operating rooms or control rooms by their roles and according to distribution of activities over time (see Figure3). The journey of key actors and their activities are described below in brief, for a typical (composite) catheterization procedure. The nurses set up the

operating room (OR), transfer the patient into the holding area, and ask the patient about whether he/she has taken any medication before the procedure. Before the procedure, the technician in the control room (CR) enters data into a specialized IT system that the technician will use to monitor the patient's status by vital signs throughout the procedure while he/she creates the real-time chronological account of the procedure. During the procedure the cardiologists perform the diagnostic procedure and interventions. The patient may be awake or asleep during the procedure. Prior to commencement of the procedure, a surgical nurse prepares supplies such as stents, sheaths, and wires from the inventory and administers medicine according to cardiologist's orders. During the procedure and/or intervention, the surgical nurse focuses on providing the catheterization supplies to the cardiologist, while a second nurse moves around with responsibilities to assist with additional supplies, administration of medication during the procedure, relay of information that the cardiologists need, and communication with the technician. The technician records various data throughout the procedure into the IT report system dedicated to the chronological log and maintains communication back and forth with the cardiologists and nurses in the operating room. After performing the procedure, a nurse and the orderlies clean up the operation room and the nurse transfers the patient to a holding room. The technician finalizes the chronological log and then prints the report for the attending cardiologist and cardiology fellow. The cardiology fellow begins entering the procedure report into the specialized Cath Lab reporting tool. The attending cardiologist may or may not be present at the time of the cardiology fellow's Cath procedure documentation.

Completion of the Cath Lab procedure report requires review by the attending cardiologist, as mentor for the fellows, and may require editing prior to the cardiologist's and cardiology fellow's final signature. The procedure report will be reviewed subsequently by a medical coder for justification of all procedures and interventions with the cardiologists' narrative notes regarding the patient's diagnosis or other medical reason for actions taken and for completeness of all elements of information required for billing and cost-capture. The coder's review may require editing for alignment between the narrative notes and structured content elements to meet medical records standards and billing requirements. The Cath Lab procedure report is sent through the hospital information system (HIS) to the physician who referred the patient to the Cath Lab cardiologist.
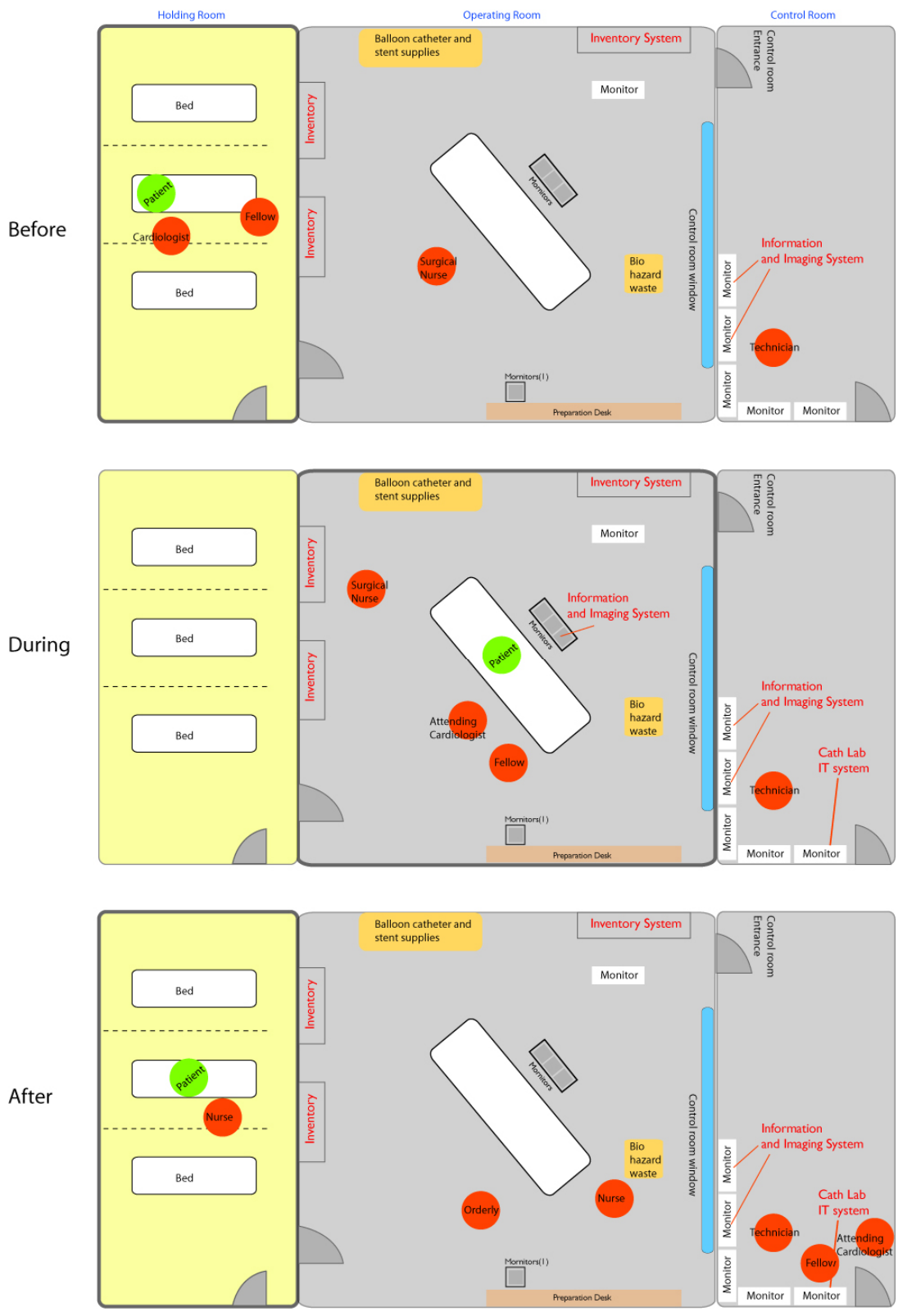
Figure3. The Journey of Cath Lab procedure

3.1.4. VIDEO DOCUMENTATION OF THE IT REPORTING SYSTEM

Video ethnography is used to document people engaging in their practices as they occur. Video documentation enables review by other research group members. Here, we used a video ethnographic approach to learn about detailed patterns of participants' uses of IT-based cognitive artifacts at the point of interactions through the interface. This combines classic ethnographic methods of observation and field notes documentation with digital video capabilities. The Cath Lab IT reporting tools used for documentation of the Cath Lab procedure report in this first study are the Centricity™ and MacLab™ systems of General Electric Healthcare (GE Healthcare). The video-capturing program was installed in the computer used by the cardiologists to create the Cath Lab procedure report after each diagnostic procedure or intervention. The video shows human-computer interaction with the application keystroke-by-keystroke by recording the on-screen movement of the cursor from within the computer running the applications. For example, the video records the sequential order of reporting, the speed of a cardiologist or technician's documentation work and system response time, as well as any errors or breakdowns occurring in use of the IT tool and actions taken to repair or address these. Ultimately, video clips such as the example shown in Figure 4 will provide a basis for developing scenarios from video ethnographic instances for designing *cognitive walkthrough* and *verbal protocol analysis* research methods that will be introduced in the next phase of the research in autumn 2007. A cognitive walkthrough tool enables design researchers, expert and novice practitioners, and IT developers to see and explicitly reflect upon individual actors' enactment of and commentary on problem-solving processes at each step of interaction with an IT system through the interface, focusing on ease of learning and use and surfacing design issues and opportunities (Preece et al. 2002).
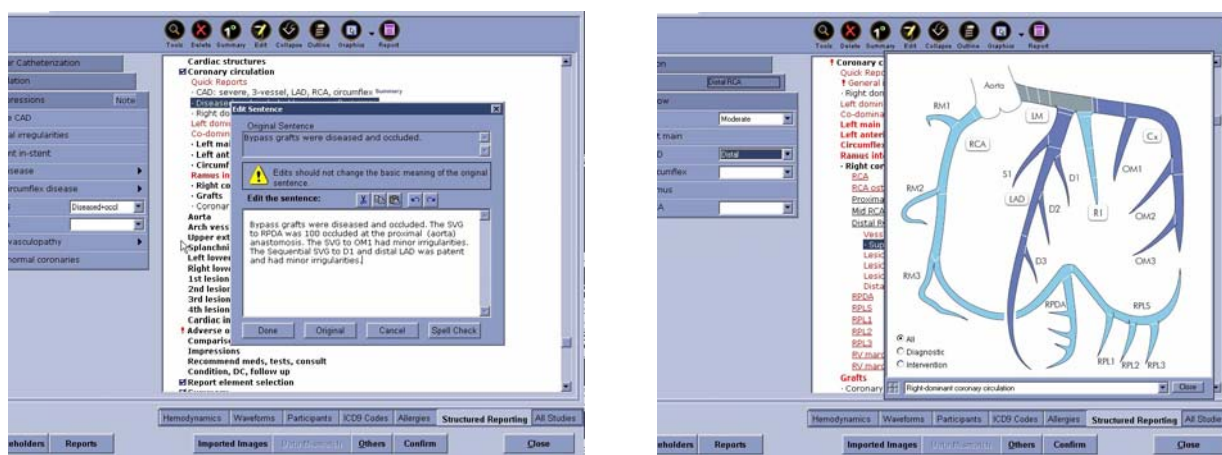

Figure 4. Cath Lab reporting tool – Centricity ™ (GE Healthcare)
Screen shots from video recording while a cardiologist documents a Cath Lab procedure, in this case in Centricity™, GE Healthcare.

4. DISTRIBUTED COGNITION

Distributed cognition offers a way to explain the interactions among people, the artifacts they use, and the environments of use (Hutchins, 1995). This is the shared awareness of a group's goals, activities, and artifacts. In the body of concepts of distributed cognition, the concern with *interaction* is central rather than studying an individual's activity or an artifact *per se*. The main goal of this approach is to understand interactions and describe how information is shared and articulated among people and between people and artifacts.

The IT system in the Cath Lab as a whole helps clinicians collaborate by organizing complex information. Here, in Cath Lab contexts, we are concerned with how information is transformed and represented in its circulation and how information-sharing occurs amongst the members of Cath Lab teams in-person and in distributed networks of individuals in the hospital who need Cath Lab data. During the Cath procedure, for example, the cardiologist and cardiology fellow concentrate on the information that is represented in the monitor in the operating room, which shows hemodynamic data of the patient and the angiogram of the heart, whereas the technician in the control room concentrates on logging the data chronologically rather than focusing on hemodynamic data and the images of the heart. Constituting this conceptual modeling of Cath Lab activity based on close empirical observation over many instances, it is possible to identity anomalies, problems, breakdowns, and problem-solving processes. In interaction design, distributed cognition is thus a useful method for research oriented toward designing new collaborative technologies (Preece et al., 2002).

4.1.1. INTERACTING WITH COGNITIVE ARTIFACTS

In clinical care environments, cognitive artifacts often take the form of tangible and written materials such as white boards, notebooks and patient charts that are commonly used to distribute memory among participants (Jones and Nemeth, 2005; Nemeth et al., 2005). The first Cath Lab observed is a site for specialized cardiac intervention in a leading research and teaching hospital, in which several of the cardiologists and the information systems manager have also been involved as co-developers of the Cath Lab IT reporting tool. In the Cath Lab, digital artifacts in the IT reporting tool such as the on-screen digital clock, 'macros' and spreadsheets also support participants' individual and collaborative cognitive activities. During a Cath procedure, these cognitive artifacts play important roles in the distributed work that must be accomplished; they are critical for the work. Observations regarding interactions with cognitive

artifacts are organized temporally by the journey framework and categorically by a user-centered observation framework in Table 1: Interacting with Cognitive Artifacts.

The IT reporting tool is the key cognitive artifact that integrates the clinical narrative account by the cardiologists with the heterogeneous data from the other Cath Lab information systems as a whole, including the technician's chronological log, images and alpha-numeric data for the patient's vital signs and condition of his or her heart, and the inventory system. The Cath Lab procedure report not only documents what happened in the procedure but carries that account forward through the distributed network of hospital information systems, for the patient's care by his or her physicians, to convey essential data from the report for billing and insurance reimbursements, ordering of supplies, quality assurance and clinical research.

Although Cath Lab reporting relies on the family of IT systems, we also observed creation and use of handwritten notes, enlargement of the digital clock that floats on the screen, and macros that are created locally beforehand by the technicians for quick entry of data. Macros are employed in order to augment the existing IT systems-as-given that lack necessary functions that Cath Lab team members need in real-time workflow. For instance, prior to the procedure, the cardiology fellow hands the technician a note that has the patient's essential information. In preparation for the procedure, the technician enters this information into the information system in which he will document the chronological log. Because the number of the patient's medical identification (ID) generated in the hospital information system (HIS) cannot be accessed from the Cath Lab IT reporting system, the technician needs to access the HIS beforehand to get the patient ID number and then go into the Cath Lab information system to enter the patient's information. The note from the cardiology fellow to the technician acts as a cognitive artifact to fill in this gap before the procedure and may re-appear during the post-procedure documentation. During the procedure, another example of a locally devised cognitive artifact is the set of 'macros' used by the technicians to quickly document both typical and procedure-specific data for regularly occurring processes of the procedure. The macros contain information about medications, catheters, stents, and wires and so on. Using macros enables the technician to log data promptly following the progression of the procedure as it occurs. The use of macros also reduces the cognitive workload of the technician and thus reduces risk of errors in the chronological log (see Figure 5).

Figure5. Cath Lab information system for vital signs and chronological log – MacLab ™ (GE Healthcare)

The screen shot from MacLab™ (GE Healthcare) shows the interface of the information system that the Cath Lab technician uses to monitor vital signs and document the chronological log.

The technician who controls the IT system during the procedure measures the time by floating the digital clock on the screen at the request of the cardiologist in the operating room. The IT system that shows vital signs and angiography is displayed on an overhead monitor in the operating room for the cardiologists and nurses to continuously see the patient's state. The floating digital clock marks the duration of time that the catheter is inside an artery. When the time is over (when the catheter should not be any longer in the artery), the technician shouts out to inform the cardiologist. The practitioners in the operating room do not generally see multiple imaging systems in the same ways that a technician does in the control room although the technician can display multiple imaging systems for them at their request. After the procedure, the cardiology fellow begins to document the procedure using the IT reporting tool. When the cardiology fellow and attending cardiologist come into the control room for reporting, they bring the handwritten notes they documented about the condition of the patient and any special orders from the attending cardiologist. In this cath lab, the local standard is that the Cath Lab procedure report should be completed on the same day as the procedure while the patient is still in the holding room at the hospital. The report should be finalized and signed the next day. The standard for completion of the Cath Lab procedure report serves two main purposes. The cardiology fellow's notes serve as cognitive artifacts to support memory for the primary clinical need for complete and accurate information. The second purpose for timely Cath Lab reporting is to meet required deadlines for cost-capture of reimbursement to the hospital insurance programs and from the national Medicare/Medicaid programs to the hospital.

	Actors	Before Procedure	During Procedure	After Procedure
Context	Cardiologist	Holding area	Operating room	Control room
	Cardiology Fellow	Control room/Holding area/Operating room	Operating room	Control room or Operating room
	Technician	Control room	Control room	Control room
	Nurse (1 or 2)	Operating room	Operating room	Operating room
Activities	Cardiologist	• Check patient record	• Performs the procedure and interventions	• Speaks with patient on findings • Joins fellow in report generation and/or review • Sends procedure report copy to referring physician
	Cardiology Fellow	• Check patient record	• Performs the procedure and interventions	• Begins data report into system • Sends procedure report copy to referring physician
	Technician	• Enters patient data into the system	• Records chronological log into Cath Lab IT Reporting System • Displays sets for operation room • Control angiograms and other imaging system	• Finalizes data entry, and transfers information to Cath Lab IT reporting system • Prints report copy for cardiologist/cardiology fellow signature of approval • Reviews the Cath Lab procedure report • Enters procedure codes to hospital billing system
	Nurse (1 or 2)	• Set up procedure room • Transfers patient into holding area	• Administers medicine, connects ECG, pulls supplies, unpacks sterilized instruments for attending/fellow, attends to patent's needs, gap-filler	• Conducts initial clean up • Transfers patient to holding room • Signs on Cath Lab procedure report
Interaction w/people	Cardiologist	Cardiology Fellow Nurse	Cardiology Fellow/ Nurse/Patient	Fellow/Technician
	Cardiology Fellow	Cardiologist Nurse	Cardiologist/Nurse/Patient	Cardiologist/Technician
	Technician	Nurse	Nurse/Cardiologist/Cardiology Fellow	Fellow
	Nurse (1 or 2)	Technician/Patient	Technician/Cardiologist/ Cardiology Fellow	Patient
Object w/ IT System	Cardiologist	-	-	Reporting system
	Cardiology Fellow	Reporting system	-	Reporting system
	Technician	Procedural report system	Procedural report system	Procedural report system/ Hospital billing system/ Inventory system, Image system
	Nurse (1 or 2)	-	Inventory system	-

Table1. Interacting with cognitive artifacts: actor journeys in a user-centered socio-technical research framework

5. DESIGNING FOR ACTIVITIES AND IT SYSTEMS IN CLINICAL CARE

From the point of view of interaction design and interface design, the Cath Lab IT system faces critical issues. The family of IT reporting tools, information and imaging systems plays a critically important role in supporting the work of key actors in Cath Labs. There are related challenges for communication and space design as well as design of the IT systems. Throughout this early period of ethnographic observation, all relevant design domains were considered (see Figure 6).

The design of the physical space affects the quality of communication between Cath Lab team members, as their view of each other may be obstructed due to the placement of equipment, the layout of the room, or the architecture of the space. During the Cath procedure, a nurse gives information about the kind of medication or supplies to a technician. If communication is difficult due to a malfunction of the intercom sound system or blockage of visibility between the operating room and the control room, the technician, nurses and cardiologists shout to each other through the dividing glass, use gestures (like a cath lab sign language), or look through the open doorway into the operating room.

Throughout the journey of the procedure or intervention, practitioners need to switch from one information or imaging system to another to accomplish their work. The problem here is that they need to make up for a lack of features and functions in the current design of Cath Lab systems and HIS that could provide transfer of information between two or more systems. Therefore, in order to do their work accurately and safely, Cath Lab practitioners try to fill in these gaps to mitigate errors or mistakes that might otherwise occur often. The cardiologists and technicians also create 'macros' to ease their documentation of procedure reports in the IT reporting tool and the chronological logs in MacLab™. In one instance, reported procedural data were missing after the technician transferred the completed chronological log into the IT reporting tool in which the cardiology fellow had already begun to enter his notes. In another instance, a cardiologist wanted to include many details in a particular procedure report by editing the standard sentences that are generated from pull-down menus in the IT reporting tool. However, the IT reporting tool in its current design does not provide features or functions for personalization or customization to accommodate individual cardiologists with different levels of skill and preferences. The feature of the user interface for editing text is not designed well in the sense that it is confusing in use. If a pull-down menu is changed before the cardiologist saves procedure-specific edited text, the edited text is lost and the system reverts back to the default text of the standard sentence so the cardiologist must enter the detailed data over again.
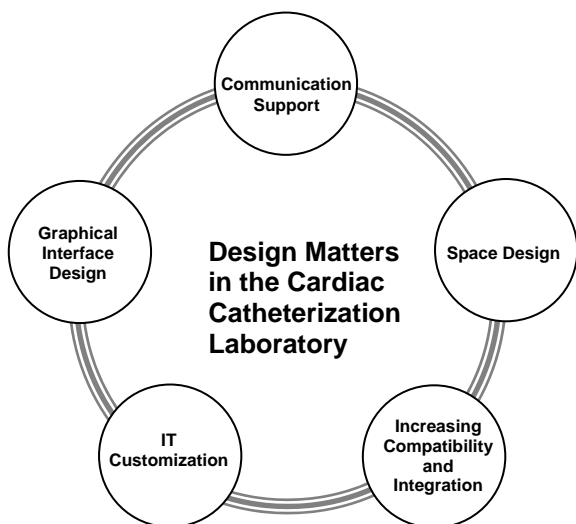
Figure6. Design matters in Cath Labs

Integration as a unified system

Information systems in Cath Labs need to be integrated in order to function as a collective Cath Lab IT system. Imaging systems, procedural reporting systems, paper-based and electronic patient records, hospital information systems, the systems for billing inventory, and more are used in a Cath Lab every day. Design for compatibility and gateways will be required to unify the overall hospital system infrastructure for seamless use in the experience of clinical and administrative staff and circulation of information among those who need vital Cath Lab data.

Design based on Activity Modeling

Current design of IT reporting systems tends to be technology-driven and based on logical models, or driven by administrative purposes and based on enterprise models of various kinds. Actor-centered design of Cath Lab IT systems will benefit from deep understanding of the practices of actors in working context, particularly in their use of cognitive artifacts. Design based on activity modeling can offer guidance to designers from analysis of patterns of activities *in situ* and attention to both moment-to-moment interactions and development of clinical activities in relation to long-term goals of distributed networks of information systems.

Customization and personalization

A Cath procedure is performed by a team comprised of highly skilled healthcare professionals who bring together a variety of expertise, knowledge and individual characteristics. Customizable features

and interface settings need to be designed in the contexts of their in-person and distributed collaborative activities to support diverse needs, skills, and preferences of individual Cath Lab practitioners.

6.1. RESEARCH GOING FORWARD

In this paper, we reported from the earliest phase of design research that aims for robust conceptualization of activity modeling as a basis from which to design for cognitive artifacts and activities in clinical care environments. In the next phases of research, ethnographic inquiry will continue and will be extended to additional Cath Labs, with further investigation of actor interface features and problematic usability of specialized information systems and reporting tools. The video ethnography approach will be expanded to incorporate documentation from within the IT systems with overview documentation of Cath Lab team activities with special attention to uses of cognitive artifacts. Scenarios will be developed from video documentation of instances that are relevant for cardiologists, cardiology fellows, technicians, nurses and Cath Lab and cardiology IS managers. The scenarios will provide grounded research material for the design of a cognitive walkthrough tool to be used with verbal protocol analysis, for cath lab team members to reflectively comment on their experiences at the interface of currently designed IT reporting tools. The cognitive walk-through tool will also support iterative design and development of Cath Lab tools and systems by hospital-based partners in this research and further innovation by Healthcare IT developers.

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