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A model for understanding collaborative information behavior in context: A study of two healthcare teams

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Abstract

Collaborative information behavior is an essential aspect of organizational work; however, we have very limited understanding of this behavior. Most models of information behavior focus on the individual seeker of information. In this paper, we report the results from two empirical studies that investigate aspects of collaborative information behavior in organizational settings. From these studies, we found that collaborative information behavior differs from individual information behavior with respect to how individuals interact with each other, the complexity of the information need, and the role of information technology. There are specific triggers for transitioning from individual to collaborative information behavior, including lack of domain expertise. The information retrieval technologies used affect collaborative information behavior by acting as important supporting mechanisms. From these results and prior work, we develop a model of collaborative information behavior along the axes of participant behavior, situational elements, and contextual triggers. We also present characteristics of collaborative information system including search, chat, and sharing. We discuss implications for the design of collaborative information retrieval systems and directions for future work.

Keywords: Collaborative information behavior model; Collaborative information behavior; Healthcare teams; Healthcare information behavior

1. Introduction

People in organizations conduct much of their work in collaborative settings. However, in these collaborative environments, information behavior is still commonly perceived at the individual level (Sonnenwald & Pierce, 2000). This perception has lead to organizations creating processes and technologies that facilitate and support individual information behavior (IIB) but not collaborative information behavior (CIB). The dearth of knowledge concerning CIB behavior is not limited to organizations; the CIB concept is still relatively new in the information sciences field. Although researchers have discussed the importance of collaboration in organizational work (Ackerman, 2000; Dourish, 2004), few have discussed the role that collaboration plays in information-seeking activities (Reddy & Dourish, 2002).

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Most information models focus on the *individual* information seeker and represent only the single user in the model (Ellis & Haugan, 1997; Kuhlthau, 1991; Wilson, 1981). For instance, Kuhlthau (1988) and Ellis' (1989) information-seeking models highlight the different stages and behaviors of an individual who is seeking information. Wilson states that "Information seeking behavior results from the recognition of some need perceived by the user" (Wilson, 1981, p. 4). Information seeking is conceptualized by many of these models as an intrinsically individual activity (Leckie, Pettigrew, & Sylvain, 1996) for two major reasons: (1) a focus on the conventional pattern of interaction between a single user and technology and (2) the emphasis on individual, not on collaborative work. What researchers and practitioners critically need is a model of CIB to form the basis of investigations of users in collaborative contexts and to create design technology to support these contexts.

A key concern when discussing CIB behavior is its definition. Although there is, to the best of our knowledge, not a universally accepted characterization of CIB, we will use as the starting point for this paper the definition proposed by researchers from the University of Washington's collaborative information retrieval project: "activities that a group or team of people undertakes to identify and resolve a shared information need" (Poltrock, Dumais, Fidel, Bruce, & Pejtersen, 2003, p. 239). The definition has two important concepts that are central to CIB behavior. The first concept is collaboration: people working together to seek information. The second concept is resolving an information need. This includes seeking, retrieving, and using information to solve a problem.

In this paper, we begin to address our lack of understanding by developing a model of CIB behavior. We based this model on findings from two field studies of CIB by patient care teams in two very different hospital settings. One setting was the surgical intensive care unit (SICU) of a large urban teaching hospital (SICU team). The second setting was the emergency department (ED) in a small rural non-teaching hospital (ED team). In both information-intensive environments, information is available from a variety of different resources. The goal of providing all these resources is to allow people to find easily needed information.

However, at the same time, the increasing number of information resources and systems has created a problem that patient-care team members must deal with: *information fragmentation*. Different pieces of the patient information are located in different resources, often for good reasons. For instance, digital images may be in one resource and lab results in another resource. Therefore, team members in both environments have to gather information from different sources to make appropriate patient care decisions; to do this, they must often collaborate. As such, these sites are rich contexts in which to investigate CIB. By studying these two teams, we developed an initial model of CIB that we present in this paper.

The paper is organized as follows: in Section 2, we discuss the literature on prior work in CIB. We present our field studies in Sections 3 and 4. In Section 5, we introduce our model based on prior work and our fieldwork. We discuss the model's applicability to helping us understand CIB. We then discuss the future directions for research in this area in Section 6. We conclude with thoughts on technology development to support CIB and implications of CIB research.

2. Background

Although collaborative work encompasses a wide variety of information-seeking activities (Cicourel, 1990; Hansen & Jarvelin, 2005; Paepcke, 1996), researchers have only recently begun to examine CIB and activities. In this section, we describe different perspectives on CIB. We also discuss why most current information behavior models focus on individual rather than collaborative behavior.

2.1. Conceptual perspective

Researchers are starting to lay a conceptual foundation for understanding CIB behavior. Karamuftuoglu (1998) outlined the beginnings of a theoretical framework for understanding the collaborative nature of information seeking. The core of this framework is that information seeking is just as much about producing new knowledge—a creative and inventive activity—as it is about finding extant information. Karamuftuoglu addresses two knowledge functions of information retrieval (IR) systems. These IR systems should support transferring knowledge and creating new knowledge, where the latter is dependent on social networks and

relations. This ties in with work on social intelligence (Cronin & Davenport, 1993) and with attempts to subsume support for information seeking in the broader area of group support (Hyldegard, 2006; Romano, Roussinov, Nunamaker, & Chen, 1999). Furthermore, conceptual elements such as trust, awareness, and coordination are important to understanding CIB. (c.f. Foster (2006) for an excellent review of these elements). For instance, Hertzum (2002) has shown that trust is an important element in information seeking of engineers.

Researchers are studying the conceptual aspects of CIB across a wide variety of domains. Researchers from the University of Washington have been exploring the collaborative information retrieval (CIR) activities of design teams (Bruce et al., 2003; Fidel et al., 2000; Fidel, Pejtersen, Cleal, & Bruce, 2004; Poltrock et al., 2003). In their studies, the researchers examined how team members actively worked together to identify information needs. They found that team members collaborated when developing information seeking and retrieval strategies to address an information problem within the team. Their research reveled factors such as communication patterns and work activities that influence the need for information and for collaboration during information searching. Hansen and Jarvelin (2005) discuss CIR practices of information workers in patent offices. They found that awareness that workers have of each other's work activities play an important role in the success of the CIR activities. Hansen and Jarvelin (2005, p. 1103) also state that there has been very little empirical work on collaborative information seeking and retrieval.

Studying the information seeking aspects of engineers, Allen (1977) addressed the role of physical distance as a factor which either facilitates or inhibits information seeking. He found that communication among engineers took a dramatic decline if the physical separation was more that 25–30 m. Sonnenwald and Pierce's (2000) study of information behavior in a hierarchical work environment (i.e., a military command and control) highlighted the collaborative nature of the activity. They described information seeking as a dynamic activity in which "individuals must work together to seek, synthesize and disseminate information" (p. 462). They placed collaborative information seeking within the wider context of the group communication process. Sonnenwald and Pierce examined how team members maintained awareness of each other's information activities and how this awareness influenced information sharing with each other.

In educational settings, Hyldegard (2006) looked at collaborative information seeking from the perspective of extending Kuhlthau's Information Search Process model. The author was interested in examining how well the model explained CIB activities in students. Hyldegard found that the model needed to be extended to support collaboration. In a survey of CIB activities among academic researchers, Spence, Reddy, and Hall (2005) found that researchers used a variety of tools ranging from e-mail to video-conferencing to support their collaboration during information-seeking activities.

In the medical domain, Reddy and Dourish (2002) described the role that work rhythms played in team members' collaborative information-seeking practices in an intensive care unit. The rhythms provided team members with information about each other, which allowed them to plan their search for information accordingly. Therefore, when team members understood the rhythms of the unit, they also knew when information was needed. Team members could then collaborate for needed information in a "just-in-time" fashion (not too soon and not too late) based on the rhythms of the unit. In their study of a patient care team, Forsythe, Buchanan, Osheroff, and Miller (1992) examined the information needs of the team. Their focus was on the questions that these members asked to satisfy their needs. In another study of an intensive care team, Gorman et al. (2000) looked at how team members worked together to find and to share needed information. They discussed the importance of tying different sources of information together to answer team members' questions.

Although much of the research on information behavior has been conducted from an information sciences perspective, researchers from the computer-supported cooperative work (CSCW) community have provided some useful insights into collaborative aspects of work. For instance, CSCW researchers have highlighted the importance of people maintaining "awareness" of each other activities to coordinate their work (Dourish & Bellotti, 1992; Symon, Long, & Ellis, 1996). Clearly, this concept of awareness applies to CIB. Similarly, CSCW researchers have also discussed the impact of distance and time on collaboration (Mark, Abrams, & Nassif, 2003; Olson & Olson, 2000). Through these and other studies (Ackerman, 2000), CSCW research has helped inform our understanding of collaborative information behavior.

2.2. Technical perspective

Researchers are also exploring CIB from a technical perspective. In their study aimed at designing interfaces to support CIR activities, Twidale and Nichols (1998) suggested that support tools must provide a visualization of the search process which can be changed and talked about by the users. In addition, they argued that "information retrieval systems should acknowledge the existence of collaboration in the search process" (p. 177). Furthermore, they believe that collaboration can improve the users' learning and understanding of the systems.

Focusing more on communication, Krishnappa (2005) designed a collaborative information-seeking and retrieval prototype—MUSE (Multi-User Search Engine). During the evaluation of the prototype, she found that the collaborative features in MUSE, specifically the chat function, played an important role in enhancing the information seeking and retrieval process for the collaborative work teams. The use of chat led to a better understanding of both the search process and the findings. CSCW researchers have also developed systems that focus on issues that are important for supporting CIB. For instance, BABBLE is a collaborative communication system designed to support awareness amongst users (Bradner, Kellogg, & Erickson, 1999; Erickson & Kellogg, 2000). BABBLE and other similar systems (Ackerman, 2000) can provide important insight for supporting CIB through awareness and coordination features.

To date, no commercial systems exist which fully support CIB. However, a few commercial systems have implemented functionality, which supports some aspects of CIB. For example, IBM[1] offers many products which allow collaborations among colleagues, customers, business partners and suppliers. These products offer presence awareness, instant messaging, and Web conferencing. In addition, the latest Netscape[2] browser allows a team leader to share their Web page with multiple users. Although not specifically focused on CIB, there are several project team environments, such as Groove. Lastly, Enlista's Chat in ContextTM allows users to browse and share information while chatting.

2.3. Focus of current information-seeking models

Most current models are representative of the shift from the system-centered to user-centered perspective in information science research; the user and not the information system is the central component of these models. Still, many researchers who are interested in IIB are also interested in the design of formal IR systems. Belkin and Vickery (1985a), Ellis and Haugan (1997), Ingwersen (1996), Marchionini (1992), and others have studied information-seeking behavior in relationship to IR systems and have developed models based on this interaction. Ellis and Gibbs (1989) describe their interest in information-seeking behavior as a way to "systematically derive recommendations from the analysis of actual information-seeking behavior" (p. 237). Vakkari (1999) calls this stream of research the "interactionistic approach" because it "supposes that information searching is an inherently interactive process between humans and texts intermediated by an IR system" (p. 823).

The most common pattern of user-IR system interaction studied is that of the *single* user interacting with the system typical of the "database query" model of information seeking. The "database query" model conceives of a single user issuing a well-formulated query against an understood data repository in order to retrieve identifiable results (Robertson, 1977). Many studies criticize this query model but not because it focuses on the individual user but rather because it takes an uninformed view of that user. Although some studies of scientists (Paisley, 1968; Pelz & Andrews, 1966) have discussed the importance of group communication in scientific work, by in large, information seeking is still seen as an individual activity.

Belkin, Marchetti, and Cool (1993) and Belkin and Vickery (1985b) argue that users does not usually have clearly defined goals and well-formulated queries in their interactions with an IR tool; instead, they are trying to resolve anomalies in their knowledge when they are seeking information. Ingwersen (1996) suggests that an individual user's cognitive space including such representations as work roles, problems, goals, and tasks should be represented in the IR system. Marchionini's (1995) eight-step process model for information seeking

[1] http://www.lotus.com/lotus/offering2.nsf/wdocs/rttc
[2] http://www.netscape.com

in electronic environments includes information problem identification, problem definition, search system selection, query formulation, search execution, results examination, information extraction, and reflection/reiteration/stop. His model reflects a single user's interaction with an IR system.

So, why do these models center on the individual? Part of the answer is, as discussed in the earlier paragraphs, researchers interested in improving IR technology focus their attention on the single user interaction with technology; these studies comprise a small portion of the larger IIB research field. Another part of the answer is that information seeking is viewed as embedded in individual not collaborative work. Information-seeking models replicate the characteristics of the studies from which they are developed. Therefore, as most information-seeking studies focus on individual work and information seeking, the models also focus primarily on individual information seeking.

A few researchers have started to challenge the focus on IIB in these models. Fidel et al. (2000) point out that most IIB studies have ignored the collaborative nature of information seeking. Sonnenwald (1996) and Sonnenwald and Pierce (2000) make similar claims in their studies of information seeking in the collaborative environments of a design team and the military. In these studies, the researchers found that information seeking is a highly collaborative activity requiring interaction among all members of the teams. However, Sonnenwald and Pierce state that "IIB research has not focused on information behavior in group, or collaborative work" (Sonnenwald & Pierce, 2000, p. 464). Twidale, Nichols, Smith, and Trevor's (1995) Twidale, Nichols, and Paice's (1997, 1995) studies of collaborative browsing also highlight these issues. The researchers argue that browsing using library systems has been incorrectly thought of as an individual activity; it is really a collaborative activity in which different individuals learn from each other's searches and incorporate what they learned in their own search.

Some models have attempted to encompass collaborative aspects of information seeking. Dervin (1992, p. 277) states that the sense-making model can be "applied to entities other than individuals (e.g., collectives)" information-seeking behavior. However, she does not provide any detail on how the model can be applied to "collectives" nor does she define what she means by "collectives". In describing her model of information seeking, Brown (1991) argues that "A general model of information-seeking behavior must allow for various patterns of behavior *among* (our emphasis) individuals as well by the same individual" (p. 9). Yet, her model does not describe any of these patterns; furthermore, it is unclear whether these patterns really reflect collaboration or IIB from another individual (interpersonal source). The lack of detail of the models makes it difficult to evaluate whether the models truly represent collaborative aspects of information-seeking behavior.

2.4. Summary

The literature examining information behavior models, CIB behavior and the information retrieval tools designed to support CIB activities is limited. We know that CIB behavior is composed of a set of complex set of interactions involving people and technology. However, we do not understand what triggers the behavior. Is it the particular context? Is it the nature of the information problem itself? What technologies would best support CIB behaviors given these triggers? How does CIB differ from IIR? These questions motivate our research.

3. Research sites and methods

To investigate CIB activities, we conducted two ethnographic field studies of patient care teams in a SICU of a large urban hospital and in an ED of a small rural hospital. By looking at teams where the members have similar professional training (e.g., physicians, nurses, pharmacists) but are in different settings (e.g., urban vs. rural hospital, teaching vs. non-teaching, SICU vs. ED), we can identify CIB activities that are common to both organizational settings.

3.1. Research methods

Researching CIB in a naturalistic setting can be done only through careful observation and questioning. Multiple people need to be interviewed and observed to discover how they collaborate in their daily

work activities when seeking and using information. Because people often cannot tell a researcher what they actually do in practice (rather than what they are supposed to do), it has been found more useful to both interview and observe study participants. Accordingly, we used standard ethnographic techniques (Miles & Huberman, 1994; Strauss & Corbin, 1990) for observing and interviewing people during our two studies.

For each study, we spent well over 100 hours in the summers of 2002 and 2005 observing the work of the patient care teams in the SICU and ED, respectively. We "shadowed" different team members during their shifts to get an in-depth understanding of their information needs and how they collaborated with each other to find needed information. We also conducted a number of formal and informal interviews focusing on the information-seeking practices of the team members and collected artifacts such as screen shots and organizational policies. The observations and interviews from both studies yielded more than 300 pages of transcribed field notes and interviews for analysis.

Once the field notes and interviews were transcribed, the data was scrutinized. Not only was each interview, field note, and artifact reviewed and analyzed, but these items also were compared (interview-to-interview, interview-to-field notes, interview-to-artifacts, field notes-to-field notes, etc.) to identify similarities and commonalities. The data was analyzed at the paragraph, sentence, and word level to identify categories and their properties from the data. At this point, initial hypotheses about categories and particularly about relationships between categories emerged from the data. We did further analyses to strengthen or dismiss these initial hypotheses. In addition, a deeper review of literature was performed to strengthen or dismiss these hypothesis (Strauss & Corbin, 1990).

3.2. Surgical intensive care unit

The SICU is a 20-bed unit of Urban Hospital[3] (Reddy, Pratt, Dourish, & Shabot, 2002). This unit is one of nine ICUs in the hospital. Each ICU provides rigorous invasive and non-invasive care monitoring for patients requiring special attention due to a critical medical condition. Specifically, the SICU consists of two 10-bed units (7SICU and 8SICU) that treat the most seriously ill surgical patients, including those who have undergone liver transplant, major trauma, or major elective surgery. Although each unit is on a separate floor, the units are identical in size, layout, and equipment, and are equipped with sophisticated equipment, including digital physiological monitors and a fully computerized patient record system. The SICU is an extremely busy with 15 out of 20 beds occupied on a daily basis. Patients usually stay in the unit for 5–6 days and are the focus of a team of health-care workers. In most cases, patients are in such critical condition that any minor change in their condition could have rapid and severe implications. The specialized equipment and staff in the SICU allow even small changes in a patient's condition to be detected early, thus permitting rapid changes in treatment to prevent problems from developing.

3.3. Emergency department

The ED at Rural Hospital[3] is a 25-bed unit that treats people suffering from a wide range of illnesses. The unit is a particularly busy because it is the only major ED in a thirty-mile radius. It deals with everything from children with fevers to severe motor vehicle accident victims. Most days, the ED team sees approximately 90 patients, but often more than 100 patients per day in the winter months.

The unit is staffed 24 hours per day by a team of specially trained healthcare professionals. In order to care for a wide-range of patients, the ED is equipped with sophisticated technical equipment including digital physiological monitors, Web-based, and a computerized patient record system similar to systems used at other hospitals (Reddy, Dourish, & Pratt, 2001). The staff is also equipped with radio pagers and two-way radios. The average length of stay per patient in the unit is three hours and twenty minutes.

[3] A pseudonym.

3.4. SICU and ED: team structure, information resources, and goals

3.4.1. Team structure

The SICU is situated within a large teaching hospital. Therefore, the team consists of three different types of physicians: (1) attending physicians who teach; (2) fellows who are doing one year of extra training in intensive care; and (3) residents who are physicians in training. The team also has nurses and a pharmacist. On the other hand, the ED is not in a teaching hospital. Therefore, the ED team consists of physicians, nurses, and a unit secretary but does not have fellows, residents, or a dedicated pharmacist.

The members on both teams interact with each other on a daily basis. They have to collaborate constantly with each other to provide continuous care for patients in the unit. As one SICU fellow stated, "each person brings something unique to the team". Team members quickly learn who has the knowledge that is needed for a particular question (Reddy et al., 2002). In this respect, it is a rich collaborative environment where multi-domain experts must work together.

3.4.2. Information resources

The information resources in both contexts (i.e., the SICU and the ED) are similar. Both teams have access to the following resources:

- *Digital physiological monitors*: Bedside monitoring devices that measure a patient's physiological data.
- *Digital X-ray workstations*: Contains the latest digital X-ray images of patients in the unit.
- *Electronic patient record (EPR) system*: Contains patient physiological, medical, and other data.
- *Health-care workers*: This includes team members, outside medical consultants, patient's primary physician/team, respiratory therapists, physical therapists, and members of the SICU team.
- *Paper-based medication chart*: Chart of medication orders kept by the patient's room.
- *Paper-based patient record*: Patient chart maintained along with the EPR record. Outside consultants write their notes in this record.
- *Reference books*: Various medical and nursing reference manuals and policy books.
- *Web-based applications*: Contain digital images and data such as culture reports that are not in the EPR.
- *White board*: Contains patient-bed information and on-call information.

Navigating these diverse information environments to locate needed information is a challenging task requiring collaboration amongst the team members. As one SICU resident stated, "Although we have a large number of resources, I sometimes still need help in finding what I need". The resources make more information available than ever before; however, they do not necessarily make it easier to find answers without collaboration amongst team members. Team members use the information resources to meet their work goals in the two units.

3.4.3. Team goals

Although providing appropriate patient care is at the heart of the team's work, each team also had different objectives that guided their daily work. For the SICU team, the critical objectives were bed management and patient stabilization. For the ED team, the objectives were problem identification and surge management.

Within the SICU, the goal of the team is not to cure the patient of his or her problem. Rather, it is to *stabilize* the patient's condition so that the patient can be moved out of the intensive care unit into a non-intensive unit. This is closely tied to the goal of bed management. The SICU only has twenty beds and if those beds are full, almost all non-emergency surgeries are stopped. Clearly, stopping these surgeries has a number of negative consequences for the hospital. Therefore, the team has to manage constantly the flow of the patients in and out of the unit to ensure that enough beds are available at all times.

Within the ED, the team's goals are slightly different. Patients often enter the ED with vague symptoms and complaints. So, unlike in the SICU where the patient's condition is fairly well-know, the ED team has to *identify* the patient's problem. They also, similar to the SICU, have to manage the flow of patients in and out of the unit. However, unlike the SICU where the patient flow is fairly predictable and occurs at predictable times, the patient flow in the ED is very unpredictable. Therefore, the ED team has to manage the *surge* of patients to

ensure that all the patients are provided treatment and that enough resources are available to treat the patients.

These objectives naturally influenced the two teams' information needs as well as their information-seeking activities. In many cases, team members had to collaborate to find needed information to meet their objectives.

4. Field study findings

The work in the SICU and ED is complex, rapid-paced, and collaborative. We identified three major characteristics of CIB in both teams. First, communication was an essential component of CIB. Second, the complexity of the information need drove much of the collaboration during the information-seeking activities. Finally, IR technologies played an important supporting role during CIB activities.

4.1. Communication

Because the work was often rapid-paced in the SICU and ED, communication was essential to finding needed information. In both units, team members were physically co-located and, therefore, much of the interaction was face-to-face. One form of communication took the form people asking questions. In studies examining information needs in the SICU and ED (Reddy et al., 2002; Reddy & Spence, 2006), we found that much of the individual information seeking took the form of simple questions and answers. For instance, a physician asked "what is the protocol for an apnea test?" This was a simple question that was answered by another physician. The focus of communication in IIB was on questions and answers. In contrast, communication in CIB was richer and focused not only on questions and answers but also on tying together different pieces of information to find the answers. This is highlighted in the following vignette from the SICU.

> John, a resident, is checking on some medication that the patient is receiving. He asks the nurse if she knows why the patient is receiving a medication that John is not familiar with. The nurse shrugs her shoulder and tells John to talk to Susan, the pharmacist. Susan who standing close by walks over and says, "I know what that medication does but I am not sure why this patient is getting it". Both John and Susan then start looking for more information about why the patient is getting this medication. Susan is providing John information about the medication and the possible side-effects. During this process, they are continuously exchanging information until they piece together the story. They realize that the patient is getting the medication by mistake. They then stop the medication.

In the vignette, the resident and pharmacist are working together to identify why a patient is taking a particular medication. He turned to the pharmacist because she had the specific domain knowledge about the medication and could provide some insight into why the patient was taking this particular medication. During their CIB activities, they are constantly talking to each other as they are finding pieces of information. This communication was essential for them to solve the information problem. Without communicating with each other, John and Susan would not have known what pieces of information that they still needed to get their answer.

Similarly, in the ED, team members also continuously communicated with each other:

> A patient arrives in the ED complaining of chest pains. ED team members are trying to determine the patient's condition and history. In particular, they want to know whether the patient has had a heart attack before. So, Tim, the cardiologist, asks if anyone knows the patient's history. One of the other physicians, Jane, says that besides chest pains, they don't have any other information. So, Tim and Jane start checking the records and talking to the ambulance crew and family members. During these activities, they are also talking with each other and sharing the information that they found.

In the ED, team members often have to search for information because patients are not able to provide them with information. Tim and Jane had to work together to find out whether the patient has ever previously had a heart attack.

Besides team member communications, the SICU and ED vignettes also highlight an iterative pattern of information seeking–sharing–seeking during CIB activities. This pattern highlights two important aspects

of communication during CIB activities. First, when team members were verbally communicating, turn-taking was involved. One team member would present some information followed by another team member's presenting what s/he found. Second, sharing information is an essential part of CIB activities. The turn-taking and information sharing allowed team members to collect pieces of information that they put together to resolve their information need.

4.2. Complex information needs

Information needs can be highly complex. For instance, deciding on a course of treatment requires not only determining the patient's problem but also determining what may be underlying features of the problem and the best approaches to dealing with the problem. The complexity of the information need often drives CIB activities. If the information need is simple, then it is relatively easy for one team member to find the needed information. However, if the information need is highly complex, team members often split up the tasks, with each member focusing on a different component of the information need. This often happens in the SICU.

> The team members are talking about a patient during morning rounds. They are concerned about the spike in the patient's temperature and are not sure what is causing it. Because there are many different aspects of the problem they want to look at, the team splits up the tasks. Susan, the pharmacist, prints out a medication list to check what the patient is on. John, a resident, checks the culture book to see if the patient has any infections that might be causing this. Gina, a fellow, is checking the patient record system for information and Vasanth, another fellow, is checking the patient to try to get more information. After bringing together all the different pieces of information together, the team decides to change patient's medications.

In this vignette, the information need—identifying the source of a patient's temperature spike—seemed simple at first. However, it was much more complex in practice. Because the team members did not know where to start, they had to try to get as much information as possible to answer the problem. The only way to accomplish that task efficiently was to split the work amongst the team members. The pharmacist checked her medication lists; one physician checked the paper records, and another physician checked the patient. It was only by bringing together all these different pieces of information were they able to solve the problem.

This also occurs in the ED.

> A patient's pain is severe enough that the nurse, Ann, starts a treatment protocol. However, she does not believe that the suggested medication is strong enough for the patient. Before deciding on a pain medication, the doctor, Patricia, wants to know the patient's weight, current pain level rating, symptoms, and pain location. Although Ann has some of this information documented, the pain level rating is not up-to-date. Therefore, another nurse, Peng, volunteers to talk with the patient about the pain rating, while Ann reviews the Emergency Department Flowsheet. Once the needed information is found by Ann and Peng, they share it with each other and Patricia. The gathered information is then used by the team to determine that Demerol should be administered for the pain.

Patricia, Ann, and Peng had to work together to determine which pain medication to administer to the patient. The physician initiated this collaboration because the information need had many components (weight, pain rating, symptoms, and pain location) that he could not easily find by himself. Therefore, the nurses who each knew where to look for these different pieces of information (e.g., asking the patient, checking the flowsheet) were drawn into the search. By working together, they were able to put all the different components of the information needs together to make a decision about how to treat the patient.

An important feature of how team members react to a complex information need is their use of expertise. Each team member brings his or her own particular expertise and perspective to the team. When team members seek information outside their domain of expertise, they can often turn to other team members for help as highlighted in the vignettes. Their differing expertise plays an important role in resolving complex information needs.

4.3. Role of IR technologies

One of the most interesting features of CIB behavior is the role that IR technologies play. In the two units, there are a number of such technologies ranging from the electronic patient record to Web-based systems. Team members used them constantly to find needed information. However, unlike in IIB where interacting with the IR technologies is the last step in the process of the information seeking, it is often the *first* step in a CIB activity as shown in the following vignette from the SICU.

> Tom, one of the SICU fellows, is listening to a resident provide details about a particular patient. As he is listening, Tom hears the resident state that the patient's blood pressure is high. This is puzzling to Tom because he was under the impression that the patient's blood pressure has been normal. So, he logins into the electronic patient record system and retrieves the blood pressure readings for the patient for the last 24 hours. He notices that there was an upward spike in the blood pressure reading in the last three hours. Tom then asks the resident if she knows why this spike occurred. She takes a look at the data and tells him she doesn't know why that is happening. He then tells her that they better find out as soon as possible.

Tom retrieved information from the information system as the first step in solving the information problem. The system contained information that was essential to answer why the patient's blood pressure was high. However, it did not have the *answer* to why the blood pressure was high. The system played an important role in supporting the CIB process but is not the only information sources used by team members.

We also found this in the ED.

> Heng, a nurse, is trying to find a protocol on how to treat seizures. He asks the unit secretary whether there is a seizure protocol on the EPR. The EPR contains a wide variety of protocols but the secretary cannot find a seizure protocol. After searching the EPR, the secretary and Heng start looking for the protocol in the paper records and also talk to other staff in the ED.

Again, in the vignette, the starting point for the CIB activities was the information system. It is important to note that we are not saying that collaborators will only use the IR systems at the beginning of the CIB activities. They may use it throughout the entire process. However, it is only one tool among many that team members use.

4.4. Summary

The results from the field studies highlight a number of important distinctions between individual and collaborative information seeking. First, communication plays different roles in IIB and CIB. In IIB, communication between people is usually limited to questions and answers. Someone asks a question, and someone else provides an answer. During CIB, communication plays a significantly more important role as a mechanism for sharing information and providing context during the search. Second, just as there are triggers for IIB activities, CIB activities also have triggers. We described one, a complex information need. As the complexity of the information need increases, so does the likelihood that collaboration is required to find the needed information. Finally, the role of IR technologies is also different in IIB and CIB. In IIB, people rely on IR technologies as the primary mechanism for searching for information and often the information can be found in the system. However, in CIB, IR technologies play an important but supporting role. Because of the complexity of the information need, people have to look for information in a wide variety of resources.

5. CIB behavior model

Based on our findings from our empirical studies and prior work, we developed a CIB model, which we present below. While based on empirical finding from a specific domain, we have focused on the generic and common aspects that would hold in a variety of contexts, situations, and domains. Therefore, we believe that this CIB model has explanatory properties in a variety of environments.

Our studies focused not the individual but on a team of individuals. Our findings show that there is clearly a relationship between individual and collaborative information seeking, with overlap between the two in their critical characteristics. This relationship is illustrated in Fig. 1.

One can view information environments along two axes:

(1) *Behavior axis*: ranging on a spectrum from information searching to information seeking and use.
(2) *Context axis*: ranging on a spectrum from IIB to CIB.

There an interaction effect between Behavior and Context in terms of either Individual or Collaborative at each of the Behavioral levels (information searching, seeking, or behavior). Each of these interactions is also influenced by characteristics of the environment in terms of interactions, agents and domains.

The behavior axis ranges from individual to collaborative, but intersects searching, seeking, and use. Along the behavior axis, people simultaneously engage in information searching (i.e., tactical maneuvering) and seeking (i.e., strategic maneuvering) in accordance with their modes of information behavior (i.e., philosophy of seeking and use). These levels are best viewed not as distinct but as a spectrum.

Along the context axis, people are engaged as individuals or in some collaborative situation along a spectrum of activity. They are affected by their interactions with other agents, the number of other agents in the environment, and the domain of the information problem or need.

These two factors interplay simultaneously across problems, agents, and interactions. The interplay of the complexity of the problem, the number of agents interacting, and the nature of these interactions initiates a trigger that transforms the context from IIB to CIB. At the individual level, the information problem is relatively simple when compared to the collaborative level. As the information problem becomes more complex and nuanced, the need to collaborate becomes more pronounced. This is especially true in domains where multiple areas of expertise are needed to address the information problem. In these domains, several agents must interact.

Certainly, what is simple, and what is complex is currently a matter of debate. As studies from online searching have shown, there are occurrences of complex searching behavior in IIB (Jansen, 2005; Jansen, Spink, & Saracevic, 2000). Several researchers have examined aspects of what are the factors inherent in an online search (c.f., Jansen & McNeese, 2005; Su, 2003a, 2003b; Yee, 1991). An area of future study in CIB

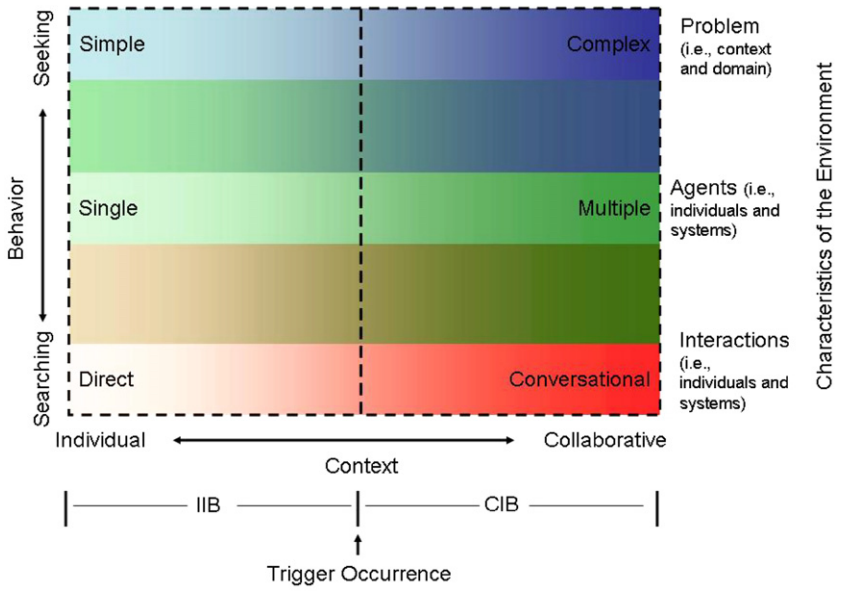

Fig. 1. Individual versus collaborative information behavior.

research would be to 'tease' apart the specific issues of what is simple versus complex searching and what triggers a collaborative search.

We define agents as both people (e.g., users) and information systems. Agents are entities that must interact to address the information problem. At the IIB level, there are usually a small number of agents, typically one person and one or more information systems. As the problem becomes more complex, the numbers of agents involved increases. Typically, in a collaborative setting, each team member usually has different expertise. Furthermore, each system agent may produce a specific type of information content. Team members often know which person or agent has the necessary information. Within CIB activities, each of these agents interacts to address or understand the information problem.

When there is only one user involved, the interactions with the information technology is direct (i.e., submit short query, view results listing, locate relevant information). Clearly, within IIB, there is communication. Asking an expert is a standard method of locating information (Hertzum, 2002; Pinelli, Kennedy, & Barclay, 1993). However, although a person may ask another person a question, there is little communication beyond this direct question–answer mode. Additionally, the exchange between user and system is also communication (c.f., Saracevic's (1996, 1997) strata view of information searching as communication). With increasing problem complexity and more agents (both human and system) involved in the activities, the interactions become complex, less directional, and more conversational in nature. This conversational interaction occurs person-to-person and may also occur person-to-system (e.g., exploratory search).

Therefore, we see that Fig. 1 displays the information environment in two dimensions: behavior and context. Using these dimensions, we can classify any particular information incident. An individual engages in searching in a direct manner, such as fact finding using one system and with the behavior motivated by a simple need. We could normally classify this as IIB. Conversely, in CIB, the searching is conversational, with the individuals engaging the system and each other in a dialogue, with typically more than one system involved, and the information need is complex.

However, there are also information problems at the individual level that are complex and the people–system interactions that are conversations. What separates this type of IIB from a CIB activity? Our analysis points to *triggers* as a key mechanism for initiating a shift from IIB to CIB.

The concept of triggers has been used when discussing individual information behavior. Orton, Marcella, and Baxter (2000) in an observational study of parliament members' information seeking behavior discuss the variety of triggers that start members on an information seeking activity. In this study, we define a trigger as: *an external event within the environment that initiates collaborative information behavior amongst a formal or informal group of people* (Reddy & Spence, in press). A typical trigger is the complexity of the information need; however, other triggers may also occur, such as lack of access to needed information and lack of domain expertise. Table 1 displays a more complete list of triggers for CIB and provides a more granular description of Fig. 1. The triggers described in Table 1 are only a small set that we have identified so far in our research. We believe that there are wide variety of triggers depending on the domain and context.

Information behavior (Table 1) is the totality of human behavior in relation to sources and channels of information, including both active and passive information seeking and information use (Wilson, 2000, p. 49.). It involves the generation, acquisition, use, and communication of information. In this regard, one can view searching, seeking, and behavior as hierarchical, with information behavior the highest level. At a lower level, information seeking is the purposive seeking for information as a consequence of a need to satisfy some goal (Wilson, 2000, p. 49). Information searching is the 'micro-level' of behavior employed by the searcher in interacting with information systems of all kinds (Wilson, 2000, p. 49). In Table 1, we present a brief snippet of the essential elements of each of these levels for both IIB and CIS.

The triggers that cause the shift from IIB to CIB are also presented in Table 1. We derived these triggers from our own field studies and from results reported in prior work discussed in the literature review. These triggers are:

- *Complexity of information need*: Complex information problems initiate much of the CIB activities.
- *Fragmented information resources*: Work environments where information resources reside in multiple and dispersed systems can trigger CIB occurrence.

Table 1
Levels of analysis and corresponding characteristics

Level	IIB	CIB	
	Characteristic	Triggers[a]	Characteristic
Information behavior	Relatively simple problem, with little need to communication, and direct interactions with a single or small number of people and systems	• Complexity of information need • Fragmented information resources • Lack of domain expertise • Lack of immediately accessible information	Relatively complex problem, with need to communication, and direct interactions with a number of people and systems
Information seeking	Use of a single system Relatively little interaction with other people or systems		Use of multiple people and systems Significant interaction with other people and systems
Information searching	Direct interaction mode to address fact finding, homepage finding, question and answer		Conversational interaction to address exploratory search, problem resolving, decision making

[a] The triggers affect all three levels, which initiates a CIB episode.

- *Lack of domain expertise*: When an individual does not have the prerequisite knowledge to answer a question, s/he will turn to people with the necessary knowledge to help him or her find the correct answer.
- *Lack of immediately accessible information*: When information is not easily accessible, people often collaborate to find the information.

6. Future research directions

In this section, we present a research agenda for improving our understanding and support of CIB. We focus on two primary areas: (1) the conceptual understanding of CIB and (2) The design and development of collaborative information retrieval (CIR) systems. The CIB model described in this paper is based on our empirical work in the medical domain. This domain has teams with unique characteristics (e.g., team members have different specialties and training, specific problems that the team must solve). Therefore, an important question to ask is whether or not this model will be relevant for teams without these characteristics. In order to address this question, we plan on conducting a series of studies in different domains such as education and national defense to validate our model. As part of this effort, we plan on further investigating the spectrum of simple versus complex searching and triggers for CIB. We will also investigate concepts such as awareness (Bradner et al., 1999; Erickson & Kellogg, 2000) in CIB activities.

To discuss our future plans for the development of CIR technology, we describe a prototype that we developed called MUSE (Multi-User Search Engine) that focused on supporting communication during the information seeking and retrieval process. Future research will focus on validating MUSE in empirical studies.

6.1. Develop a better conceptual understanding of CIB

Researchers have only begun to study CIB activities. Most of these studies have been in the form of ethnographic field studies focused on organizational teams seeking information. These studies have begun to help us better understand how people collaborate when seeking, retrieving, and using information. However, there is still much work to be done before we truly understand CIB.

First, the limited number of CIB studies has focused on a few domains (e.g., healthcare, education, military, and design) and even these have only touched the surface of these domains. We need to expand CIB studies into other domains such as crises management and explore these domains in greater detail. Furthermore, we need to focus also on collaborators who are geographical dispersed. Most current studies have focused on physically co-located collaborators. The physical co-location does make it easier to study these teams and observe their interactions, but many work teams are geographical dispersed. The geographically dispersed teams may have other situations that trigger CIB activities. They also will carry out these activities in a different manner than in face-to-face situations. To date, we have little understanding of CIB in these teams. Therefore, we need to start examining how CIB occurs over distance.

Second, as previously stated, most CIB studies have been ethnographic in nature. These studies have provided important insight into CIB by providing, for instance, into how people interact during CIB activities. However, we need to consider how we can use quantitative studies to examine CIB. One question that the qualitative studies have not answered is how CIB has improved team performance or information-retrieval practices. Although this is difficult to quantify, developing strong quantitative studies examining CIB would be immensely valuable. Both quantitative and qualitative studies can provide important insight into understanding CIB activities.

Finally, we need to continue to develop models of CIB and refine existing models to encompass collaboration. To do these, we need to continue to expand the number and variety of CIB studies. With this data, we can develop CIB models that can provide us with a greater understanding of CIB activities.

6.2. Develop collaborative information retrieval systems

Although we have some conceptual understanding of CIB behavior, there are very few tools designed to support *explicit* CIB activities. Based on our field studies and prior work, CIR technologies that truly support CIB behavior must have certain essential features:

- *Awareness*: Knowing what other people are doing is an important during CIB activities. Therefore, the system should provide presence awareness information for the group members (e.g., letting the user know if the person she wants to collaborate with is or is not busy (Erickson & Kellogg, 2000)).
- *Chat*: Clearly, one of the most important functions that CIR systems need to support is communication. A chat function allows collaborators to interact with each other and will play an important role in enhancing the information-seeking and retrieval process.
- *Conferencing*: Chatting is typically viewed as a mechanism for communication between two users; the system should provide mechanisms for communication amongst many users. This would be especially useful for members of geographically dispersed groups.
- *Visualization*: Users must have access to a visualization of not only their search process but also of their collaborators. Providing this feature will allow users to discuss each other's searches and provide feedback on how to improve them.

In the following section, we briefly describe a collaborative information retrieval prototype that we have developed based on our studies.

6.3. MUSE: an example of a CIR prototype

To explore the best methods to support CIB, we developed a prototype application, Multi-User Search Engine (MUSE) (Krishnappa, 2005) (Fig. 2), which allows two users to search independently for information but at the same time share that information with each other. During the information retrieval process, they can communicate with each other through a built-in chat feature. We connected MUSE to a biomedical article database, PubMed, and conducted a brief evaluation of the tool.

MUSE is a fully functional prototype developed using JAVA and JAVA Swing. An Apache server was used to enable networking between different computers. MUSE has collaborative features to support communication and sharing of the search results between two users. The front-end interface consists of three distinct features: (1) search (2) share and (3) chat (Fig. 1).

- *Search*: Users type in a keyword to search for information. The search engine retrieves the available results from the database and displays the first twenty results.
- *Chat*: Users can chat with each other in the chat window. MUSE supports text based messaging between two users.
- *Share*: Users can share the search results with each other in the share window. The users first select the results they want to share from the retrieved results in the search window and then click the 'share the search results' button. The results will appear in the share window of the other user.

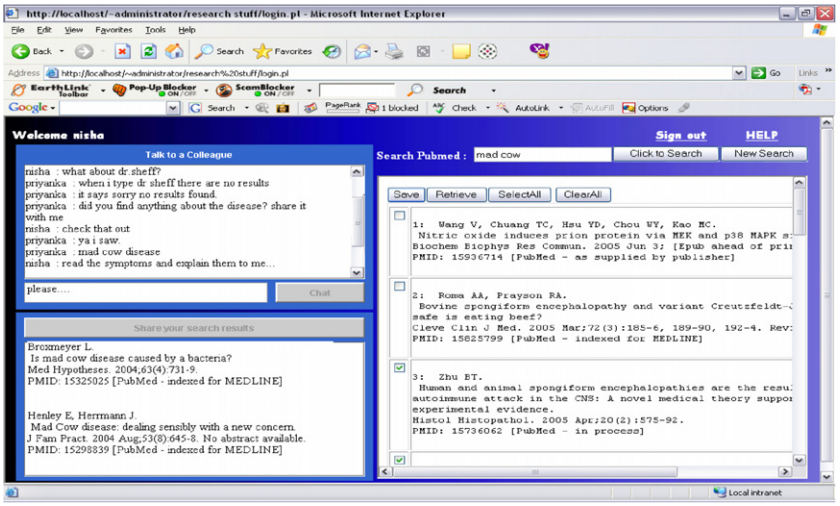

Fig. 2. MUSE interface with three windows: (a) chat, (b) share, and (c) search.

Participants who used MUSE found the integration of chat and share features in a single application very useful. The chat feature highlighted some interesting issues about the role of communication in collaborative information retrieval. For instance, participants often used chat to consult with each other when the search was not going well. The participant would then ask the other team member for information that she could use in her own search. Our preliminary evaluation of MUSE found that the chat feature played a prominent role in supporting the collaboration between team members during their information seeking and retrieval activities. This highlights an interesting area for investigation concerning the role of information technology in the CIB process and environment. Other areas include the incorporation of automated assistance, software agents, and patterns of interaction, which builds off of the research team's prior work (Jansen, 2003; Jansen, 2006; Jansen & Kroner, 2003; Jansen & McNeese, 2005).

6.4. Summary

Features such as chat support collaborative interaction by allowing communication amongst users, sharing of findings and search techniques amongst users, and expanding the different methods those users have for seeking information. Implementing these features will help users successfully complete their search.

7. Conclusions

In everyday work, information seeking is an important activity. Current organizational practices and technologies are designed to support IIB. Much of current research activity has also primarily focused on IIB. However, as a number of researchers have articulated, collaboration and teams are growing in importance in organizations, and we need to understand information behavior in these collaborative contexts. Therefore, we have to shift our attention from focusing on primarily IIB to examining more CIB activities.

Through studies of two different healthcare teams, we described the role of communication in CIB, how the complexity of the information need drove CIB activities, and the supporting role that IR technologies played in CIB activities. Based on our research as well other studies, we developed a model of CIB behavior. This model is based on two dimensions of behavior and context and how they affect the environmental characteristics of interactions, agents, and problems. We illustrate how these two dimensions interplay along the IIB–CIB spectrum. We also isolate the triggers that occur within this interplay as IIB transitions to CIB. Finally, we outline directions for future research in the areas of conceptual understanding of CIB and CIR technologies to support CIB.

We are also in the process of developing a prototype CIR system using commercial off-the-shelf applications (COTS) and in-house developed middleware. We believe that the use of COTS systems is critical to achieve the needed robustness within a timely manner. This prototype CIR system integrates a communication mechanism to facilitate dialogue among group members, to provide automatic searching capabilities to multiple information resources based on the on-going dialogue, and the ability to share the information results in real time. Once fully developed, we aim to initially test our CIR system in a laboratory and then in naturalistic settings.

Our aim is to contribute to a greater understanding of CIB and its effect on group members and organizations and to enhance technology to support the effective and efficient resolution of issues in these critical and complex information environments.

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