UNDERSTANDING TOGETHER: SENSEMAKING IN COLLABORATIVE INFORMATION SEEKING

A Dissertation in
Information Sciences and Technology

by
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Abstract

In recent years researchers have found that people often collaborate during information seeking activities. Collaborative information seeking (CIS) is composed of multiple different activities like seeking, sharing, understanding, and using information together. However, most studies of CIS have focused on how people find and retrieve information collaboratively, while overlooking the important question of how people collaboratively understand the information found by different group members. This thesis focuses on a specific aspect of CIS, namely collaborative sensemaking, which is the question of how people together understand the information found during CIS activities.

The term sensemaking has been used in a variety of disciplines and simply means ‘understanding the meaning of’. Sensemaking is an important aspect of information seeking tasks. However, most of the sensemaking research has been at the individual level and there is little understanding of how sensemaking takes place in collaborative work, specifically collaborative information seeking.

In this thesis, I address two important gaps in current research on sensemaking in CIS activities. First, there is a lack of conceptual understanding about why and how people collaborate to understand the information found during CIS activities. Second, developers of collaborative information retrieval tools have rarely focused on helping users of such tools make sense of the information found.

To address these research gaps I undertook a multi-method research approach in which I conducted two studies in two different CIS domains. The first was an ethnographic study of the CIS activities of healthcare providers working in the emergency department of a large teaching hospital. In this study, I used qualitative methods like interviews, observations,
shadowing, and artifacts collection to examine how groups collaboratively find, understand, and use information in a highly collaborative and information-intensive environment. The second study was conducted in the domain of collaborative Web search where I examined the search and sensemaking behavior of users of collaborative Web search tools. Through lab studies and the development of a tool, CoSense, I examined how collaborative sensemaking can be supported during Web search tasks.

Through these studies, I provide two important contributions to our understanding of sensemaking in CIS activities. First, I expand our conceptual understanding of collaborative sensemaking by highlighting the occasions and characteristics of collaborative sensemaking in CIS activities and by presenting a framework of collaborative sensemaking. Second, I provide insight into the design-features that can support sensemaking in collaborative information retrieval tools and also the challenges in designing such features.

The research presented in this thesis helps us extend our conceptual understanding of collaborative sensemaking and also provides insight into how collaborative sensemaking can be supported in collaborative information retrieval tools.
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Dedication

To

My parents, Manju and Milton K. Paul
1. Introduction

Time: 7:20pm
Location: Emergency Department of the Penn State Hershey Medical Center

It is a busy evening in the emergency department with monitors beeping, alarms blaring, the phones ringing, and the overhead paging system crackling with messages. The nurses are running back and forth between the rooms, weaving around the patients on hallway beds. The doctors are talking in groups while referring to large overhead displays showing the status of patients. The charge nurse is looking at her computer screen, trying to find beds for waiting patients.

A patient is brought in via Emergency Medical Services (EMS) and taken to the charge nurse. The charge nurse assigns a room to the patient. A registration associate, RA, follows the EMS members into the room. After a few minutes RA comes out of the room looking worried. The patient has two different medical record numbers, one that RA derived from the electronic medical record, Eclipsys, and the other provided by the patient. RA pulls up Eclipsys on her computer and looks through the patient’s record to figure out which of these numbers is correct. The EMS member, EM, who brought in the patient, is standing next to RA, waiting for the patient’s paperwork. RA asks EM whether he knows why the patient has two different medical record numbers.

EM: That’s because she went to [another hospital] for a while?

RA (looks through Eclipsys): Ah, I found it. You’re right. It seems she hasn’t come to us in a while. What is the address you picked her up at?

EM tells her where he picked up the patient. RA uses the address information to verify that she now has the correct medical record number. She enters this into Eclipsys, along with a note explaining the discrepancy in medical record numbers.

Research in information seeking has traditionally focused on the individual information seeker. However, in recent years researchers (Hansen & Jarvelin, 2005; Reddy & Spence, 2008; Reddy & Jansen, 2007; Twidale, Nichols, & Paice, 1997) have found that people often collaborate during information seeking tasks in both their personal and professional lives. For instance, family members might collaboratively search the Web to plan a vacation (Morris,
or healthcare providers might collaboratively search for information to diagnose and
treat patients in a hospital (Reddy & Spence, 2008). The vignette above provides an example
of healthcare providers in a busy emergency department (ED) collaborating to answer the
question “what is the patient’s medical record number?” To answer this question, the
registration associate (RA) and the EMS member (EM) must find, synthesize, and understand
various pieces of information about the patient. Furthermore, the information pieces that
must be synthesized to answer the question are distributed among the various actors based on
their organizational roles; RA has access to the patient’s medical record numbers while EM
has the address where he picked up the patient. Complicating the scenario is the ambiguity in
the information available to the care providers, namely, the two different medical record
numbers identifying the patient. Thus, answering the information need requires not only
finding and synthesizing the right pieces of information, but also disambiguating the
information available to create a shared understanding of the situation.

To find an answer to their information need, RA and EM assimilate the information
available to each of them and apply their role-based expertise (i.e., RA knows that a patient
cannot have different medical record numbers while EM has experience with transporting
patients to different hospitals) to understand the information.

As this vignette illustrates, CIS is composed of multiple collaborative activities
including seeking, sharing, understanding, and using information. Understanding these
various activities is important to gain a detailed understanding of CIS behavior. However,
this thesis focuses on a specific aspect of CIS activities – the question of how people working
together can understand the information found during CIS activities.
1.1 Research Motivation

Collaborative information seeking (CIS) has broadly been defined as “activities that a group or team of people undertakes to identify and resolve a shared information need” (Poltrock et al., 2003). While resolving a shared information need can encompass a range of activities, most studies of CIS have focused on how people find and retrieve information collaboratively, while overlooking the important question of how people collaboratively understand the information found by different group members. For instance, in the vignette described above, healthcare providers collaborate to not only find and share information, but also to enhance their understanding of the situation, or their sensemaking (Weick, 1995).

The term sensemaking has been used in a variety of disciplines (Dervin, 2003; Jacobson, 1991; Jensen, 2007; Klein, Moon, & Hoffman, 2006b; Russell et al., 1993; Sarmiento & Stahl, 2006; Schoenfeld, 1992; Weick, 1995) and simply means ‘making sense of’ or ‘understanding the meaning of’. Sensemaking is an important aspect of information seeking tasks (Dervin, Foreman-Wernet, & Lauterbach, 2003; Russell et al., 1993; Savolainen, 1993) and has frequently been modeled as a part of the information seeking process (Pirolli & Card, 2005; Russell et al., 1993). However, most of the models and theories of sensemaking in information seeking have been at the individual level and there is little understanding of how sensemaking takes place in collaborative information seeking.

Though sensemaking has not been explicitly studied as part of CIS activities, studies of CIS have found that sensemaking is an important aspect of such tasks. During CIS tasks people share not only information, but also their understanding of the information. For instance, Harper & Sellen (1995) conducted a study of information workers at the International Monetary Fund and found that social interaction plays an important role in their
information seeking activities and that such social interaction was not as important to the
sharing of *objective* information as it is to the sharing of *interpreted* information. Hansen &
Jarvelin (2005) conducted a study of Swedish patent work and found that in addition to
sharing information, patent engineers shared working notes, annotations, representations of
their information needs, decisions, and subjective opinions. Hertzum (2008) emphasized the
importance of “collaborative grounding” in CIS activities. Collaborative grounding is “the
active construction by actors of a shared understanding that assimilates and reflects available
information” (p. 214). Thus, collaborators assimilate information relevant to the task to
create a shared understanding. However, in spite of the indications of how important
sensemaking is in CIS activities, few studies have examined in depth how collaborative
sensemaking takes place.

With the growing evidence of CIS practices, several tools (Amershi, 2008; Freyne &
Smyth, 2006; Morris & Horvitz, 2007; Pickens et al., 2008) have recently been designed to
support collaborative information retrieval. These tools are focused on helping users
collaboratively search for and retrieve information relevant to shared information needs.
However, researchers building these tools lack models of users’ collaborative information
behavior (Golovchinsky, Pickens, & Back, 2008). Such models can explain how people
collaborating on information seeking tasks alternate between searching for information,
sharing information with others, and making sense of the information found. Sensemaking is
an especially challenging aspect of using collaborative information retrieval tools since users
need to understand the different kinds of information generated during the use of these tools,
such as information relevant to the search task, information about group dynamics, and
information about decisions reached (Paul & Morris, 2009). Designing effective
collaborative information retrieval tools requires understanding users’ collaborative sensemaking behavior.

Thus, there are two important gaps in current research on sensemaking in CIS activities that motivate the research presented in this thesis:

**Research gap 1: Sensemaking as a collaborative activity**

Sensemaking has mostly been viewed as an individual cognitive activity consisting of iteratively finding information based on an initial framework; organizing information into frameworks or representations; and changing representations or frameworks in use to fit new information (Klein et al., 2006b; Russell et al., 1993). As a result, the social and interactive aspects of sensemaking have not been studied in detail. Consequently, there is a lack of understanding of how sensemaking occurs in groups. Furthermore, although sensemaking has implicitly been considered an aspect of information seeking tasks (Dervin, 1998), few studies of information seeking have explicated how sensemaking actually occurs during information seeking tasks. Furthermore, research on collaborative information seeking has not explored sensemaking as part of such activities. Thus, there is a lack of conceptual understanding about why and how people collaborate to understand the information found during information seeking activities.

**Research gap 2: Designing to support collaborative sensemaking**

Designing interfaces to support sensemaking has been a challenging problem in general (Whittaker, 2008), and is an especially difficult problem for the development of information retrieval tools (Gotz, 2007). Supporting sensemaking is especially difficult for collaborative information retrieval tools as users of such tools need to make sense of not only task-related information, but also group dynamics information, awareness
information about what other group members found and their decisions about the task, as well as task state and progress on goals. Most of the research in tool-development for CIS has been in helping users find and retrieve information, with little attention paid to enhancing users’ sensemaking. Hence, few extant tools have explored what kinds of design features can support sensemaking during collaborative information retrieval tasks.

1.1.1 Research Questions

To address the research gaps outlined above, the goals of my research were to gain a conceptual understanding of collaborative sensemaking and to inform the design of technology that can enhance collaborative sensemaking. Thus, I investigated the following research questions about collaborative sensemaking in the context of CIS activities:

- **RQ1:** Why do people collaborate for sensemaking in CIS activities?
- **RQ2:** What are the characteristics of collaborative sensemaking during CIS activities?
- **RQ3:** How can sensemaking be supported in collaborative information retrieval tools?

RQ1 and RQ2 were aimed at gaining a conceptual understanding of why and how collaborative sensemaking takes place in CIS activities. RQ3 provided a technical understanding of how collaborative sensemaking can be supported in collaborative information retrieval tools. Transferring conceptual ideas to technical design often requires selecting a specific domain to design tools for. I chose the domain of collaborative Web search to explore the conceptual ideas that resulted from answering RQ1 and RQ2. Collaborative Web search is a growing area of collaborative information retrieval and several tools (Morris & Horvitz, 2007) have recently been designed for collaborative Web search. However, most of these tools provide little sensemaking support. Hence, I explored RQ3 by
designing and evaluating features to support collaborative sensemaking in collaborative Web search tools.

The rest of this section describes the multi-methodology research approach I took to answer my research questions.

1.2 Research Approach

To answer my research questions, I examined collaborative sensemaking as part of CIS activities in two information seeking domains – healthcare and Web search – via two different but related studies.

**Study 1**: The first study was an ethnographic study of the CIS activities of healthcare providers working in the emergency department (ED) of a large teaching hospital. In this study, I examined how groups collaboratively find, understand, and use information “in the wild”, using interviews, observations, and artifacts collection. This study provided a conceptual understanding of why and how collaborative sensemaking takes place during information seeking activities of groups. The findings from Study 1 led to the conceptualization and design of Study 2.

**Study 2**: Drawing on the findings and design implications resulting from Study 1, the second study was designed to examine sensemaking-enhancing design features in collaborative information retrieval tools. I selected the specific domain of collaborative Web search to implement design ideas from Study 1. Through lab studies and the development of a collaborative sensemaking tool, I examined how people find and understand information during collaborative Web search tasks and the sensemaking challenges faced during such tasks. Based on my findings, and drawing on conceptual
findings and design implications from Study 1, I evaluated various design features for helping Web searchers overcome sensemaking challenges.

Thus, through studies 1 and 2, I examined collaborative sensemaking in the context of CIS from both conceptual and technical perspectives, and using multiple research methods. This multi-method research approach was helpful in providing a holistic understanding of collaborative sensemaking in CIS activities. The following sub-section provide details about the two studies.

1.2.1 Research Design

As described above, I conducted two studies of collaborative sensemaking using different, yet complementary research methods. The first study was an ethnographic study of collaborative sensemaking among healthcare providers working in the ED of a large teaching hospital. The ED is an ideal setting to study collaborative sensemaking within the context of CIS activities. Emergency care providers are constantly faced with novel situations that they need to respond to in a time-critical manner. While healthcare work is inherently collaborative in nature, the time-criticality of situations in the ED make it imperative that seamless and effective collaboration take place between various actors having different expertise and skills. Furthermore, this collaboration often involves finding and making sense of large amounts of information since the ED is a highly information-intensive environment. In taking care of critically ill patients, healthcare providers need to find, understand, and assimilate information from a variety of information sources such as other care providers, auxiliary health services, and paper and electronic information artifacts. They also need to understand various types of information such as the patient’s medical history, details about
the injury or illness, and results of tests ordered. Often patient’s are too ill to provide information about their past history or their current condition, leading to situations where ED care providers must diagnose and treat patients given inadequate information.

Given these characteristics of the ED, care providers with varying experience, skills, and roles often collaborate to find and understand information. I examined healthcare providers’ interactions as they collaboratively found, made sense of, and used information during their work using ethnographic methods such as, observations, interviews, and artifact collection. This study provided insight into the occasions and characteristics of collaborative sensemaking during CIS activities and lays the foundations for a conceptual understanding of sensemaking in collaborative information work.

In the second study, I examined collaborative sensemaking from a technical perspective in the domain of collaborative Web search. With the proliferation of the Web and the rising popularity of social media Web sites, collaborative and social Web search tools are becoming increasingly popular. I conducted a study of sensemaking during collaborative Web search using the tool SearchTogether\(^1\). When group members collaboratively search the Web, they need to constantly make sense of task-related information (such as relevant Web pages), information about group members’ preferences (such as which Web pages are highly recommended) and group dynamics information (such as group members’ roles and skills with respect to the search task). I conducted a formative study to examine how sensemaking takes place during collaborative Web search tasks, using SearchTogether, and what the sensemaking challenges encountered by participants were. Based on findings from the formative study, I designed a new tool, CoSense, to enhance sensemaking in SearchTogether.

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\(^1\) SearchTogether is a collaborative Web search tool developed at Microsoft Research. Chapter 7 provides details on SearchTogether’s features. Additional information about SearchTogether can be found at [http://research.microsoft.com/en-us/um/redmond/projects/searchtogether/](http://research.microsoft.com/en-us/um/redmond/projects/searchtogether/)
CoSense provides different views of the information found during a collaborative Web search task to help address the sensemaking challenges identified in the formative study. Finally, I conducted an evaluation of CoSense to understand how the different features of CoSense enhanced group members’ sensemaking. The evaluation of CoSense provided insights into users’ sensemaking behavior during CIS activities and design features that can enhance sensemaking in collaborative information retrieval tools.

1.3 Dissertation Roadmap

The remainder of this thesis is structured as follows:

Chapter 2 provides a review of two streams of relevant research, research on sensemaking and research on collaborative information seeking. I discuss sensemaking research at both the individual and group levels and point out the gaps in the literature.

Chapters 3, 4, 5 and 6 describe my study of collaborative sensemaking in the emergency department. Chapter 3 provides details about the methodology used for the study. Chapter 4 describes the research site, providing organizational background about the ED and insight into the nature of collaborative information seeking activities in the ED. Chapter 5 describes the findings about why and how collaborative sensemaking occurred during CIS activities of healthcare providers in the ED, and thus focuses on the occasions and characteristics of collaborative sensemaking. Chapter 6 discusses the findings and presents a framework of collaborative sensemaking in CIS activities.

Chapters 7, 8, and 9 describe my study of sensemaking in collaborative Web search. Chapter 7 provides background about extant research in sensemaking in collaborative Web search and then describes a formative study of collaborative sensemaking using the collaborative Web search tool, SearchTogether. Chapter 8 provides the design of a tool
CoSense for enhancing sensemaking in SearchTogether, based on the findings of the formative study. Chap 9 describes the evaluation of CoSense and discusses the findings from the evaluation. It highlights the insights gained about the utility of various design features for supporting sensemaking in collaborative information retrieval tools as well as about the nature of collaborative search and sensemaking behavior of the users of such tools.

Chapter 10 brings together the findings about collaborative sensemaking from both studies using the socio-technical circle as a framework. Finally, in Chapter 11, I summarize the contributions of my research and discuss avenues for future work.
2. Background

This chapter provides an overview of two bodies of literature – sensemaking and collaborative information seeking. The main focus of this chapter is a review of the sensemaking literature which identifies the salient characteristics of sensemaking research and identifies gaps in the literature. I highlight that while sensemaking has been studied in a variety of fields at the individual level, there has been little exploration of sensemaking at the group level. I also provide an overview of the research in CIS since my focus was to examine sensemaking within this context. I highlight that even though making sense of information has been found to be important during CIS activities, most studies have not explicitly focused on this aspect of CIS. Finally, I tie together the sensemaking and CIS literatures to define collaborative sensemaking during CIS activities; this working definition was later used to guide data collection during my ethnographic study of collaborative sensemaking in the ED.

2.1 Sensemaking

In this section I provide an overview of sensemaking literature from various fields, covering the theories and models of individual sensemaking, the few extant empirical studies of collaborative sensemaking, and sensemaking-support tools. From this varied literature, I synthesize a working definition of the term ‘collaborative sensemaking’ that will later be used to guide data collection and analysis for my field study of collaborative sensemaking among healthcare providers.
2.1.1 Sensemaking: An inter-disciplinary view

The term ‘sensemaking’ has been used in various disciplines such as organizational science (Weick, 1995), education and learning sciences (Sarmiento & Stahl, 2006; Schoenfeld, 1992), communications (Dervin et al., 2003), military command and control (Jensen, 2007; Ntuen, Munya, & Trevino, 2006), human-computer interaction (HCI) (Russell et al., 1993), intelligent systems (Jacobson, 1991; Savolainen, 1993), and information systems (Bansler & Havn, 2006; Griffith, 1999). Simply stated, sensemaking is finding meaning in a situation. At the individual level, sensemaking is concerned with how a person understands and reacts to a particular situation in a given context. One of the prominent methodologies in this thread of research is Dervin’s (2003)“Sense-making”. Sense-making occurs when a person, embedded in a particular context and moving through time-space, experiences a ‘gap’ in reality. The person bridges this gap by constructing bridges consisting of ideas, thoughts, emotions, feelings, and memories.

In the field of HCI, sensemaking has focused on how users understand large, complex information spaces or large document collections (Russell et al., 1993). When interacting with large amounts of information, people create representations such as maps, diagrams, and tables to organize information in order to make sense of it. Therefore, sensemaking is the process of encoding information into external representations to answer complex, task-specific questions. In the education literature, sensemaking has been explored in the context of how it applies to teaching and learning (Duffy, 1995), specifically in mathematical problem-solving in classrooms (Schoenfeld, 1992) and in online communities (Stahl, 2006). In this context, sensemaking refers to how students ascribe and derive meanings about their
Weick (1995) has explored sensemaking in the context of organizations. For Weick, sensemaking is an effort to create order when the current state of the world is perceived as different from the expected state. People organize their world to make sense of ambiguous situations they encounter and enact this sense back into the world to make that world more orderly (Weick & Sutcliffe, 2005). Drawing mostly on Weick’s (1995) perspective, studies in the information systems literature have focused on how adoption of new technologies is affected by how features of these new technologies trigger sensemaking among users (Griffith, 1999). In the military command and control literature sensemaking is defined as being aware of, and understanding, situational elements associated with executing a mission (Jensen, 2007).

Given these various perspectives, the term ‘sensemaking’ has become an umbrella term for research conducted in a variety of disciplines, and at different levels of analysis. However, there are three salient characteristics of the sensemaking literature across these various disciplines. First, the common thread in the various definitions of sensemaking is that sensemaking is about meaning generation and understanding. It is a cognitive activity that is part of, but distinct from, other cognitive activities like decision-making, problem-solving, comprehension, creativity, mental modeling, and awareness (Klein, Moon, & Hoffman, 2006a). Second, sensemaking is an important aspect of information seeking tasks. Most of the models and theories of sensemaking have described it in the context of finding, understanding, and using information. Similarly, most sensemaking-support tools have been designed for information seeking tasks. Third, most of the research in sensemaking has been
at the *individual* level. While some studies have tried to explore how sensemaking takes place in collaborative work, there is still a lack of understanding of the nature and characteristics of collaborative sensemaking. The rest of this chapter highlights these salient characteristics of the sensemaking literature.

### 2.1.2 Individual sensemaking

Most of the sensemaking literature has focused on the individual sensemaker. In this section I summarize the prominent theories, models, and tools of individual sensemaking and conclude by highlighting the important features of the research on individual sensemaking.

#### 2.1.2.1 Dervin’s Sense-Making methodology

One of the prominent theories of individual sensemaking is Dervin et al.’s (2003) Sense-Making Methodology. Sense-making is concerned with how a person understands and reacts to a situation in a given context. This methodology has been applied to studies in electronic communication, health communication, information seeking, pedagogy, audience studies, and telecommunication policy (Dervin, 2006). Sense-making occurs when a person, embedded in a particular context and moving through time-space, experiences a ‘gap’ in reality (Figure 1). The person facing this gap constructs bridges consisting of ideas, thoughts, emotions, feelings, and memories. The primitives – time, space, gap, bridge, movement, power, constancy, and change – are drawn into a metaphor (Figure - 1), that has been used to guide observations of information seeking and use.

Apart from developing the metaphor, Dervin (1998) has provided a guide to sensemaking research methods, particularly methods for interviewing participants and framing questions for interviews. An example of interview methods is the Micro-Moment
Time-Line interview where respondents are asked to reconstruct a situation in terms of what happened in that situation. Other interview methods derived from this are the Abbreviated Time-Line interview (Dervin et al., 2003) and the “neutral” question-asking method which was used by librarians and healthcare practitioners to asses a person’s information needs when faced with gaps. In these method, subjects are asked questions such as “what issues are you dealing with?”, “what led you to confront this issue?”, “what was confusing about the situation?”, “what answers helped you better understand the situation?” etc. to provide insight into how they made sense of situations they encountered.

![Dervin et al.'s (2003) Sense-Making metaphor](image)

Figure 1: Dervin et al.’s (2003) Sense-Making metaphor

The Sense-Making methodology is useful in guiding researchers towards the kinds of questions to ask subjects when studying the sensemaking process. However, there are two limitations to this methodology. First, it stresses individual rather than collaborative sensemaking and as a result seems to be inadequate for explaining group and organizational sensemaking (Tidline, 2005). Second, the Sense-Making metaphor is at too abstract a level to be able to guide the design of sensemaking tools.
2.1.2.2 Russell et al’s sensemaking model

Sensemaking research in the field of HCI has been guided by Russell et al.’s (1993) model of individual sensemaking. Russell et al. have examined sensemaking in the context of understanding a large body of information such as a large document collection. The model (Figure 2) is based on retrospective studies of information systems and field studies of information workers (Russell et al., 1993). This model focuses on two aspects of understanding large amounts of information – the representations used to encode information and the cost of tasks performed in finding relevant information. Sensemaking is modeled as cyclic processes of searching for external representations and encoding information into these representations to reduce the cost of tasks to be performed.

The sensemaker first creates representations to enter information into – this is the generation loop. Next, the sensemaker finds information relevant to a task and places it in these representations; representations containing information are called encodons and creation of encodons happens in the data coverage loop. When information does not fit in current
representations, this ill-fitting data is called *residue*. As more residue is discovered, representation shifts take place where old representations are modified or abandoned and new representations are created. Finally, the sensemaker uses the encodons for task-specific purposes. Russell et al. (1993) explain how and why representations are created, abandoned, and changed. They show that sensemakers change representations either to reduce the time taken to perform the task or to improve a cost vs. quality tradeoff.

As is evident from Figure 2, Russell et al’s (1993) model focuses on the activities that constitute individual sensemaking. There are no indications of how interactions between sensemakers might fit into the loops discussed in the model. The model is also designed for a single task being performed by the sensemaker and hence does not consider the case when several tasks are being performed by the sensemaker or when several sensemakers are involved (Russell et al., 1993).

### 2.1.2.3 Klein et al’s Data/Frame model

Klein et al (2006b) have proposed a model of sensemaking based on Minsky’s (1995) concept of frames in artificial intelligence. The data/frame model suggests that when people try to make sense of events, they begin with some perspective or framework – this is called the *frame*. Examples of frames can be stories, maps, diagrams, etc. Frames shape and define data that is considered for sensemaking and the data itself changes the frame. The basic sensemaking act is data-frame symbiosis as shown in Figure 3.
The frame acts as a hypothesis about the connections among the data. Sensemaking involves elaborating a frame, questioning the frame as data is discovered, and changing the frame. When the frame is questioned, one might explain away troublesome data and preserve the frame or one might reject the current frame and replace it with a better one.

The data/frame model is used to explain how domain practitioners make decisions in complex, real-world contexts with a view to helping design intelligent systems. The model was developed by using cognitive task analysis methods to uncover how sensemaking takes place in certain domains (Hutton, Klein, & Wiggins, 2008). The primary knowledge elicitation technique here is the Sensemaking Critical Incident Method (SCIM). This is an interview method which focuses on the elicitation of an incident where the interviewee experienced a surprise or growing sense of doubt with respect to a situation that he needed to understand. The interviewer constructs a timeline of how an initial frame was identified by the sensemaker, how information was collected and assessed based on that frame, and how various competing frames were assessed and elaborated.
The data/frame model is similar to Russell et al.’s (1993) model, in that it views individual sensemaking as the organization of data into templates (frames in this model, representations in Russell et al.’s (1993) model). The organizing of data into frames is a cognitive activity. Also, like Russell’s et al.’s (1993) model, Klein’s model does not consider people’s interactions in the process of fitting data into frames or how frames may be changed as a result of such interactions.

2.1.2.4 Pirolli and Card’s sensemaking model

Pirolli & Card (2005) describe sensemaking as a process of transformation of information into knowledge. Their model describes the sensemaking process of intelligence analysts based on cognitive task analysis and think aloud protocol analysis. Figure 4 shows this process; the rectangular boxes represent data flow while the circles represent process flow.
The sensemaking model broadly consists of two loops of activities: (1) the foraging loop in which people search for information and read and extract it into schemas, and (2) the sensemaking loop in which people develop hypotheses that best fit the evidence. Sensemaking can be either bottom-up (i.e., theory is derived from data), or top-down (i.e., theory is used to collect data).

The Pirolli and Card model is an extension of the Russell et al. (1993) sensemaking model which describes the “learning loop complex” of sensemaking. While the Pirolli and Card model describes ‘collaborative’ sensemaking in that it is derived from the collective activities of intelligence analysts, it does not describe how collaboration occurs between multiple people during sensemaking. For instance, if multiple people are engaged in reading and extracting information, they might share importance pieces of evidence with each other and that might affect how they create the evidence file. However, the model does not take into account interaction that might occur between individuals during a collaborative task.

2.1.2.4 Other models of individual sensemaking

Zhang et al. (2008) extended the extant models of sensemaking by drawing on cognition and learning literature. They focused on different types of conceptual changes that happen to representations during sensemaking and the cognitive mechanisms that contribute to changing of the structural representations.

2.1.2.5 Weick’s sensemaking

While the previously mentioned models and theories focus on the cognitive aspects of sensemaking, Weick provides a descriptive account of sensemaking in organizational contexts (Weick, 1995; Weick & Sutcliffe, 2005). According to Weick, sensemaking is about
constructing meaning, placing items into frameworks, and redressing surprise (Weick, 1995). Sensemaking begins with an “extraction of cues” from an ongoing flow of experience. Extracted cues are familiar structures in ongoing events from which people develop a larger sense of what may be occurring (Weick, 1995). Weick describes several characteristics of sensemaking, such as – it is grounded in identity construction, retrospective, focused on and by extracted cues, ongoing, enactive of sensible environments, and driven by plausibility rather than accuracy. Sensemaking arises from the need for individuals to have a sense of identity and to maintain a consistent, positive self-conception. Sensemaking is retrospective in that people make sense of their actions only after they have performed them. Weick also emphasizes that sensemaking is enactive in that people create, via their actions, the world that they need to make sense of. Though most of Weick’s characterization of sensemaking is at the individual level, Weick highlights the social character of sensemaking and emphasizes that during sensemaking people interact to gain mutual understanding.

One of the important contributions of Weick’s (1995) discussion of sensemaking is that he highlights the uniqueness of sensemaking by differentiating it from other cognitive activities such as problem-solving, interpretation, and comprehension. Sensemaking is not synonymous with problem solving. Sensemaking occurs when an unfamiliar situation is encountered but the problem that is being faced has not yet been identified in a way that solutions can be considered.

“In real-world practice, problems do not present themselves to the practitioners as givens. They must be constructed from the materials of problematic situations which are puzzling, troubling, and uncertain. In order to convert a problematic situation into a problem, a practitioner must do a certain kind of work. He must make sense of a situation that initially makes no sense.” (Weick, 1995, p. 9)
Thus, sensemaking takes place in the process of identifying the problem and stating it in such a way that solutions can be considered. Furthermore, sensemaking continues during the entire problem solving process, from identifying the problem to solving it.

Weick (1995) also distinguishes between sensemaking and interpretation using the following analogy: sensemaking is about invention while interpretation is about discovery. Sensemaking is about the way people generate what they interpret. The act of interpreting implies that there is something out there in the world waiting to be discovered. Sensemaking suggests the very construction of that which then becomes sensible. Finally, sensemaking is different from comprehension in that traditionally, the latter term has referred to the understanding of individual stimuli such as words, sentences, prose etc. while sensemaking refers to the understanding of more complex things like events and situations (Klein et al., 2006a).

While Weick provides a rich account of what sensemaking means, what characterizes it and what makes it a unique cognitive activity, he is primarily concerned with the role of sensemaking in organizations. His focus is on understanding how sensemaking affects organizational roles, leadership, management, and projects. A substantial part of Weick’s discussion of sensemaking in his book *Sensemaking in Organizations* (Weick, 1995) has focuses on individual sensemaking. Though Weick highlights that sensemaking is social in nature, he does not explicate what characterizes group sensemaking. In his examination of sensemaking among a group of firefighters engaged in tackling a huge forest fire in Montana (Weick, 1993), he conducts a post-hoc analysis of the disaster through a sensemaking lens (see section 2.1.3.3). Even then, he treats the group of firefighters as an organization (p. 632).
and highlights the characteristics of organizations that enhance sensemaking in tough situations.

2.1.2.6 Tools to support individual sensemaking

Most sensemaking support tools have been designed for individual information seeking tasks and to enhance sensemaking of either information retrieved from searching over large, heterogeneous, document collections or information retrieved from searching the Web. Sensemaker (Baldonado & Winograd, 1997) supports information exploration tasks, that is, tasks in which users look for new information within a defined conceptual area such as “graphical user interfaces” or “Greek art”. The tool supports searching of multiple, heterogeneous sources of information. It is specifically built to support the evolution of a user’s interests depending on the changing characteristics of the information context. When people search for information, as each new piece of information is found it gives the information seeker new ideas and directions to follow and, consequently, a new conception of the search query. Sensemaker lets users bundle returned search results into topics of interest and search within these topics, thus helping them to evolve their query according to the context of the information found. Entity Workspace (Billman & Bier, 2007) helps users make sense of large document collections. It facilitates sensemaking by providing an integrated work environment for searching over document collections and within documents. It supports reading with automatic highlighting of important terms. It also supports note-taking with an electronic notebook and quick methods for importing text from documents, adding comments, and organizing information.

Many of the sensemaking-support tools have been designed to support sensemaking during Web search tasks. The Sensemaking-Supporting Information Gathering (SSIG)
system was developed by (Qu, 2003) based on Russell et al.’s (1993) model of sensemaking. The SSIG system provides tree structures for the representation of information. The user searches information on the Web and organizes the information gathered into a hierarchical tree structure. Each folder in the tree corresponds to a topic or sub-topic that the user is interested in. Different features are provided to help the user search the Web, and construct, refine and re-construct the tree representation. ScratchPad (Gotz, 2007) was developed as an extension to the standard browser interface to assist users in making sense of information found on the Web. ScratchPad provides tools for users to capture both user-generated content and user-created insight. Captured information is visually displayed for review and re-access. More importantly, ScratchPad defines an algorithm for calculating and conveying the relevance of previously captured information to a user’s current browsing behavior. Chapter 7 focuses on sensemaking during collaborative Web search tasks and provides an overview of other tools designed to support sensemaking during collaborative Web search tasks.

2.1.2.7 Summary of individual sensemaking research

Research on individual sensemaking has been conducted from widely varying perspectives, but there are two important features of this research – first, that individual sensemaking has been primarily viewed as a cognitive activity and second, that the emphasis has been mostly on sensemaking in information seeking tasks.

Individual sensemaking has been primarily viewed as a cognitive activity consisting of iteratively finding information based on an initial framework (Klein et al., 2006b); organizing information into categories (Balandonado & Winograd, 1997) or representations (Russell et al., 1993); refining the search criteria (Balandonado & Winograd, 1997) or representations used (Russell et al., 1993) based on new information found; and changing
representations (Russell et al., 1993) or frameworks (Klein et al., 2006b) in use to fit new information. Similarly, Dervin’s Sense-making methodology focuses on the cognitive faculties, like memories, stories, experiences, and identities, which an individual might use to make sense of gaps in reality. Due to its conception as a cognitive activity, most theories and models of sensemaking have not examined its social aspect. (Weick, 1995) has stressed that sensemaking is social, but he has not explored in detail how it is social. At the same time, studies of collaborative information seeking (described in the Section 2.2) have found evidence that people often communicate their understanding of information to each other and build a shared understanding of situations, indicating that sensemaking is not merely a cognitive activity that occurs inside the sensemaker’s head.

Second, most of the sensemaking research has focused on sensemaking in the context of information seeking tasks. Dervin’s (2003) Sense-making has been applied to a variety of information seeking studies and the models of (Pirolli & Card, 2005; Russell et al., 1993) are based on information seeking activities of intelligence analysts. However, most collaborative information seeking studies have not examined how sensemaking takes place as part of this activity. This is partly due to the conceptualization of sensemaking as a cognitive activity which has little or no social component.

2.1.3 Sensemaking in collaborative work

As highlighted above, sensemaking research has focused on how individuals understand information and situations using their cognitive faculties. Collaborative sensemaking extends beyond the creation of individual understandings of information to the creation of a shared understanding of information. What has been missing from the studies of individual sensemaking, and is important in the context of collaborative work, is the interaction that
occurs between individuals as they create this shared understanding. This interaction can be in the form of verbal communication, gestures, and the creation and manipulation of shared workspaces and representations. Although some researchers (DeJaegher & Paolo, 2007; Weick, 1995) have theorized about the importance of such interactions in sensemaking, few have explored empirically how these interactions lead to the creation of a shared understanding in collaborative work.

In this section, I review the few extant studies of sensemaking in collaborative work. Most of these studies have been in domains of time-critical, high-reliability, collaborative work such as military command and control, firefighting and rescue operations, and healthcare. Sensemaking is crucial in such domains because the work is typically information-intensive and the information relevant to group tasks is usually distributed across group members who may each have a different understanding of the information they possess. An understanding of how sensemaking occurs in such collaborative work can also help us design technology to support the same. As discussed before, few tools exist to support sensemaking in collaborative work; in this section, I review such tools and end with a summary of the salient features of research on collaborative sensemaking.

2.1.3.1 Sensemaking in military command and control teams

Military command and control (C2) is one of the few domains in which sensemaking has been studied at the team level. The notion of sensemaking in C2 research is grounded in Endsley’s (2000) situation awareness; sensemaking is conceived as an understanding process applied to awareness of the elements of a situation (Jensen, 2007). “Sensemaking spans a set of activities that begins with developing situation awareness and ends with preparing for action” (Jensen, 2007, p. 2).  

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Jensen (2007) extended this traditional view of sensemaking in C2 literature by drawing on Weick’s (1995) work. She proposed a model in which the functions required for successful sensemaking during a C2 mission are to understand the mission, understand the preconditions, find a way to accomplish the mission and evaluate the situation. She conducted one of the few extant empirical studies of sensemaking in teams where the quality of both the process and products of sensemaking were measured. In Jensen’s study, Army captains participated in teams to complete the task of producing a brigade order. Jensen examined the effects of the amount of information available to team members and the mode of communication between team members on the quality of plans and the sensemaking process. The characteristics of each team’s sensemaking process were assessed from video recordings of their planning sessions. The researchers found that both the quality of information presented to team members and the ability to meet face-to-face failed to affect either plan quality or the sensemaking process. However, the quality of the team’s sensemaking process affected the quality of plans produced. They concluded that the better the sensemaking process, the better the plans.

Another important contribution of the C2 literature is Ntuen et al.’s (2006) study which defines collaborative sensemaking as a situation where “multiple agents with different thoughts about the world engage in the process of making sense of ‘messy’ data or information with a high degree of uncertainty” (p. 7). Four elemental activities are crucial to the process of sensemaking – the communication process, the knowledge management process, developing shared situation awareness and understanding process, and the process of developing collaborative knowledge.
2.1.3.2 Sensemaking in the ICU

Although medical work is rife with occasions of sensemaking, there has been little research on sensemaking in healthcare settings. One of the few studies in this domain is Albolino et al.’s (2007) study which emphasized the role of sensemaking in high-tempo, high-uncertainty work settings such as an intensive care unit (ICU). This ethnographic study examined verbal communications among healthcare providers in the ICU, primarily during clinical rounds. Two kinds of sensemaking were found to occur – ‘sensemaking-at-intervals’ and ‘sensemaking on-the-fly’. Sensemaking-at-intervals referred to sensemaking during rounds. Time was set aside for it and its conduct was formalized. In contrast, sensemaking on-the-fly was interspersed with the care process and not something for which time was separately set aside. This sensemaking took place in parallel with process control activities as providers tried to keep pace with the tempo of operations in the ICU. The study concluded that,

“The balance between these two types of sensemaking reflects, among other things, the amount of irreducible uncertainty in the workplace, the confidence of practitioners in their ability to achieve shared, collective understandings, and the need to balance efforts among short-term and long-term needs” (Albolino et al., 2007) (p.137).

Thus, a balance between the two kinds of sensemaking helped the ICU care providers deal with the uncertainty of their work and achieve a shared understanding of the environment.

2.1.3.3 Sensemaking in firefighting and rescue operations

Firefighters are professional sensemakers (Dyrks, Denef, & Ramirez, 2008). When firefighters enter the site of a fire, they usually have little or no knowledge of the situation and context surrounding them. One of the key sensemaking activities for them is understanding space. Dyrks et al. (2008) studied the collaborative sensemaking activities of the Paris firefighting brigade by running simulated reconnaissance missions where the goal
for the firefighters was to enter a “burning” building and find water bottles (victims) that were hidden. They focused specifically on handoffs and debriefings between firefighters. An important finding was the use of ad-hoc maps by team members to help each other gain an understanding of the space. The study concluded that the process of using maps for collaborative sensemaking needs to be supported by ubiquitous computing technology.

Another related study was Weick’s (1993) study of the Mann Gulch disaster using a sensemaking lens. Weick examined the account of the Mann Gulch disaster provided by Norman McLean’s (1992) book *Young Men and Fire* and showed how sensemaking broke down in the team of 13 smoke-jumpers called upon to tackle a huge forest fire in the Mann Gulch in Montana. Weick analyzes the account of the disaster through a sensemaking lens, treating the team of firefighters as an organization (p. 632) and proposes four potential sources of resilience that makes organizations less vulnerable to disruptions in sensemaking – improvisation, virtual role systems, the attitude of wisdom, and norms of respectful interaction.

Landgren and Nulden (2007) conducted an ethnographic study of the use of mobile phones among police patrol units and firefighting crews during emergency response operations in the Swedish rescue services. Patterns of mobile phone interaction work were analyzed showing how the dyadic exchange of mobile phone numbers between the actors plays an important role in organizing and sensemaking during the emergency. ‘Enacted sensemaking’, a term borrowed from Weick (1995), was used as an analytical framework to understand mobile phone use. Sensemaking is “enactive” in that people act to create the situations that they then need to make sense of. The study concluded that instead of adding yet another system and additional artifacts for the emergency responders, it might be better to
make use of the technology already in use, namely mobile phones, for supporting the work of emergency responders.

2.1.3.4 Tools to support collaborative sensemaking

Few tools have been developed to support sensemaking in groups. EWall (Keel, 2007), a visual analytics environment, was developed to support remote-collaborative sense-making activities. It enables individual users to navigate shared information and helps remotely dispersed team members combine their contributions, work independently without diverting from common objectives, and minimize the necessary amount of verbal communication. EWall users operate their individual graphical interfaces to collect, abstract, organize and comprehend task-relevant information relative to their areas of expertise. A computational agent infers possible relationships among information items through the analysis of the spatial and temporal organization and collaborative use of information. All information items and relationships are stored in a shared database. Another computational agent evaluates the contents of the shared database and provides individual users with a customized selection of potentially relevant information. A learning mechanism allows the computational agents to adapt to particular users and circumstances.

Most tools designed to support sensemaking in group work have been specifically designed to support collaborative information retrieval tasks; Section 2.3 discusses some such technologies.

2.1.3.5 Important features of research on collaborative sensemaking

The field studies described above have shown the importance of sensemaking in time-critical, high-reliability collaborative domains such as military command and control, critical
care, and firefighting. These studies have examined how sensemaking occurs as part of collaborative work, focusing more broadly on how sensemaking affects planning (Jensen, 2007), knowledge management (Ntuen et al., 2006), awareness (Jensen, 2007), communication (Landgren & Nulden, 2007), and achievement of shared goals (Jensen, 2007; Weick, 1993) in groups. While individual sensemaking research conceptualized sensemaking as the cognitive activity of finding information and organizing it into frameworks to fill gaps in understanding, interestingly, studies of collaborative sensemaking have not focused on how individuals together find and organize information, but rather on the interactions between people as they conduct their work.

None of the studies of sensemaking in groups has specifically focused on the context of collaborative information seeking. Also, these studies have only started to delve into aspects of collaborative sensemaking and have some limitations. For instance, although Jensen’s (2007) study showed that the quality of sensemaking in military C2 teams can be measured, the applicability of the method is limited because the measures of the sensemaking process were based on C2 literature and hence cannot be easily exported to other domains. Also, the teams were homogeneous and the task was low stress, making it difficult to translate the results to domains such as firefighting or emergency care. The drawback of Ntuen et al.’s (2006) ‘framework’ of collaborative sensemaking is that the authors do not explicate what the framework is, nor do they empirically validate the framework.

Studies such as Weick’s (1993) and Langren and Nulden’s (2007) applied theories of sensemaking as a post-hoc lens to understand collaborative work rather than actually examining how sensemaking takes place. Weick’s (1993) study was a retrospective examination of a disaster through the sensemaking lens rather than a study of sensemaking
activities of smoke-jumpers. Similarly, in Landgren and Nulden’s (2007) study ‘enactive sensemaking’ is used as a framework to examine mobile phone patterns of use. One reason for the lack of empirical studies of collaborative sensemaking is that sensemaking in groups is hard to observe for researchers, especially using ethnographic techniques of observations and interviews. Also, sometimes a long period of observations can result in the occurrence of very few instances of sensemaking activities. For instance, Sharma (2008) conducted a study of sensemaking during non-shift change handoffs among computer help desk support personnel. In spite of using sensemaking theories to contextualize handoffs, Sharma could not provide much detail into how sensemaking occurs during handoffs; this was partly because they didn’t find many instances of sensemaking during handoffs. They concluded that handoffs occurred either early or late in the process of troubleshooting computer problems and that low-cost communication channels should be implemented to support handoff.

Finally, there is a gap in the technical aspects of collaborative sensemaking research. Not only is there a lack of sensemaking-support tools for groups, but also tools like EWall (Keel, 2007) have been designed with the narrow definition of sensemaking as “inferring relationships between pieces of information”. Collaborative sensemaking involves more than finding relationships and patterns between information; it involves communication and collaboration to create a shared understanding of situations and events.

In summary, there are several gaps in our understanding of how people collaboratively make sense of situations and how tools can be designed to support them. The methods, models, and tools for sensemaking research at the individual and group level of
analysis is presented in Table 1. As the table highlights, there is a need to extend this research to the group level.

<table>
<thead>
<tr>
<th>Models</th>
<th>Individual sensemaking</th>
<th>Collaborative sensemaking</th>
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<tr>
<td>• Dervin et al’s (2003) Sense-Making metaphor</td>
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<td>None</td>
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<tr>
<td>• Russell et al’s (1993) sensemaking model</td>
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<tr>
<td>• Klein et al’s (2006b) Data/Frame model</td>
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<td>• Pirolli &amp; Card's (2005) model</td>
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<tr>
<td>Methods</td>
<td>Neutral and time-line interviewing (Dervin et al., 2003)</td>
<td>• Quality of a team’s sensemaking process assessed by experts. (Jensen, 2007)</td>
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<td></td>
<td>Sensemaking Critical Incident Method (Hutton et al., 2008)</td>
<td>• Ethnographic studies (Albino et. al., 2007; Landgren, 2007; Dyrks et al., 2008)</td>
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<tr>
<td>Tools</td>
<td>Sensemaker (Baldonado &amp; Winograd, 1997)</td>
<td>• EWall (Keels, 2007)</td>
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<td>Entity Workspace (Billman &amp; Bier, 2007)</td>
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<td>ScratchPad (Gotz, 2007)</td>
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Table – 1: Summary of the models, methods, and tools of sensemaking

2.2 Collaborative information seeking

I was interested in studying sensemaking as part of collaborative information seeking (CIS) and hence, this section provides an overview of research on CIS. There has been growing evidence that collaboration occurs frequently during information seeking activities, and that understanding information together is an important aspect of CIS. However, there has been little exploration of how sensemaking occurs during CIS activities. In reviewing the CIS literature, I highlight that though sharing individual understandings of information and creating a shared understanding have been found to be an important aspect of CIS, researchers studying CIS have not examined sensemaking in much detail.

Traditionally, information seeking models (Ellis & Haugan, 1997; Kuhlthau, 1991; Wilson, 1981) have focused on the individual information seeker. However, in the past
decade, field studies of information seeking have revealed that people often collaborate and communicate during information seeking activities. Beginning in the late 1990s, researchers started focusing on understanding collaborative information behavior. Many of the early studies of collaborative information behavior were conducted in the military command and control (C2) domain. (Sonnenwald & Pierce, 2000) explored information behavior in army battalions and uncovered three characteristics of collaborative information behavior. First, team members were required to maintain interwoven situational awareness consisting of individual, intra-group, and inter-group shared understanding of a situation. Second, there was a need for dense social networks and frequent communication between participants in order to support the development and maintenance of situational awareness. Finally, they observed contested collaboration where team members maintain an outward stance of cooperation but worked to further their own interests.

Another study in the C2 domain is Prekop’s (2002) study of collaborative information seeking in the Australian Defense Forces. He focused on three components of information seeking activities – information seeking roles, information seeking patterns, and the contexts in which the roles and patterns are performed. He found four information seeking roles – information gatherer, information referrer, information verifier, and information indexer/abstracter – and two contexts of collaborative information seeking. These contexts were the collaborative information seeking context which captured what was collectively known, understood, felt, and believed by group members, and the organizational context which contained specialist information and knowledge. He also discovered three patterns of information seeking – information seeking by recommendation, direct questioning, and advertising information paths.
Apart from the C2 domain, researchers have found evidence of collaborative information seeking in a range of other domains. (Twidale et al., 1997), in one of the seminal studies of collaborative information behavior, studied collaboration during library-usage. They found that a range of interactions took place between users searching library online catalogues, from asking for help on a topic to observing others to see how they searched. They stressed that interactions occur during the search process to share both the process and products of search. Talja (2002) conducted a study of academics’ information sharing behavior and found four types of information-sharing practices – strategic, paradigmatic, directive, and social. Spence and Reddy (2005) conducted a study of the collaborative information seeking practices of academic researchers to explore what triggered collaborative information seeking, what media and channels of communication were used, and how successful collaborative information seeking activities were. They found that academic researchers collaborated most often because they required the expertise of others. Also, the most common means of collaboration were face-to-face, email and phone, and collaborative information seeking activities were usually more successful than individual ones. In the healthcare domain, Reddy & Dourish (2002) studied information seeking activities as part of the work of healthcare providers in the intensive care unit. They emphasized the effect of temporal work patterns on collaborative information seeking activities in the ICU and found that staff work rhythms acted as both a resource and a constraint on collaborative information seeking. Spence & Reddy (2007) studied the collaborative information seeking activities of healthcare providers in the ED and found that collaborations occurred because healthcare providers could not easily access required information or they did not know where the information they needed was located. The study highlighted the role of the unit secretary as
the “gatekeeper” who played a crucial role in ensuring that team members found the information they needed and acted as a conduit between information seekers and sources of information.

Hansen & Jarvelin (2005) conducted an empirical investigation of the collaborative information seeking and retrieval (IS&R) activities of Swedish patent engineers and focused on how collaborative activities manifested themselves, when collaborative activities took place, and what the characteristics of such activities were. They identified document-related and human-related collaborative IS&R activities. Document-related collaboration took place for sharing information objects, sharing representations of information needs, sharing information seeking and retrieval strategies, and communication of personal opinions. Human-related collaboration took place for sharing task strategies, division of labor, expertise, and for end-product creation.

2.2.1 Collaborative information retrieval

The information retrieval (IR) community has studied the collaborative aspects of finding and using information. Karamuftuoglu (1998) reframed the problem of IR from finding information to “the production and consumption of knowledge”, and stressed that IR research needed to re-conceptualize the terms “user” and “relevance” focusing on the social relations among users of IR systems. Romano et al. (1999) reviewed the experiences of users of IR systems and group-support systems and found that there was a demand for systems supporting multi-user information retrieval. Poltrock et al. (2003) defined collaborative information retrieval as “the activities that a group or team of people undertakes to identify and resolve a shared information need.” (p.239). They conducted field studies of collaborative information retrieval carried out by two design teams, one at Microsoft, and the
other at Boeing, and found that across both teams, team members collaborated during the
different information retrieval activities. Team members collaboratively identified
information needs, formulated queries, retrieved information, and also communicated about
information needs and sharing information. Fidel, Pejtersen, Cleal, & Bruce (2004) took a
multi-disciplinary approach to understanding the complex phenomenon of collaborative IR
and stressed that the following dimensions were important for understanding collaborative IR
– the actor’s dimensions, the task dimension, and the organizational analysis dimension.
These dimensions consisted further of the cognitive dimension, the specific task and
decision, the nature of the information sources and the information needed, the organization
of the team’s work, and the organizational culture.

There are few models of collaborative information behavior. (Reddy & Jansen, 2007)
proposed a model of collaborative information behavior based on empirical findings from the
healthcare domain. It views information behavior along two axes – behavior axis and context
axis. The behavior axis ranges from information searching to use, while the context axis
ranges from individual to collaborative information behavior. Table 2 summarizes
collaborative information behavior aspects studied in the literature. As is evident from this
table, sensemaking has not been explicitly examined, though these studies have found
evidence that sensemaking is an important part of collaborative information behavior (as
highlighted in section 2.2.2).

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2 For a comprehensive summary of collaborative information seeking and retrieval literature, please see (Foster, 2006)
<table>
<thead>
<tr>
<th>Aspect discussed in the literature</th>
<th>Studies</th>
</tr>
</thead>
<tbody>
<tr>
<td>Situational awareness</td>
<td>(Sonnenwald &amp; Pierce, 2000)</td>
</tr>
<tr>
<td>Communication</td>
<td>(Poltrock et al., 2003; Sonnenwald &amp; Pierce, 2000; Twidale et al., 1997)</td>
</tr>
<tr>
<td>Information sharing strategies and patterns</td>
<td>(Prekop, 2002; Talja, 2002)</td>
</tr>
<tr>
<td>Information seeking roles</td>
<td>(Prekop, 2002; Spence &amp; Reddy, 2007)</td>
</tr>
<tr>
<td>Information seeking contexts</td>
<td>(Prekop, 2002; Reddy &amp; Jansen, 2007)</td>
</tr>
<tr>
<td>Triggers for collaborative information seeking</td>
<td>(Spence &amp; Reddy, 2005)</td>
</tr>
<tr>
<td>Temporality of collaborative information seeking</td>
<td>(Reddy &amp; Dourish, 2002)</td>
</tr>
<tr>
<td>Collaborative formulation of information needs and queries</td>
<td>(Karamufluoglu, 1998; Poltrock et al., 2003)</td>
</tr>
<tr>
<td>Range of behavior</td>
<td>(Reddy &amp; Jansen, 2007)</td>
</tr>
</tbody>
</table>

Table 2: Summary of concepts explored in collaborative information seeking and retrieval literature

Collaborative Web search is an area of collaborative information behavior in which researchers have found people often collaborate to perform joint tasks like finding information for vacation planning or finding medical information for loved ones (Morris, 2008). Like the rest of the collaborative information behavior literature, studies of collaborative Web search have focused on how and why users collaborate during Web search, and have mainly had a technical focus with a lot of emphasis on developing tools to support such collaboration. These studies and tools have not explored sensemaking in collaborative Web search. The second part of my thesis explores sensemaking in collaborative Web search; Chapter 7 provides background on collaborative Web search research before describing my study of sensemaking in collaborative Web search.

2.2.2 Sensemaking in collaborative information seeking

As summarized in Table 2, some studies of collaborative information behavior have focused on the process of collaborative information seeking with attention to how people collaboratively formulate information needs, share information needs and information
seeking strategies, and communicate during information seeking. Other studies have explored
the characteristics of collaborative information seeking such as temporality, triggers, and
situational awareness. Thus, these studies have focused on how collaborators find and
retrieve information together without paying much attention to how collaborators assimilate
and understand the information found by different group members. For instance, Poltrock et
al. (2003) identified four collaborative activities among design teams – identifying
information needs, formulating queries, retrieving information, communicating information
needs and sharing retrieved information; they did not examine how group members
collaboratively understood the information found and shared during these activities.
Similarly, the behavior axis of Reddy and Jansen’s (2007) model of collaborative
information behavior includes information searching (i.e. tactical maneuvering), seeking (i.e.
strategic maneuvering), and use but does not include sensemaking. While none of the
empirical studies have focused on sensemaking as part of the process of collaborative
information seeking, these studies have often found that sharing the understanding of
information and passing on this understanding to others (e.g. in the form of annotations and
notes) is an important aspect of collaborative information seeking activities.

For instance, Gorman et al. (2002) observed the factors that affect efficacy of
information sharing in ICUs and found that physicians used informal annotations and note-
taking when selecting information sources. Physicians were also interested in knowing how a
previous physician had navigated the information space and they selected, organized, and
shared subsets of information drawn from diverse information sources. Hansen & Jarvelin
(2005) found that in addition to sharing information objects (such as documents and articles),
patent engineers also shared contextual relationships between information objects (in the
form of annotations, references, etc.); representations of their information needs; decisions, judgments, and assessments of the problem and the information available; personal and subjective opinions; and history of information objects. These kinds of information, in addition to the task-related information, helped enhanced group members’ understanding of the information itself. Hertzum (2008) stresses that during collaborative information seeking, the uneven distribution of information and the different meanings actors might derive from the information known to them poses a challenge. He emphasizes that many definitions of collaborative information seeking dissociate the acquisition of information from being informed by it, such as Foster’s (2006) definition which states that collaborative information seeking is “the study of the systems and practices that enable individuals to collaborate during seeking, searching, and retrieval of information” (p. 151). Instead, Hertzum proposes that collaborative information seeking be defined “as the information seeking activities performed by actors to inform their collaborative work combined with the collaborative-grounding activities involved in making this information part of the actors’s shared understanding of their work”. (p. 958). Thus, an important aspect of the process of finding and using information to inform collaborative work is creating a shared understanding of information, i.e. collaborative sensemaking. This thesis takes a similar view of sensemaking in collaborative work and examines how this sensemaking takes place and how it can be supported by technology used in collaborative work.

Various collaborative IR technologies have allowed users to share their understanding of the information found. Collaborative filtering systems (Konstan & Riedl, 2003) allow people to recommend information items to other users while social navigation systems allow users to view the trace of other users’ information seeking activities (Foster, 2006). Such
traces provide evidence of the use of digital objects (like documents, links, and paths taken through the information) that help users make sense of the information space. Another way of helping users understand others’ interactions with information is through the use of history-enriched digital objects (Foster, 2006). History-rich digital objects bear the imprint of an “interaction history” or a record of the interactions past users have had with the object in the form of maps, path views, annotations, and comments (Wexelblat & Maes, 1999). Synchronous social navigation systems allow user to co-browse information together and use chat features to discuss the information (Foster, 2006). Thus, even though studies of collaborative IR have not explicitly focused on sensemaking-support, they have explored design features to enhance users’ understanding of the information space such that they can collaborate more effectively.

2.3 Defining collaborative sensemaking in information seeking

Given the fragmented sensemaking literature at the individual level, and the lack of a universal definition of sensemaking (at both the individual and collaborative levels), I synthesized a working definition of the term ‘collaborative sensemaking’ from the literature. I drew on CIS literature to contextualize this definition for my study of sensemaking in that context. Such a definition was aimed at helping guide my observations of collaborative sensemaking among healthcare providers in the ED. Since sensemaking is often intricately intertwined with other information seeking activities like formulating information needs, sharing information, and using information for diagnosis, decision-making, and problem-solving in the ED, one of the challenges I anticipated I would face as a researcher observing information work was to answer the question “how do I know collaborative sensemaking when I see it?” Answering this question would not only help me in collecting data but also in
analyzing the copious amounts of data that the qualitative methods (like observations and interviews) used in my ethnographic study are known to generate (Mason, 2002). It is important to note that such a definition of collaborative sensemaking did not bound data collection because I did not restrict my data collection to only observations that strictly followed this definition. Rather, having this working definition in mind helped ensure that I did not miss important collaborative sensemaking incidents.

I defined collaborative sensemaking by bringing together the following common aspects of various descriptions of sensemaking (Weick, 1995, DeJaegher & Paolo, 2007) – meaning generation, enactive nature of sensemaking, and social nature of sensemaking. I contextualized this definition in CIS by drawing on Hertzum’s (2008) idea of collaborative grounding in CIS activities.

2.3.1 Meaning Generation

Weick (1995) highlights several definitions of sensemaking from the organizational science literature. Sensemaking is “the placement of stimuli into a framework” which allows people to comprehend, understand, explain, attribute, extrapolate and predict. Sensemaking can also be seen as the retrospective ascription of meaning to discrepant events or ‘surprises’. Some investigators have defined sensemaking as “the reciprocal interaction of information seeking, meaning ascription and action”, that is, the processes by which people attribute meaning to events and actions in a social setting. Other investigators have perceived sensemaking as the act of “developing cognitive maps of the environment”. The common thread in all these definitions is that sensemaking is the act of finding meaning or understanding. As cognizers, humans try to find significance or meaning in their interactions with the world; the difference
between a strictly physical encounter with the world and a cognitive encounter lies in the dimension of significance of the encounter for the cognizer (DeJaegher & Paolo, 2007).

2.3.2 Enactive nature of sensemaking

Another important aspect of sensemaking is that it is enactive. Weick (1995) differentiates sensemaking from interpretation by pointing out that sensemaking is not only about noticing and extracting cues from an ongoing flow of experience but it is also about the creation of those cues. Thus sensemaking includes not only the construction and bracketing of cues but also the revision of those interpretations based on action and its consequences. One of Weick’s (1995) seven properties of sensemaking is that it is “enactive of sensible environments” in that people receive stimuli as a result of their own activity. Thus, action is a precondition for sensemaking.

DeJaegher & Paolo (2007) emphasize the enactive aspect of sensemaking from a different yet complementary perspective to Weick’s (1995); they stress that sensemaking is a core aspect of enactive cognition. Organisms do not passively receive information from the environment that they translate into internal representations; they participate in the generation of meaning from their actions. Thus, the finding of meaning must be enacted, it is not merely about the extraction of information from the environment.

2.3.3 Social nature of sensemaking

Weick (1995) stresses that human thinking and social functioning are essential aspects of one another. Since sensemaking is enactive and human action often depends on the actions of others, an important property of sensemaking is that it is social. DeJaegher & Paolo (2007) also see sensemaking as an inherently social process and emphasize the importance of social
interactions in sensemaking. They highlight the fact that in socially interactive situations, the
dynamics of the interaction often change the sensemaking of individuals. Individual
sensemakers coordinate their sensemaking in social interactions and the patterns of
coordination (or the breakdowns of coordination) can influence the significance of the
situation for individual sensemakers.

2.3.4 Collaborative grounding

Hertzum (2008) emphasized the importance of collaborative grounding in collaborative
information seeking activities. Collaborative grounding is “the active construction by actors
of a shared understanding that assimilates and reflects available information. This involves
that information items are shared and their meanings debated and resolved.” (p.958).
Hertzum describes collaborative information seeking to consist of two distinct activities –
information seeking and collaborative grounding. Over time, these two activities repeatedly
change the balance between individual and shared understanding of information. As actors
find information, they create their individual understandings of the information. However, as
they share this information, along with their understandings of the information, they create
shared understandings.

2.3.5 Working definition of collaborative sensemaking

Drawing on the above aspects of sensemaking and information seeking literature, I
synthesized a working definition of collaborative sensemaking in the context of information
seeking, as follows:

“Collaborative sensemaking occurs when two or more people create a shared understanding of information by 1) interacting with others to share individual understandings of information and 2) interpreting other’s interactions with information.”
The first part of the definition emphasizes the social nature of sensemaking and draws on what studies of collaborative information seeking have found, i.e. that people often interact with each other to share not only information, but also their understanding of the information. The second part of the definition emphasizes the enactive nature of sensemaking. When individuals interact with information, they make sense of it by creating representations to encode the information into (Russell et al., 1993), annotating and organizing the information (Hansen & Jarvelin, 2005), and noting their own understanding of the information. During collaborative information seeking, group members share and interpret each others’ representations and notes, and this leads to the creation of a shared understanding.

I would like to note here that this definition might give rise to the following question: “how do we know when ‘meaning’ or ‘understanding’ of information is generated?” While there is an entire body of work on how meaning is generated via social interactions (Blumer, 1969) and on the social construction of meaning (Shaila & Carol, 2003), for the purposes of my study ‘creating a shared understanding’ implies that the sensemakers understand the information well enough to fulfill their shared information needs and successfully accomplish their joint task. More details about the role this definition played in collection and analysis of data in my field study of healthcare providers in the ED are provided in Chapter 3.

This chapter provided an overview of the theories, models, and tools of individual and group level sensemaking research. The salient characteristics of sensemaking research were highlighted, along with gaps in the research. I also provided an overview of the issues examined in collaborative information seeking literature, pointing out the lack of research on how sensemaking takes place as part of this activity. I tied these literatures together and
synthesized a definition of collaborative sensemaking in information seeking activities. The next two chapters describe Study 1, i.e. my study of sensemaking in the CIS activities of healthcare providers in the ED. The following chapter describes the study design and methodology for conducting Study 1.
3. Study 1: Study Design and Methodology

The first study I conducted was an ethnographic field study of the collaborative sensemaking activities of healthcare providers in the emergency department. The ED was an ideal setting to study sensemaking since emergency care is highly collaborative work centered on information. Emergency care providers constantly collaborate to find and understand information in order to treat patients; hence I was interested in studying the interactions between healthcare providers as they collaboratively found and understood information during their work. This chapter details the design and methodology for my study of collaborative sensemaking in the ED while the following chapter describes the findings. The following sections describe the rationale behind the study design, selection of the research site, and the data collection and analysis techniques.

3.1 Choosing qualitative methods

One of the important steps in determining the research methodology for a study is to select the appropriate methods for conducting the research. Qualitative and quantitative research methods have different strengths which make them suitable for different types of research studies. Quantitative methods such as surveys and experiments are appropriate for data gathering when the research questions are clear and precise, when the researcher has prior knowledge of the issues that characterize the phenomenon and the range of responses likely to emerge, and when the respondents are familiar with the response (Bryman, 1999). Although useful for studying large populations, it is difficult for quantitative methods to provide detailed insights into particular activities of participants. Often, quantitative methods
can help explain how variables of interest are related but not about the processes that link those variables. Qualitative methods, on the other hand, can capture the details and complexities of people’s *interactions and actions*, especially in collaborative work. They are useful when the goal of the research is to construct a detailed picture of a certain situation or flow of events and when the study requires an examination of complex social relationships or intricate patterns of interactions (Bryman, 1999).

I chose qualitative methods for studying collaborative sensemaking among healthcare providers in the ED. This was largely due to the nature of the research problem I was studying and my research goals (Mason, 2002). My goal was to understand the motivations, nature, and characteristics of collaborative sensemaking. I did not have any a-priori hypothesis about the nature and characteristics of collaborative sensemaking that might have been tested through quantitative methods. I also did not have pre-conceived ideas about the variables the might affect collaborative sensemaking to experimentally measure. Since few studies have examined sensemaking at the group level, I had no pointers to the variables that I might have measured had I chosen to conduct a quantitative study using surveys. Furthermore, I viewed collaborative sensemaking as a social activity, embedded in the context of everyday information work; collaborative sensemaking activities are *interactive* and *enactive* because they arise from interactions between people (as per the definition in Section 2.2). Consequently, I intended to gain an understanding of collaborative sensemaking by studying the *dynamics of interactions* between people as they searched for, shared, and made sense of information in a *natural setting*. Qualitative methods were better-suited to allow me to capture these interactions than quantitative methods.
3.2 Research site selection

I designed my study as a single-site qualitative study. Hence, the first step for me was to select a research site. Research sites selected for qualitative research studies must allow the researcher to collect rich data, achieve intimate familiarity with the setting, and engage in face-to-face discussions with participants (Lofland & Lofland, 2005). I chose the emergency department (ED) at the Penn State Hershey Medical Center (HMC) as the research site. HMC is a hospital associated with the Penn State medical school and the ED there fulfilled not only the criteria set forth by Lofland & Lofland (2005) but also had several characteristics that made it an ideal site to study CIS activities.

- Work in the ED is highly collaborative, information-intensive, and time-critical.
- Emergency care providers work together, using various digital and non-digital information artifacts, to find and understand information needed to treat patients.
- Sensemaking is an important aspect of medical work in general (Albolino et al., 2007) and is especially important in emergency care.
- Emergency care providers need to provide care to critically ill patients (such as trauma victims or motor vehicle crash victims) who are often not able to provide adequate information about the cause and symptoms of their illness or injury.
- The ED sees a wide variety of cases and often experiences peaks in demand when care providers must provide quick and efficient care to a large number of patients in a short period of time.
- ED care providers are faced with both information scarcity and information overload during their work and hence, finding and making sense of information together is critical to emergency work.
Choosing the HMC ED also helped me overcome several practical difficulties that often make qualitative research difficult. One of the most difficult steps in setting up an ethnographic study is gaining access to a research site. Due to HMC’s association with Penn State, there is a tradition of research collaboration between the College of IST and HMC. This made gaining access to HMC easy for me as compared to other hospitals. Also, at the time that I was evaluating research sites for my study, the ED at HMC was undergoing re-organization of physical space and re-design of process flows. The administration at the HMC ED were interested in involving researchers as part of interdisciplinary research teams involved in these re-organization efforts. Finally, having a “champion” for the research project at the organization where research is being conducted makes it easier for the researcher to gain the involvement of participants. I found such a champion in the Director of Emergency Medicine at the HMC ED. The Director was extremely enthusiastic about research examining the use of information technology to improve healthcare processes in emergency care and eagerly embraced my presence at the ED. He also encouraged other healthcare providers in the ED to participate in my research by informing them about the significance of my research to their work. Due to these reasons, I selected the HMC ED at the research site for my study.

### 3.3 Data collection

Ethnography has a long tradition of being used as a research instrument in the field of sociology and anthropology (Hughes, Randall, & Shapiro, 1993). The ethnographer studies the social practices, knowledge, beliefs and attitudes of participants in a natural setting. Due to its emphasis on studying how work is socially organized, the ethnographic approach has been widely applied in computer-supported cooperative work (CSCW) research to gain
insight into the role of technology in supporting work (Hughes, Randall, & Shapiro, 1992). In particular, since medical work is socially organized (Strauss et al., 1985), ethnography has been used in medical settings (Bardram & Bossen, 2005; Nyssen, 2007) to study collaboration and coordination issues. Since I was interested in examining the details of people’s interactions and actions as they collaborated during sensemaking activities, I chose ethnographic data collection techniques for my study. Ethnographic data collection has the following characteristics (Hammersley, 1990):

- People's behavior is studied in everyday contexts, rather than under experimental conditions created by the researcher.
- Data are gathered using a range of methods, but observation and/or informal conversations are usually the main ones.
- The focus is usually a single setting or group of relatively small scale.

I studied the sensemaking and information seeking behavior of healthcare providers in the context of their everyday work in the ED using a range of observation methods such as observations, formal and semi-formal interviews, and artifact collection. The research was conducted at a single site – the emergency department of the Penn State Milton S. Hershey Medical Center (henceforth referred to as the HMC ED). In the next section I describe the field site in more detail; in the remaining part of this section I elaborate on the data collection and analysis techniques used.

### 3.3.1 Immersion in the field

The ethnographic method requires the observer to immerse herself in the world of the “other” (Geertz, 1973). In order to immerse myself in the domain of emergency care, I faced certain challenges. One of these challenges was my lack of knowledge of medical terms and medical
work. Thus, the first step in data collection was to immerse myself in the world of emergency care in order to learn about the nature of the work and to gain familiarity with medical terminology. My immersion into the world of emergency care took place in several phases over May 2006 – May 2007. During the summer and fall of 2006, I conducted focus groups with EMS and ED staff at HMC for a research project where the goal was to examine coordination between pre-ED services and the ED during crisis response (Paul et al. 2008; Reddy et al., 2009). Participating in this research project helped me gain an understanding of the interface between pre-hospital services and the ED, the work of the EMS and ED staff, and the role of various information and communication tools in their work. It also helped me gain context of the organization (HMC) where I would be conducting my dissertation research.

In the spring of 2007, I conducted preliminary fieldwork for my dissertation to understand the nature of work in the HMC ED. I met with the Director of the ED whose support for my research helped make me comfortable in my new surroundings. We met once every two weeks and discussed issues being faced by the ED (such as overcrowding and long wait times) and information systems in use. Apart from my dissertation work, I also involved myself with the Healthcare Engineering project which was an interdepartmental research project involving the College of IST, the Department of Industrial Engineering and the HMC ED. The goal of this project was to examine how systems engineering techniques could be used to improve wait times in the ED. I spent time in the ED observing care providers work and gained familiarity with the physical layout of the ED, patient flows, resources, and the information and communication tools in use.
While the above activities helped me understand the particulars of work in the HMC ED, I also enhanced my general knowledge of emergency care by reading medical blogs (Geenes; Kim; Miller) of ED professionals, by reading books (Grim, 2000; Rubin, 1972) written by emergency room physicians, and by attending the Penn State Mini Medical School series in spring 2007.

The other challenge I faced in immersing myself into the field was that of gaining the trust of the ED care providers. Due to the time criticality of work in the ED, the serious consequences of errors, and concerns regarding patient privacy, it was difficult for care providers to accept the presence of a stranger. In medical settings, there is also the issue of provider liability and providers are usually uncomfortable with researchers observing them work. In order to gain the trust of my participants, I made sure that they knew what the goals of my study were and that my research was sanctioned by the Director of the ED. I introduced myself to the attending physicians and charge nurses so as to gain legitimacy and to build their trust in me. I was provided an ID card that helped me gain access to the ED; I made sure to always wear the ID card as a badge to prove that my presence was legitimate. I also made my data collection transparent; sometimes I was asked by participants what kind of data I was collecting and I told them they could read through my notes if they wished to do so. Some healthcare providers jokingly asked me if I was noting their activities to report to their supervisors and I assured them that I was never going to do that. I also gained the trust of participants by attending meetings related to various research projects that I was involved in. Several of my participants were present at such meetings and seeing me at the meetings helped me gain familiarity and trust with them. During less busy periods in the ED,

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3 The Penn State College of Medicine offers a free series of lectures at the Hershey Medical Center where faculty present talks on important trends in medicine and health. More information can be found at [http://www.hmc.psu.edu/ce/MiniMed/](http://www.hmc.psu.edu/ce/MiniMed/)
I often participated in informal chats with the nurses or spent time talking to them in the “break room” where they relaxed during breaks. I also ensured that my research activities were unobtrusive; I kept out of patient rooms as far as possible, placing myself in areas of the ED where I was not in the way of ED staff or patients.

### 3.3.2 Data collection techniques

Data collection took place over the period Jan 2007 to Dec 2008, with preliminary fieldwork occurring between Jan – Aug 2007. In Aug of 2007, I started collecting data specifically aimed to answer the research questions noted in Section 3.1. I studied the collaborative information seeking activities of clinical and non-clinical staff working in the ED as well as EMS members who transported patients into and out of the ED in order to examine how they made sense of information during their work. I used a variety of techniques to collect data as summarized in Table 3.

<table>
<thead>
<tr>
<th>Data collection technique</th>
<th>Quantity (number of hours/units)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Observations</td>
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<tr>
<td>Informal interviews</td>
<td>17 interviews</td>
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<tr>
<td>Artifact collection</td>
<td>12 artifacts</td>
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<tr>
<td>Shadowing</td>
<td>15 shadowing sessions</td>
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<tr>
<td>Critical incidents collection</td>
<td>17 critical incidents</td>
</tr>
<tr>
<td>Formal semi-structured interviews</td>
<td>14 interviews</td>
</tr>
</tbody>
</table>

Table 3: Data collection statistics

Here I provide details about each of these data collection techniques:

- **Observations:** Since examining the interactions, behavior, and actions of care providers as they collaborated to understand information was central to this study, observations were the main data collection method. These observations were non-participant because I did not have expertise in the medical domain and could not
“participate” in any medical activities. Even though the focus of the study was collaborative sensemaking, initially I observed individual participants as they carried out their work in general, in order to get a sense of the roles and responsibilities of various actors in the ED. Later observations focused more specifically on collaborative information seeking activities. Observations were conducted by standing in areas of the ED where key activities (such as registration, triage, and room allocation) took place; in busy areas of the ED where interactions between providers occurred frequently; and in places where technological artifacts (such as the whiteboard and computers) were in use. During observations, I took notes using a notebook and pen as these tools proved to be the most mobile and least intrusive for note-taking in the ED. I later transcribed these notes into electronic form. In my observations I noted collaborative information seeking events during both clinical activities such as medication administration, ordering of tests through the computerized order entry system, and diagnosis and treatment of patients and organizational activities such as bed allocation, registration, and billing. I noted interactions between providers as they searched for, shared, and made use of information together. I also observed care providers’ interactions with various information systems used in the ED. I spent a total of 180 hours conducting observations (this included time spent on conducting informal interviews and collecting artifacts).

- **Informal interviews**: During my observations I asked questions to participants to enhance my understanding of what I was observing. For instance, when I noted one end of a conversation on the phone, I waited till the participant hung up to ask them
questions like “who were you talking to?”, “why did they call you?”, and “what will you do with this information?” These interviews often took the form of informal chats with participants as they are working. I noted the answers to my questions, as well as any additional information participants provided about their work.

- **Artifact collection**: I routinely came across various artifacts being used in the ED, specifically paper forms used for various ED processes. I collected these artifacts and asked questions to participants to help me understand the use of these artifacts in their information seeking activities. Collecting and examining various artifacts helped me understand the nature of the work and also the information sources and information flows in the ED. I took photos of artifacts and information systems in use and obtained screen-shots of information systems interfaces.

- **Shadowing**: I shadowed participants over the course of a few hours or their entire shift while noting their information seeking activities. This helped me understand specific roles in the ED (such as nurse, physician) and also how these roles intersected with other roles. For instance, I frequently shadowed the charge nurse because she performed both clinical and organizational functions in the ED and interacted with various other role players during her shift. A typical shadowing session with a charge nurse started with watching the patient hand-off process between her and the outgoing charge nurse at the beginning of the shift. During hand-off, the outgoing charge nurse conveyed her understanding of the current state of the ED to the incoming charge nurse. I then observed the charge nurse as she tried to understand the status of various patients and beds in the ED by going through the electronic medical record and reading the whiteboard. During this process, she
frequently asked questions to other nurses to understand information about patients. Then the charge nurse typically started assigning rooms to waiting patients by walking around the ED, asking other care providers information not available in information systems, and physically checking on availability of rooms. I followed the charge nurse on these “rounds” and observed her interactions with others. I conducted a total of 15 shadowing sessions (7 with the charge nurse, 2 with nurses, 2 with physician assistants, 2 with residents, and 2 with attending physicians). These sessions varied in duration from 30 minutes to 4 hours.

- **Critical incidents collection**: I followed certain events and incidents in the ED from start to finish and observed how different care providers interacted to share and understand information during these events. Critical incidents could be unexpected incidents that occurred in the ED (such as the sudden deterioration of a patient’s condition), critical cases (such as trauma patients) being brought in to the ED, and surges in demand (such as arrival of a large number of motor crash victims due to bad weather conditions). In observing critical incidents, I paid particular attention to how participants collaborated to find and understand information required to deal with these incidents. I observed a total of 17 critical incidents, where these incidents spanned 30 minutes to several hours during the day.

- **Formal semi-structured interviews**: I conducted formal semi-structured interviews with available care providers to gain richer insights into observed information seeking and sensemaking activities. It is hard to ask people how they make sense of situations, because like cognition, people are often not aware of their sensemaking or may not be able to articulate how they make sense of situations. However, I asked two kinds of
questions to help me gain insight into participants’ collaborative sensemaking. First, I asked post-hoc questions about instances where I observed participants collaborating with others to understand information about a particular situation or patient. Second, I asked participants to explain how they understand typical situations that frequently arise in the ED. Such questions were in the context of specific roles of participants in the ED. For instance, a common situation in the ED is the arrival of trauma cases and the charge nurses play an important role in determining the care plan of the trauma patient post-resuscitation. Thus, I can asked the charge nurse the following questions regarding trauma cases:

- What do you do when you receive a call from EMS regarding an incoming trauma patient?
- What kinds of information do you need to gather about the trauma case once the patient has been brought into the ED?
- Who do you collaborate with to find information about trauma cases and to perform your duties with respect to caring for the trauma case?
- What do you do when you do not understand what you need to do with respect to a particular trauma patient?

Asking such questions helped me understand how charge nurses understand the information pertaining to trauma cases and how and why they collaborated with others. I conducted 14 formal interviews with a range of role-players in the ED; 6 were with nurses (including the charge nurse), 4 with physicians (including residents), 3 with administrative staff, and one with a support assistant.
3.3.3 Observing collaborative sensemaking in CIS activities

As I was gathering data using the above techniques, I needed to ensure that I was capturing collaborative sensemaking activities of participants. As noted in Chapter 2, I grappled with the question of “how do I know collaborative sensemaking when I see it?” As a starting point in my data collection, I used the definition of collaborative sensemaking derived from the literature (Sec 2.2), and re-stated here:

“Collaborative sensemaking occurs when two or more people create a shared understanding of information by 1) interacting with others to share individual understandings of information and 2) interpreting others’ interactions with information.”

During information seeking activities, sensemaking is often triggered due to the inability of information seekers to understand the information found or available to them. Thus, the starting point of an instance of collaborative sensemaking often is an individual group member’s inability to understand the information available to her. Dervin (2003) has identified as ‘sensemaking moment’ an instance where an individual moving through time-space faces a ‘gap in reality’. In this study, I identified as sensemaking moments instances where care providers were not able to understand the information available to them during CIS activities and hence were unable to continue their work. Furthermore, if in such instances they interacted with others to improve their understanding of the information, I considered these to be instances of collaborative sensemaking. Thus, in my data collection, I tried to capture instances where 1) one or more care providers were not able to continue their work because they didn’t understand the information found during CIS activities, and 2) care providers worked together to understand the information in order to continue the CIS activity and hence move their work forward. Typical sensemaking instances ‘ended’ when providers were able to fulfill their information need and were able to continue with their work again.
3.4 Data analysis

Data were analyzed using a grounded theory approach (Glasser & Strauss, 1967). Grounded theory is a systematic generation of theory from empirical data. In this approach, the researcher does not start with a-priori hypotheses about the nature of the phenomenon being investigated; rather the goal is to formulate hypotheses or ‘theory’ based on conceptual ideas that emerge from an analysis of the data. Grounded theory is ideal for understanding the nature of social processes like collaborative sensemaking. I observed work practices to gain insight into why and how care providers collaborated for sensemaking, what set apart collaborative sensemaking from individual sensemaking, and what role information and communication tools and artifacts played in collaborative sensemaking. I did not approach my data analysis using any theoretical frameworks but rather identified themes in the data through an iterative process of coding (as described below). Also, I did not have a-priori hypotheses about the motivation for, nature of, and aids for collaborative sensemaking.

In grounded theory, the unit of data analysis is the incident. Several incidents are compared to find relationships between emerging concepts (Glasser & Strauss, 1967). In analyzing my data, the units of analysis were instances of collaborative sensemaking as identified by my working definition. In coding my data, I looked for the following cues:

- Collaborative information seeking: Two or more people were together looking for, sharing, and retrieving information. For instance, the vignette at the beginning of Chapter 1 illustrated the EMS personnel and the registration associate together trying to find the correct medical record number of a patient.
• Shared understanding: During information seeking, the goal of one or more collaborators was to understand information with the help of others and/or to pass on his understanding to others. For instance, often the charge nurse would ask other nurses why a certain patient appeared to have been discharged but the room assigned to that patient showed up as ‘occupied’ in the information system.

• Interactions with others: People interacted (either verbally, or through information and communication tools) to share information and their understanding of the information. This was also illustrated by the vignette in Chapter 1.

• Interactions with information: People observed others’ interactions with information. For instance, a nurse might observe the charge nurse assigning rooms to patients in FirstNet, and this would enhance her understanding of where to find her patient.

Using these cues I identified instances of collaborative sensemaking in the data. These instances were then coded on three levels as explained in the next section.

3.4.1 Coding the data

Collaborative sensemaking instances identified in the data were coded in three steps. The first level of coding was open coding, where a core set of codes was developed by iteratively examining the data. In open coding, the instances of collaborative sensemaking were given conceptual labels (codes). In this way, conceptually similar instances of collaborative sensemaking were grouped together to form categories and sub-categories. Once this core set of categories was developed, axial coding was performed in which the categories were related to subcategories and the relationships were tested against data. Finally, selective coding was performed in which all categories were unified under a “core” category which
represented an important phenomenon/concept that would help answer the research question.

Table 4 provides examples of some of the codes developed with respect to research question RQ1.

<table>
<thead>
<tr>
<th>Research question</th>
<th>Open codes</th>
<th>Selective codes</th>
</tr>
</thead>
</table>
| RQ1: Why do care providers collaborate for sensemaking? | Unclear information  
Missing information  
Incorrect information  
Inconsistent information  
Inconsistent with previous experience  
Inability to interpret information  
Information unavailable  
FirstNet access issues  
Lack of communication  
Role-based access to information  
... | Ambiguity of information  
Role-based distribution of information  
Lack of expertise |

Table 4: Sample codes developed for RQ1 using the grounded theory approach

### 3.4.2 Validity and reliability

The trustworthiness of a research study is often discussed in terms of its validity and reliability. A research study needs to be internally and externally valid. In my study, I triangulated (Lincoln & Guba, 1999) different data sources and methods to achieve internal validity. The data sources used are documents, interview transcripts, observation transcripts, and paper and visual artifacts collected. The different data collection methods are listed in Sec 3.3.2. These data sources and collection methods were used in conjunction with each other to ensure robustness of the data collected. For instance, in order to understand the patient flows in the HMC ED, I first placed myself at multiple locations and tried to gain an understanding of the processes that patients went through depending on their mode of entry into the ED (walk-in or ambulance) and their acuity level (more acute patients are seen first). I further enhanced my understanding of the patient flows by looking at process flow
diagrams provided by the ED Director. Finally, I used member-checking (Mason, 2002) to verify with participants my understanding of the data. In this case, I discussed my understanding of the patient flows with the ED Director during our bi-weekly meetings. I also questioned the participants about these patient flows. Thus, triangulation and member-checking helped increase the robustness of my data.

External validity of the study addresses whether the findings can be generalized across different settings (Lincoln & Guba, 1999) Ethnographic techniques usually present “thick descriptions” of phenomenon occurring in particular settings (Geertz, 1973). In this case, the specific findings about why and how healthcare providers collaborate for sensemaking are particular to the HMC ED. However, my goal was to find the general in the particular. In other words, I wanted to identify some of the general features of collaborative sensemaking in groups through the descriptions of particular sensemaking events occurring in the HMC ED.

Finally, the reliability of a study is judged by consistency and accuracy of methods used. One of the limitations of this study is that I was a single researcher recording data and hence could not check my assumptions and biases by comparing notes with other researchers. However, in order to increase the reliability of the study, I ensured a prolonged period of engagement in the field (i.e. two years), persistently taking notes and transcribing them immediately, and using triangulation and member-checking to ensure the accuracy of my observations.

This chapter provided an overview of the study design for my study of sensemaking in the CIS activities of healthcare providers in the hospital ED. I described the rationale for choosing qualitative methods, the process of site selection, data collection and data analysis.
The next chapter provides organizational background about the HMC ED, including details about study participants, nature of work in the ED, and how collaborative information seeking takes place during the clinical and organizational activities of healthcare providers in the ED.
4. Study 1: Organizational Background

In this chapter, I describe the ED including details about the ED staff and layout, patient flows, information and communication tools, and descriptions of CIS activities in the ED.

4.1 The ED at the Penn State Hershey Medical Center

The Penn State Milton S. Hershey Medical Center (HMC) is a 500-bed teaching hospital affiliated with the Penn State University. HMC is one of seven academic health centers in Pennsylvania and serves about 1.5 million people living in central Pennsylvania. Located in the town of Hershey, it houses the Penn State College of Medicine, a teaching hospital, a children’s hospital, and a research center. HMC annually admits nearly 26,000 patients and conducts nearly 740,000 outpatient visits (HMC, 2004).

The major role of the ED is to provide care for acutely ill and injured patients 24 hours a day, 7 days a week. By law, all patients arriving at an ED must be provided with medical screening and stabilization of their conditions, irrespective of their ability to pay (Lee, 2004). As a result, EDs provide care not only for acutely ill patients but also for underserved populations who have no other options for medical care because of various socioeconomic barriers (Trzeciak & Rivers, 2003). Thus, the ED is the ‘safety net’ of the healthcare system due to its role in providing care to uninsured, indigent and otherwise vulnerable patients (Altman, 2000; IOM Committee on the Changing Market, 2000).

One of the main problems facing emergency departments over the last decade has been overcrowding and today this problem has reached crisis proportions (Derlet, 2002; Derlet, Richards, & Kravitz, 2001; Institute of Medicine, 2004; Richardson & Hwang, 2001; Trzeciak & Rivers, 2003). Between 1993 and 2003, ED visits increased by 23.6 million,
while at the same time 425 EDs closed and total hospital beds declined by 198,000 (IOM, 2006). ED overcrowding leads to excessive numbers of patients in the ED, patients being treated in hallways (Derlet et al., 2001), ambulance diversions (Fatovich & Hirsch, 2003), long patient wait times, and patients leaving without treatment. Overcrowding has also been found to lead to increased medical errors (Trzeciak & Rivers, 2003), poor patient outcomes (Derlet & Richards, 2002; Sprivulis et al., 2006), high levels of stress among ED staff, and decreased capacity of EDs to respond to mass casualty incidents (IOM, 2006). Overcrowded conditions are frequent in most EDs today, and make the work of care providers difficult and stressful.

The ED is a high-reliability organization. High-reliability organizations are marked by an accurate, precise, and commonly held understanding about current operations and the relationship between those operations and potential accidents (Albolino et al., 2007). Information plays a key role in such high reliability organizations, not only for performing the work but also to ensure safety. The work of care providers in the ED is a mix of clearly defined, well-structured work, such as that of military training teams, and ill-structured problem-solving, such as that of emergency response teams. Finally, work in the ED is highly collaborative in nature and providers often form patient care teams. Although care providers may be assigned to patient care teams, they often form ad-hoc groups and collaborate across these teams. Collaborative work is a mix of face-to-face collaboration and distributed collaboration using various communication tools such as phones and pagers.
The ED at HMC has 37 beds and sees more than 50,000 patients every year (HMC, 2004). The ED is a Level I Trauma center\(^4\) and is the only Level 1 pediatric trauma center in central Pennsylvania. The Penn State emergency medicine residency program was started in 2004 and residents receive training in clinical research along with opportunities to train with the pre-hospital services of LifeLion and UEMS. The following section provides details about the pre-hospital services that interface with the ED as well as details about the ED, such as the physical layout, important roles and responsibilities of healthcare providers, patient flows, and technology used.

### 4.1.1 Pre-hospital services

The pre-hospital services or the EMS organizations play an important role in transport of patients into and out of the ED and hence an understanding of the EMS is important to gain a holistic picture of work in the ED. The ED at HMC is serviced by two emergency medical services (EMS) – the LifeLion air-medical service (HMC, 2004), and the UEMS ground advanced life support.

The LifeLion critical care transport service consists of medical transport specialists who transport ill and injured patients to the HMC ED. Two medically equipped helicopters and a pediatric mobile intensive care ground ambulance are the key components of LifeLion. The flight team on helicopters is comprised of a pilot, nurse, and paramedic; the ambulance teams consist of an emergency medicine technician (EMT) driver, nurse, and paramedic. LifeLion covers a 15-county South-Central Pennsylvania region. About 50% of the patients transported by the LifeLion service are trauma victims from motor-vehicle accidents, farming

\(^4\) HMC is accredited as a Level I Regional Resource Trauma Center by the Pennsylvania Trauma Systems Foundation. Trauma patients are the most severely injured patients (eg. motor accident victims) coming to the ED and are seen by a multi-disciplinary team led by a surgeon specializing in trauma management. Source: [http://www.hmc.psu.edu/trauma/](http://www.hmc.psu.edu/trauma/)
or industrial accidents, falls, and assaults. The rest are patients requiring transport from one healthcare facility to another.

The University Emergency Medical Services system (UEMS) is an Advanced Life Support (ALS), Basic Life Support (BLS), and Mobile Intensive Care Unit (MICU) system which services the local community surrounding HMC. The service has nine ALS-equipped ambulances used to transport patients from the hospital or another care facility to other locations such as homes or doctors’ offices.

4.1.2 ED physical layout and staff

Within the ED, there are 27 private rooms and a clinical decision unit (CDU) with 8 observation beds (Figure 5). Patients are kept in the CDU if they are under observation or if they are awaiting a hospital bed. There are 2 trauma resuscitation bays – trauma A and trauma B. These are rooms equipped with advanced medical equipment to treat trauma patients. In addition to beds in rooms, there are several ‘hallway beds’, i.e. beds placed in hallways to accommodate patients when rooms are full. Finally, an important room in the ED is the communications center. This room is occupied by members of the Life Lion EMS. Communications center personnel manage communications between incoming and outgoing EMS units (ambulances and helicopters) and the ED. They often alert the ED about trauma patients being brought in or put paramedics on incoming EMS vehicles in contact with physicians to guide the transport of difficult cases.

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5 Figure 4 shows the physical layout of the HMC ED during the period of this study (Jan 2007 – Dec 2008). Several construction projects were undertaken while the study was in progress; hence the current physical layout of the ED differs significantly from that depicted in this thesis.
Figure 5: Layout of the emergency department at HMC

There are three care teams in the ED – the red, white, and blue teams – with separate physical coverage of the ED. The clinical staff in the ED comprises attending physicians, housestaff physicians (e.g. residents), physicians’ assistants, nurses, and nurse practitioners. The non-clinical staff includes emergency medicine technicians (EDTs), registration associates (who perform administrative jobs such as registration, billing), support assistants, and housekeeping.
The three teams are each headed by an attending physician and have 1-2 residents and 3-4 nurses assigned to them at any time. Assignments to the teams are not fixed and different nurses and residents might serve different teams on different days. At any time, there are 1-2 triage nurses who assess walk-in patients to determine their level of acuity (1-5). Lower acuity levels are assigned to more urgent cases. Hence, an acuity level of 1 indicates the most urgent case. Patients with lower levels of acuity are seen before those with higher acuity levels.

The participants in the study were nurses, attending physicians, residents, physicians’ assistants, EMTs, and support assistants. I chose these staff members as they are the most important role players involved in patient care and are involved in most information seeking activities in the ED. I provide an overview of the roles and responsibilities of each of these participants.

4.1.2.1 Nurses

There are usually 16 registered nurses (RNs) on duty during any shift in the ED including the charge nurse and the two triage nurses. The charge nurse assigns the rest of the 13 RNs to the red, white and blue teams. Typically, each RN is in-charge of 3-4 patients at one time. The charge nurse is the head nurse in the ED and coordinates patient care of the entire ED. The responsibilities of the charge nurse include assigning nurses and rooms to patients, distributing the patient caseloads as evenly as possible between nurses; resolving interpersonal problems among staff; adjusting staff according to changing workloads; and projecting staffing needs for oncoming shifts. Apart from this, the charge nurse takes part in direct clinical care of patients by setting up beds and equipment and physically examining patients, among other patient care activities. Bed management is one of the key
responsibilities of the charge nurse; she moves patients between rooms, hallway beds, and the clinical decision unit based on their acuity level and the resources available.

4.1.2.2 Physicians

There are three attending physicians in the ED at any time, one physician per team. The attending physician performs a physical assessment of the patient and diagnoses the patient’s conditions. He may order lab tests, x-rays, and CT scans. Since HMC is a teaching hospital, attending physicians also teach residents about emergency care. Residents are physicians in-training. They have completed medical school and use the residency to learn the practical aspect of clinical work. Typically 3-4 residents are assigned to each of the three teams in the ED and they perform assessment and treatment of patients in collaboration with the attending physicians on those teams.

4.1.2.3 Registration Associates

The registration associates perform administrative duties such as registering ambulance and walk-in patients and filling out paperwork for billing patients and EMS units. Typically, one associate performs mini-registration of walk-in patients before they are triaged by the triage nurse while two associates are assigned to registration of ambulance patients.

4.1.2.4 Various support staff

Non-clinical support staff plays an important role in patient care. ED technicians perform non-clinical duties like entering data, transporting patients within the ED, setting up medical equipment in patient rooms. Housekeeping services clean rooms and beds. There is usually a support assistant who acts as a link between patients and the nursing staff. She makes sure patients are comfortable, talks to family members and occasionally helps nurses move beds and equipment.
4.1.3 Information and communication tools in the ED

There are computers located in all areas of the ED and most important patient care activities such as patient registration, billing, ordering of medications and lab tests, discharge are done electronically. The ED uses an electronic medical record called Eclipsys, which is integrated with the hospital-wide information system Connected™. The Connected™ portal in the ED is called FirstNet.

4.1.3.1 FirstNet

The computerized provider order entry system, FirstNet, plays an important role in the ED. Physicians enter orders for patients through FirstNet which provides standardized patient order sets. Also, notes and verbal orders can be dictated into the FirstNet system. Nurses document their care process online, often by using computers present in patient rooms. With FirstNet, nurses and physicians in the ED have a consistent view of all patient care information. The FirstNet interface (Figure 6) is pervasive in the ED; it is displayed on large overhead displays in all main areas and is available on all computers (Figure 7).

When a provider logs into FirstNet, they see the FirstNet interface, which contains tabbed views of patient information. The “All beds” tab (Figure 6) displays a list of all patients in the ED in a spreadsheet-like layout, with the following information available about each patient: Bed number, triage level (1-5), name of patient, age, chief complaint, RN (nurse assigned to the patient), Cos (co-signee for the resident. Residents cannot order drugs, an attending has to co-sign on medications residents order), MD (attending physician assigned to the patient), RES (resident), events, lab, radiology, comments, LOS (length of stay). For each patient, the ‘lab’ and ‘radiology’ columns show how many orders were sent and how many of them have been received. When an order is entered for a patient, it creates an event
in the ‘Events’ field of that patient’s record. Events provide a history of the medications ordered, procedures performed, as well as any other significant information such as insurance etc. Events appear as icons in the ‘events’ field of the FirstNet interface.

Figure 6: Screenshot of the FirstNet interface showing the tab “all beds”

Figure 7: Care providers in the ED  
Figure 8: Whiteboard in the ED
4.1.3.2 Whiteboard

The whiteboard (Figure 8) is situated in the central and busiest area of the ED. It is primarily used by the charge nurse (who is the head nurse in the ED) to assign patients to nurses and by the nurses to keep track of patients assigned to them. The whiteboard lists the names of the charge nurse, the triage nurses, the attending physicians and all the other nurses in the ED, along with their phone numbers. It is divided into three parts, one each for the red, white, and blue teams. For each team it lists the names and phone numbers of the nurses on that team (Figure 8). Stickers with room numbers are placed next to each nurse’s name to indicate the patients assigned to her. Thus, the whiteboard provides a snapshot of the state of the ED at any time. The whiteboard plays a crucial role in the ED in scheduling of resources and information sharing between providers.

Figure 9 shows what the whiteboard looks like on any given day. The whiteboard is primarily used by the charge nurse to assign patients to the nurses. When the charge nurse makes a room assignment to a patient, she simultaneously updates the whiteboard by placing a magnet with the room number of that patient under the name of the nurse in-charge of that patient. This lets the nurses know at a glance, without logging into the system, when they have been assigned a new patient. The whiteboard also lists the names of the nurses for each shift. At the end of a shift, charge nurses move the magnets of the nurses for the next shift to the red, white, blue areas of the whiteboard. While in some hospital units the whiteboard is used to provide patient information (name of patient, room, MD, RN, treatment details etc) (Bardram & Bossen, 2005), in the HMC ED, this information is displayed via the FirstNet interface. Interestingly, the whiteboard is used in spite of the FirstNet system, to provide an alternative representation of the information contained in FirstNet.
Figure 9: Diagram of the ED whiteboard.
4.1.3.3 Paper

Along with the variety of computer-based technologies available in the ED, paper is an important information tool. When talking to other providers on the phone, doctors and nurses frequently note information onto paper charts, Post-it notes, and paper forms. These paper artifacts are later used to transfer the information to digital form or to share the information with others.

Paper plays an important role in trauma cases. When registration staff is alerted about an incoming trauma patient, they print sheets containing temporary patient numbers such as “TRAUMA 75000052” and stick the sheets on the doors to the trauma room. This helps providers know which trauma room a particular patient is in. Once the trauma patient has been stabilized, the patient is moved to a regular ED room and a similar piece of paper is stuck to the door of this room. Also, in the first few minutes of treating a trauma case, patient information is mostly noted on paper forms.

Paper artifacts displayed at various locations in the ED serve as reminders or reference material for staff. For instance, a paper sheet stuck to the charge nurse computer says “Charge nurse, ask the previous shift charge nurse ‘Is anyone in restraints?’. Please remember to do all your shift checks on carts, pyxis, I-stat.” This reminds the charge nurse of her duties. Finally, to handle excess ED patients, several beds have been placed in the hallways and are referred to as ‘hallway beds’. Since these beds are not in numbered rooms, pieces of paper bearing numbers have been stuck to the wall above the beds. Unlike room beds, hallway beds are not tracked by the FirstNet system. So, housekeeping staff sticks paper with “clean” written onto the beds to indicate that they are ready to be used.
4.1.3.4 Pagers and phones

Like other hospital staff, pagers are an important communication tool for ED care providers. The registration staff carries pagers. They get paged when a patient is ready to be registered (admissions pager) and they also get paged regular updates on the status of incoming trauma patients (trauma pager). The ED physicians carry pagers but not the nurses. Also, physicians and nurses in the ED have special internal mobile phones, similar to cell phones. During the study period, this phone system was in the initial stages of deployment and so phone numbers were assigned everyday. Thus, the phone numbers for the charge nurse, the triage nurse, and the attending physicians were updated everyday on the ED whiteboard and sometimes entered into the FirstNet system. The phones are used by the providers to call each, as well as used by the EMS personnel to get in touch with the charge nurse.

4.1.4 Patient and information flows in the ED

In order to understand information work in the ED, it was important to understand the information flows. These information flows were intricately intertwined patient flows and hence I spent some time observing the patient flows in the ED while noting how and where information seeking took place within these flows. Here I provide a brief description of these patient flows and how information is integral to the steps in these flows. I also point out how the FirstNet system is used during these steps.

ED patients can be categorized along various dimensions and different EDs have different ways of categorizing patients. Based on their category, patients follow different paths through the ED. In the HMC ED, there are two kinds of ED patients based on the mode of entry – walk-in patients and ambulance patients. Also, severely ill or injured patients, brought in via private vehicle or ambulances, are called trauma patients.
4.1.4.1 Walk-in patients

Walk-in patients are those who arrive at the ED via private vehicle instead of being brought via an EMS service such as LifeLion. These patients undergo the following steps in the care process – registration, triage, room assignment, nurse assignment, physician assessment and discharge. Registration typically begins with a mini-registration of walk-in patients when they enter the ED. During mini-registration the patient’s medical record, if it exists in the Eclipsys system, is accessed (or a new record is created) by a registration associate and patient details are entered into FirstNet. The registration associate prints paper forms for the patient’s paper chart and then the patient waits in the waiting room for the next step of the process, triage. A more complete registration process takes place later when the patient has been allocated a room.

The triage nurse performs a preliminary assessment of the severity of the patient’s condition and place the patient in a room. She asks questions to the patient regarding his chief complaint, pre-hospital treatment, medical history, current medications etc. and then physically examines the patient to note vital signs. The nurse enters information into the triage form in FirstNet and the patient’s name drops from the Triage tab and appears in the Registration and Waiting tabs. If a room is available the triage nurse assigns the room to the patient and the patient waits to be taken to the room. When a room is not available, the triage nurse can order x-ray, labs, EKG, and IV medications through the FirstNet system and the patient is taken for tests or test samples are collected while the patient waits.

Rooms are primarily assigned by the charge nurse who is physically located in the main area of the ED. The charge nurse monitors the list of waiting patients in FirstNet as well as the list of occupied rooms/beds. As soon as a bed becomes available she assigns it to a
waiting patient and now the patient appears in the red, white or blue team tab in FirstNet. The charge nurse tells an EDT to bring the patient from the waiting room to the assigned room. Once the EDT has transported the patient to the room, he lets the charge nurse know and the charge nurse assigns a nurse to the patient. She also makes the changes on the whiteboard to reflect the nurse assignment.

The nurse assigned to the patient physically assesses the patient and charts her assessment on-line in FirstNet. She places orders in the Orders tab and the orders appear in the MD box for signature by the attending physician. The nurse then draws samples for lab tests and also performs bedside tests. Once all tests are done the physician views the results of the tests to diagnose the patient’s condition.

When the charge nurse assigns a bed to the patient, the MD icon launches in FirstNet and usually a resident or Mid-level Practitioner (MLP) assesses the patient (this may be along with an attending physician) and then the resident presents the case to the attending. The attending reviews the case, along with test results, and signs the online assessment form which completes the assessment of the patient. Once the patient assessment is completed, the patient can either be kept further in the ED for observation or the patient may be discharged from the ED. A discharged patient may be admitted to the hospital for further treatment or may be sent home directly.

### 4.1.4.2 Ambulance patients

The flow of ambulance patients differs from that of walk-in patients in terms of how they arrive in the ED and how they are placed in a room. When an ambulance patient is being brought in via EMS services, often the EMS personnel call the charge nurse while they are on their way to the ED and the charge nurse finds a room for the patient. When the patient is
brought in, the charge nurse asks the paramedics some of the triage information that the triage nurse asks the walk-in patients. The EMS personnel tell the charge nurse as much as they know and she notes it on paper triage forms. Next, the EMS personnel place the patient in the room. Since ambulance patients are frequently too ill to talk, the EMS personnel provide the registration associates with details about the patient’s conditions, history, how and where they found the patient and other information that they might have. The registration associates use this information to register the patient and give the EMS a copy of the face sheet which they need for billing purposes. Once the patient is placed in the room, the process of assessment and discharge is the same as for walk-in patients.

4.1.4.3 Trauma patients

Trauma patients can be brought in by private vehicle but are usually brought in by EMS personnel. These patients are the most severely ill or injured patients seen in the ED and are usually victims of motor vehicle accidents, farming or industrial accidents, assaults, etc. They require immediate resuscitation and are attended to in the trauma bays by specialized 16-person trauma teams. The registration of trauma patients takes place in a way different from non-trauma patients. Since time is of the essence in treating trauma patients, they are assigned temporary trauma numbers such as “TRAUMA 750XXXX” upon arrival, which is then entered in FirstNet, along with the little information that can be gleaned from EMS personnel, so that their orders can be started. A paper with “TRAUMA 750XXXX” written in big letters is stuck on the door of the trauma bay in which the patient is being treated. Later the registration staff tries to find out as much information about the trauma patient from EMS personnel as she can to complete the registration of the patient in FirstNet. More information is obtained from family members when they arrive. Once the trauma patient has been
stabilized, tests such as MRIs and x-rays are performed and the patient is either taken to another unit (such as surgery) or moved to a room in the ED.

The descriptions of the flows of different types of patients in the ED helped me understand how information flows and the information artifacts used in the work of care providers.

4.2 Collaborative information seeking in the ED

The preceding sections provided an overview of the physical layout of the ED, the care provider roles, the important information and communication tools used, and the patient and information flows. This section highlights the nature of work in the ED with a specific focus on the information seeking activities of healthcare providers. There are two main categories of collaborative work activities in the ED – clinical and organizational. These two types of activities are intertwined and conducted in parallel during a patient’s stay in the ED. Clinical activities relate to providing medical care to the patient, from diagnosis to stabilization of his conditions such that the patient can be either sent home or admitted to the hospital. Organizational activities typically include bed management, nurse allocation, allocation of medical equipment, and shift assignments for care providers, patient registration, billing, discharge, and charting.

Information plays a key role in collaborative work activities in the ED. The ED deals with a variety of medical cases and fluctuating patient demand; hence, care providers are constantly faced with novel situations. The time-criticality of patient care make it imperative that seamless and effective collaboration take place between various actors having different expertise and skills. Furthermore, this collaboration is centered on finding and making sense of information. ED care providers encounter both information overload and information
Information overload occurs due to the variety of information sources (such as other
care providers, auxiliary health services, and paper and electronic artifacts) and types of
information (such as patient’s medical history, details about injury or illness, and results of
tests ordered) that healthcare providers need to assimilate in their work. Information scarcity
occurs due to the inability of critically ill patients to provide information about the nature and
cause of their illness. Thus, care providers often collaborate to find and understand
information. I observed CIS during both clinical and organizational collaborative work
activities. The first vignette highlights how physicians collaboratively diagnosed a patient
while the second describes how an EMS member and a registration associate determined a
patient’s room number.

Vignette 1

Resident R1 is telling doctor D about a patient who has a history of asthma and fell on his right
side. A few days after the fall, the patient was in gym class and experienced shortness of breath
and pain near his ribs. D asks R1 what the differential diagnosis is. R1 says that though the
patient’s history and symptoms indicate pneumothorax but she doesn’t think that it is. D asks her
why and R1 gives him a couple of reasons, but D is not satisfied with her reasoning.

Resident R2, who had been following the conversation, tells R1 and D that it is unlikely to be
pneumothorax because the patient is experiencing pain near the ribs whereas in pneumothorax the
pain occurs near the collar bone. R2 suggests it is more likely a fracture. Following this cue, R1
and D together look at the patient’s x-rays results. They find anomalies in the x-rays that might
indicate a fracture. D concludes that the patient is probably negative for pneumothorax.

R1 feels the need for more information to confirm their diagnosis. She calls radiology to ask what
the anomalies in the x-rays are. Radiology confirms that the anomalies are fissures.
D and R1 conclude that the patient is “negative for pneumothorax”

Healthcare providers often collaboratively diagnose a patient by finding and understanding
different types of information. Here, R1 tells D the patient history information and they try to
understand whether the information indicates a diagnosis of pneumothorax. R2, who has
been listening to their conversation, suggest the possibility of a fracture. R1 and D follow up
on this suggestion and look for further information (x-rays) that they discuss with radiology
personnel to eliminate the diagnosis of pneumothorax.
Vignette 2

An EMS member, EM1, is trying to find the patient he just brought in. He comes up to the secretary, SC, and asks her: “Do you know the Trauma Number of the patient that just came in?” SC looks through FirstNet to see if any patient records contain a ‘TRAUMA 750XXXX’ number. This is a temporary number that is assigned to trauma patients. She sees only one such record, a patient in room Trauma A. She points to it asking, “That the one? Came in 30 minutes ago?”

EM1: “No, this just came in a few minutes ago. 17-year-old motor vehicle accident.”

SC, not finding any other record with the TRAUMA 750XXXX number, asks the registration associate, RA1, “Is the patient in Trauma A 17-year-old MVC (motor vehicle crash)?”

RA1 (to SC): “I don’t know but I don’t think we got any other traumas.”

SC: “Nah. Then that must be the patient.”

EM1, after listening to this conversation, concludes that the patient in Trauma A is the one he is looking for.

Here, EM1, SC, and RA1 collaborate to find the location of a patient. SC finds information in FirstNet to answer EM1’s question but is not sure if this is indeed the correct information. To verify, SC asks RA1 a different question, i.e. whether the patient in Trauma A is a 17-year-old motor crash victim. While RA1 doesn’t know the specifics of the patient in Trauma A, she provides the information that they haven’t received any other trauma patients recently. This leads all parties to conclude that this is the patient they are looking for.

These vignettes highlight that CIS consists of an iterative pattern of searching-sharing-sensemaking-searching of information, until the right information is found. CIS activities in the ED started with an information need that required multiple workers to search for information. As care providers shared information found, they also tried to make sense of the information together, and based on their understanding of the available information their information need evolved. For instance, in the first vignette, the information need that D and R1 started with was “Does the patient have pneumothorax?”, When R2 made sense of the information about the patient’s symptoms to suspect a fracture instead, the information need
evolved into “What do the anomalies in the patient’s x-rays indicate?”. This led the care providers to consult with radiology. Similarly, in the second vignette, EM1 began with the information need “What is the trauma number of the patient just brought in?” However, as he and SC found and made sense of information in FirstNet, this information need evolved into “Is the patient in Trauma A the patient we are looking for?” which further evolved into “Did we get any other trauma patients in the last few minutes?”

Thus, as group members collaborated on information seeking tasks, they iteratively searched for and made sense of information and refined their information needs accordingly. In the next chapter I focus on the sensemaking part of this process and describe when, why and how it occurred during CIS activities.

As this chapter illustrates, the ED is a highly collaborative environment where the work of healthcare providers involves finding and making sense of information from a wide variety of sources. Here I provided insight into the information work in the ED at HMC, highlighting the role players and the information sources and tools they use in their work. The vignettes presented above from my field notes show that seeking information, sharing it with others, and making sense of it is an important aspect of emergency care. In the next two chapters I delve deeper into the sensemaking aspect of the information work in the ED. The next chapter highlights the occasions for sensemaking during CIS activities in the ED and some important characteristics of collaborative sensemaking.
5. Study 1: Findings

In this chapter, I present findings from the study of sensemaking in the emergency department. I first address the question “why does collaborative sensemaking takes place during CIS activities?” by discussing occasions for collaborative sensemaking. Next, I address the question “how does collaborative sensemaking occur during CIS activities?” by highlighting the following salient characteristics of collaborative sensemaking:

- Persistence and sensemaking trajectories
- Prioritization of relevant information
- Activity awareness

5.1 Occasions for collaborative sensemaking

During CIS activities, making sense of information is often closely intertwined with finding and retrieving information. I was interested in exploring the reasons why people collaborate for making sense of information during CIS activities. I found that collaborative sensemaking occurred due to ambiguity of available information, role-based distribution of information, and lack of expertise.

5.1.1 Ambiguity of information

One of the key reasons for care providers to collaborate during information seeking activities was ambiguity of the information found. Ambiguous information is information that is unclear or that can be interpreted to have multiple meanings. Weick (1995) has discussed ambiguity as an important occasion for sensemaking in organizations. I found that ambiguity often triggered collaborative sensemaking during CIS activities. The vignette presented in
Chapter 1 illustrates an instance where collaborative sensemaking occurred because of ambiguity of information. In that vignette, RA2 encounters ambiguous information, namely two different medical record numbers for the same patient. She consults EM2 who, given his experience with transporting patients to multiple hospitals, suggests that the discrepancy might be because the patient was treated at another hospital. On this cue, RA2 consults Eclipsys and finds additional information (the patient’s record) that confirms that this is indeed the case. To confirm her understanding, she asks EM2 for the patient’s address information. Similarly, in the pneumothorax patient’s case (vignette 1 in section 4.2), the patient history and symptoms seemed to indicate a diagnosis of pneumothorax. However one piece of information, namely the location of pain, was ambiguous because it did not fit with this diagnosis. Noticing this ambiguity was crucial to the sensemaking process.

Ambiguity of information typically arose due to various reasons: inadequate information was available, time and attention were lacking, and information was fragmented across group members. There were several cases in which information required to perform a task was not adequate because critically ill patients were not able to provide information about their illness or injury. Additionally, due to the fast-paced environment of the ED, care providers often found it hard to understand the limited information available because of lack of time or ability to pay attention. For instance, there was one case where a hemophiliac patient was brought in and he was crying in pain due to internal bleeding from a fall. He needed to be immediately treated so the bleeding could be stopped. This time pressure, coupled with the inability of the patient to provide information due to his critical condition, led to a situation where adequate information about the patient’s condition was not available at the time of starting his treatment. The charge nurse, the EMS personnel who brought the
patient in, and the nurse in-charge came together to discuss the limited information they knew in order to understand the patient’s case, the cause of his pain, and the best way to treat him.

Finally, ambiguity of information arose because information was spread out across different care providers who might each have a different understanding of the “big picture”. To deal with such ambiguity, fragments of information had to be synthesized across different group members to create a shared understanding of the information available. The next subsection on role-based distribution of information discusses this in more detail.

5.1.2 Role-based distribution of information

Often care providers felt the need to engage in collaborative sensemaking during information seeking activities because information was not distributed equally among team members; rather the information was distributed based on team members’ roles. Different team members, depending on their roles, had access to different pieces of information and hence had different understandings of the situation. The vignette below illustrates how role-based distribution of information led to an occasion for collaborative sensemaking:

Vignette 3:

The house manager comes over to talk to CN1 about an ED patient who has been recently assigned a floor bed. The house manager is responsible for overseeing that appropriate beds are assigned to patients and patients flow smoothly between different hospital units. The house manager asks CN1, “What’s going on with your patient X? He went from floor to IMC to ICU to IMC and back to the floor?”

CN1 reads the patient’s record in FirstNet. She finds that the patient was originally admitted to a hospital in Florida for surgery. He was then admitted to the ED here and was transferred between several hospital units. This is surprising to CN1. But since she doesn’t have access to the detailed medical history of the patient, she is not able to make sense of the information about his transfers and hence unable to answer the house manager’s question.

CN1 finds the ED nurse in charge of the patient, RN1, and asks her: “Hey, what’s with 11? Went from Florida IMC to SICU to floor?”

RN1 looks through her nursing notes and tells CN1: “She had surgery but then had hernia, which sent her to the ED. Now she’s been assigned to the floor.” RN1 tells CN1 the details of the
patient’s history which make it clear why the patient was moved between so many different hospital units.

CN1, who now knows the patient’s medical history, explains to the house manager why the patient had the particular trajectory. Once the house manager understands the patient’s complicated history she authorizes the patient’s move to the floor bed.

In this vignette, different people had access to different pieces of information based on their roles. The house manager had access to the transfer history of the patient but not his medical history. So she was not able to understand why the patient had followed an unusual path through the hospital system and hence was not able to decide whether the patient should be assigned to the floor bed. The charge nurse had access to more detailed information about the patient’s transfers and also information about the surgery in Florida but did not have detailed medical history. The nurse in charge of the patient had access to detailed patient history which she had obtained during her physical examination of the patient. The different role players had to collaborate to put together these pieces of information to understand why the patient had followed an unusual path through the hospital system and whether he was now appropriate for a floor bed. In general, due to their varied roles care providers often had access to different pieces of information relevant to a given situation. For instance, the charge nurse had information about the availability of rooms and the caseloads of nurses, the physicians had information about the patient’s diagnosis and condition, and the registration associates had information about the patient’s past history and financial information. During a CIS activity involving multiple role players, sensemaking consisted of synthesizing these different pieces of information and forming a shared understanding.

Studies of information seeking and sensemaking have found that group members’ roles are important for how information is found and shared. For instance, during the Mann Gulch disaster, breakdown in the role structure of the group of firefighters led to breakdown in sensemaking (Weick, 1993). Researchers developing CIS tools have also emphasized that
there can be several kinds of roles in CIS tasks such as that of peers, search or domain expert, search or domain novice, and prospector/miner roles (where the prospector searches broadly while the miner searches deeply) (Golovchinsky, Qvarfordt, & Pickens, 2009). In these studies, the roles were either driven by group members’ knowledge levels (e.g. expert vs. novice) or derived ad-hoc by decomposing the information seeking task into sub-tasks and having different group members handle different sub-tasks (e.g. during a generic collaborative Web search task). In the ED, roles were either based on the organizational hierarchy or defined by specialized knowledge. Hence putting together information available across multiple role players was a challenge during CIS activities. This has important implications for the design of collaborative information retrieval tools for supporting information seeking and sensemaking in organizational settings where information is distributed based on organizational roles.

5.1.3 Lack of expertise

The lack of expertise has been found to be an important trigger for collaboration during information seeking activities (Reddy & Spence, 2008) and I found that it often required participants to engage in collaborative sensemaking. While role-based information led to lack of adequate information being available with individual team members, sometimes adequate information was available but hard to understand due to lack of expertise of individual team members. When a single care provider lacked the expertise to make sense of information pertaining to a situation, he often called on the expertise of other team members. This was especially true in the ED where multidisciplinary teams consisting of emergency medicine physicians, physicians from other specialties, nurses, and various specialized support staff are involved in caring for patients. In the following example the charge nurse and the physician’s
assistant seek the expertise of a specialist to understand why a patient was reacting unfavorably to given medication:

**Vignette 4:**

The charge nurse comes up to the physician’s assistant, PA, and asks her whether the patient in room 18 needs to be admitted to the hospital. PA looks through the patient’s information in FirstNet by reading through the history and notes. She finds that the patient, a 3-year old, has been vomiting up his medication. This is a cause for concern for PA. She asks the charge nurse if she has any idea why the patient is vomiting up the current medication and if they should change the dosage.

The charge nurse says she has no idea because with kids she is unsure of the dosage to assign for the given medicine. PA and the charge nurse decide to call the Pediatric resident on-call to help them understand this patient’s case.

The Pediatric resident is here and PA is telling him about the case. After PA tells the resident about the patient’s tendency to vomit the medication, the resident asks for the patient’s lab results. On going through the patient’s lab results, the resident tells PA to switch the patient to a different medication since the current one is known to cause nausea in patients like this one.

The charge nurse and the physician’s assistant were unable to understand why the patient was vomiting up the medication. They consulted a pediatric specialist who used his expertise to interpret the lab results and came to the conclusion that the medication needed to be changed. Similarly, residents often came across patient information in FirstNet (e.g. “why have these tests been ordered for this patient?”) that they needed the expertise of attending physicians to understand. I also noted instances of collaborative sensemaking arising from lack of expertise during non-clinical activities. For instance, during bed management activities, charge nurses would often encounter information in FirstNet that they needed the expertise of attending physicians to understand in order to assign the appropriate kind of bed to the patient.

There are two kinds of expertise that are required during information seeking activities – domain expertise and search expertise. Domain experts are those who have specialized domain knowledge and can help those lacking expertise in that domain to understand information (Golovchinsky et al., 2009) Search experts are those skilled in the process of searching for information, that is they have superior procedural search knowledge
(Bhavnani et al., 2003). I found that during CIS activities, combining both domain and search expertise led to success in collaborative sensemaking. Some care providers had domain knowledge which they contributed to help others interpret information better (as in the case of vignette 4 above). Other care providers were skilled in the process of finding information. They knew where to find a required piece of information, the relative importance of information sources to a given information need, and often the right organizational “channels” to go through in finding a piece of information.

Both domain and search experts were often called upon to help with understanding information during the information seeking process. For instance, the resident found out that her patient was not reacting favorably to the drug that had been prescribed by the specialist consulting on the patient’s case. He asked the charge nurse where he could find information about alternative drugs. The charge nurse knew where to find information about drug alternatives and pointed the resident towards some information sources. Once the resident had found alternative drug information, he came back to the charge nurse to ask her which of the alternatives she would suggest for the patient. The charge nurse was not sure and told the resident to consult the specialist who was involved in this case. While the charge nurse had search expertise and could point the resident towards information sources, she did not have the domain expertise to be able to interpret the information found by the resident. The specialist provided the domain expertise needed to help the resident understand the information about the drug alternatives. Thus, both domain and search expertise were often combined during collaborative sensemaking activities.

In summary, occasions for collaborative sensemaking during CIS activities were determined by the quality of the information (such as ambiguity), how the information was
distributed (such as role-based distribution), and the characteristics of group members (such as their roles and levels of expertise).

5.1.4 Collaborative sensemaking in ‘routine’ vs. ‘problematic’ situations

Healthcare providers collaborated to understand information both during routine and problematic situations in the ED. Routine situations were those that occurred often and were closely related to routine tasks. For instance, several of the observed collaborative sensemaking instances arose during patient handoffs (or shift changes between providers). Vignette 6 is an instance of collaborative sensemaking during handoff. Situations like handoffs require transfer of patient information from one healthcare provider to another, and hence handoffs were a routine situation requiring collaborative sensemaking. Other routine situations during which collaborative sensemaking took place were diagnosis and treatment of patients (e.g. vignette 1), patient registration (e.g. the vignette in Chapter 1), and patient transport (e.g. vignette 8).

Problematic situations were situations that did not occur often and were “out of the ordinary”. Collaborative sensemaking often occurred in these situations because such situations were unfamiliar and care providers often did not have sufficient information or experience to solve the problem. Vignette 3 illustrates such a situation where the patient had an unusual trajectory through the hospital. Collaborative sensemaking during problematic situations arose due to the arrival/care of critical patients or when patients had adverse reactions to administered treatments.
5.2 Characteristics of collaborative sensemaking

Collaborative sensemaking arising in the ED from ambiguity of information, role-based distribution of information, and lack of expertise, had three important characteristics: sensemaking trajectories, prioritization of information, and activity awareness:

5.2.1 Persistence and sensemaking trajectories

Collaborative sensemaking in the ED had a strong temporal aspect. The “sense” that was made earlier of a particular situation by one group member influenced the sense made later of the same situation by others. Thus, persistence of the products of sensemaking was important; sensemaking products were passed on not only across time, but also across group members. Knowing the “path” that a group member had followed to make sense of information during a particular information seeking activity helped other group members’ sensemaking. I call such paths sensemaking trajectories, that is, the steps in the sensemaking process and the “sense” made at each step. Sensemaking trajectories were specifically prominent during patient handoffs when outgoing care providers passed on patient information to incoming care providers at shift changes. In the HMC ED, handoff is an informal activity where patient information is passed on one-on-one between residents, physicians, and nurses. I observed that during handoffs, not only was information passed on to others, but also the sense made of that information. Thus the sense made by one group member taking care of a patient influenced other group members’ understanding of the patient’s case. The example below illustrates this:

Vignette 5:
1:40pm:
Registration associate RA2 tells me that she feels sorry for the patient in room 20 who is 8-weeks pregnant and was hit by a car. The next shift’s charge nurse, CN3 arrives and the current
charge nurse, CN2, tells CN3 information about each patient by going through FirstNet. CN2 tells CN3 that the patient in room 20 was hit by a car and is 8 months pregnant. CN2 remembers the case of a former patient who was 7 months pregnant when brought to the ED and the baby had been lost because no one realized that the patient was pregnant.

5:00pm:

CN3 is talking to the attending AP about her patients. She specifically tells AP that she is worried that the patient in room 20 who is 8 months pregnant.

AP (surprised): “How pregnant?”

CN3: “8 months. I’ve been told baby is ok.”

AP is still concerned so he and CN3 pull up the patient’s record in FirstNet and discuss various aspects of her case. They don’t verify the pregnancy information. They miss that the record says 8-weeks pregnant. They discuss how the patient should be treated given the advanced stage of pregnancy.

This example illustrates a sensemaking trajectory during patient handoff. Not only was the information about the patient’s pregnancy passed on during this trajectory, but also the understanding of the patient’s case in light of the pregnancy information. CN2 passed on wrong information about the stage of the patient’s pregnancy to CN3. But this was not merely a case of miscommunication of information. Along with discussing wrong information, CN2 passed on what this information meant for the patient. This meaning was shaped by her recall of an earlier case where similar circumstances had led to an undesirable medical outcome (death of the baby). This made the wrong information (i.e., 8-months) ‘stick’ in CN3’s memory and changed what this patient meant for CN3, namely a case that was critical and needed to be paid particular attention to. Later, she discussed her concern about this patient with the attending physician. Based on CN3’s understanding, the physician understood that this was a critical case. Thus, the physician’s understanding of the patient’s case was influenced by CN3’s understanding, which was influenced earlier by CN2’s understanding.

I found that FirstNet played a key role in transferring the products of sensemaking between group members involved in caring for a patient. There were two mechanisms in
FirstNet by which care providers passed on products of sensemaking – the ‘Comments’ column and the ‘sticky note’. The comments column is part of the universally used spreadsheet like view of patient information in FirstNet; each patient’s record in FirstNet has a comments column. This column is used by care providers to note information and the sense made of that information. At triage, the registration staff note in the comments column what the patient tells them about their illness or injury. For example if the patient is coming from another hospital and tells the registration staff at triage that they were diagnosed with a fracture, the registration staff might write “+fx” (positive fracture) in the comments column. This may not be the correct diagnosis, but by writing that comment, the registration staff pass on to the triage nurse the sense that they have made of the information given to them by the patient. The physician’s assistant said:

“This patient coming in says ‘we have a fracture here’. It’s all very subjective. This may very well not be the case but by putting comments there [the registration staff] let the nurses in triage know that this is what they’re going to be dealing with. So by the time the nurse brings them back, they may change that comment and they’ll write “needs to be seen next”. And then they’re meaning, who they’re really typing to is the charge nurse, they’re saying ‘this guy is in a lot of pain, he has an obvious deformity, we know he’s got a fracture, he has a blue hand, he really needs to get in there quicker.’ If they’re going to be someone who needs a reduction, then it’s going to be ‘fracture needs a room’ [in the comments column], meaning they are going to need medication monitor, IV sedation, orthopedics involved.”

Thus, the few words written in the comments column not only passes on information (i.e., the patient might have a fracture) from the registration staff to the triage staff but also the sense made of that information (i.e. the patient has a deformity, a blue hand, and needs to be assigned a room quickly). Notes made in the comments column help nurses understand the patient’s case better and it also signals other implicit details like how critical the patient is, whether the patient is drug-seeking or not, and even who the author of the comment is (even though the comments are anonymous) since care providers come to recognize each others’ styles.
Apart from the comments column, the other FirstNet feature used for handing off the products of sensemaking is the ‘sticky notes’. This is a virtual sticky note that is used mostly by physicians to note information and the sense made of that information as passed on to them by care providers from the previous shift. Thus, the products of sensemaking were made persistent in FirstNet and passed on across group members as sensemaking trajectories.

Trajectories play an important role in medical work (Strauss et al., 1985) and have been applied to the study of temporal rhythms in information seeking (Reddy & Dourish, 2002). My finding of sensemaking trajectories emphasizes the temporal nature of information seeking and sensemaking. Sensemaking trajectories highlight that in collaborative information seeking, both the products and process of sensemaking persist over time and across multiple people. This has important implications for the design of CIS tools as discussed later.

5.2.2 Prioritizing relevant information

Making relevance judgments on information found is an important aspect of the individual information retrieval process. As people find information pertaining to their information need, they make a judgment about how important that information is for fulfilling that information need. I found that during CIS activities, group members shared information with others depending on how relevant they thought the particular piece of information was in fulfilling a shared information need. Whether a piece of information was relevant, and hence important enough to share with others, was often a crucial decision that had consequences for collaborative sensemaking. Prioritizing the ‘right’ pieces of information as relevant enhanced group sensemaking, but it was often challenging for group members to judge what these right
pieces of information were. Failing to prioritize certain information as relevant led to undesirable consequences, as seen below.

Vignette 6:

7:05pm:
EMS member, EM2, brings in a patient and the charge nurse, CN4, directs him to a hallway bed. EM2 is holding the patient’s hand and the patient is sobbing. EM2 comes up to CN4 and says “She’s intoxicated and delusional. 6-year-old called us. At first we thought it was an overdose. She’s going to be a handful I can tell you that now. Wants someone to hold her hand” (sarcasm in his voice)

CN4 asks EM2 if the patient has any family and EM2 said she had a husband but did not want to call him.

CN4: “Well she’ll have to deal with it then.”

In the meantime, the ED gets busier and the charge nurse directs her attention to other patients who are more critical.

7:20pm:
CN4 asks EM2 how the patient he brought in is doing.

EM2: “She says she has a headache. She slipped and hit her head in the bathtub today.”

CN4 (angry): “And now you’re telling me that?”

EM2: “Sorry I forgot to tell you.”

CN4 directs her attention to the patient. She makes a note in FirstNet about the head injury and that it could possibly be related to the headache and delusional state of the patient. She then makes preparations for finding the patient a room and ordering a CT scan for the head injury.

Here, EM2 made a judgment about which pieces of information were important to share with the charge nurse such as symptoms (“intoxicated”, “delusional”) and emotional state (“wants someone to hold her hand”). The information passed on gave the charge nurse the impression that this patient was not really sick, but was seeking attention and would be high-maintenance. EM2 failed to prioritize, and hence share, an important piece of information – the patient had suffered a head injury. The charge nurse formed an understanding of the patient’s case based on the information shared by EM2 and didn’t think it was critical to focus on this patient. Later when EM2 mentioned the head injury, the charge nurse’s
understanding of the patient changed – the patient went from being a “handful” to one who required attention.

The example of the pneumothorax patient (vignette 1 in section 4.2) had similarly showed how prioritizing the right piece of information was crucial to sensemaking. In that case, the resident R1 told the doctor about the history of the patient (“asthma”), cause of injury (“fell on right side”), and symptoms (“shortness of breath”, “pain near his ribs”) but could not explain why the patient should be negative for pneumothorax. R2 prioritized one of the pieces of information, i.e., the location of the pain, which did not indicate pneumothorax. By highlighting this piece of information as highly relevant, R2 guided R1 and D towards the diagnosis of fracture.

Not only was it important for individual group members to prioritize and share the right pieces of information, it was also important for the group as a whole to decide which pieces of information were important to the shared information need. Thus, the group had to prioritize the shared information, i.e., make decisions about which pieces of information were highly relevant to the task. This was challenging because different group members (based on their roles and expertise) would assign different priority to information and hence there was often need for negotiation between group members as to which pieces of information were important to fulfill the shared information need. The following vignette illustrates how group members together prioritized information that was important to the information seeking activity at hand:

**Vignette 7:**

EMS personnel have brought in a 22 year-old female patient. They report that the patient is complaining of back pain since last night. She is also suffering from neck pain, headaches and is feeling fatigued. After the patient is admitted the attending physician AP1 and the resident R3 discuss the patient. RN2, who has looked at the patient’s past medical history, points out that the patient had neck surgery for cancer several months ago. The resident, who has physically
examined the patient, tells AP1 that the patient’s neck had a thyroidectomy scar. Everything else was normal but he thinks the indication of neck surgery might be important to the diagnosis.

AP1 and R3 go through the patients lab results. AP1 points out the low levels of Calcium and thinks that this is significant. R3 suggests that the fact that the patient had thyroid surgery is significant. AP1 and R3 decide that both the facts that the patient is low on Calcium and had thyroid surgery are important to the diagnosis and hence order ECG tests. ECG results show prolonged QT and ST intervals which indicate hypocalcemia, a deficiency of Calcium. R3 and AP1 decide that The ECG results, coupled with the indication of thyroid surgery, indicates that the patient is suffering from hypoparathyroidism which usually leads to hypocalcemia. (Parathyroid insufficiency is a common complication of thyroid surgery and the low levels of Calcium and ECG results confirmed the diagnosis.)

As this vignette illustrates, care providers often assigned significance to different pieces of information which they thought were relevant to an information need. In this case, RN2 prioritized the surgical history of the patient by pointing out the patient’s neck surgery. The resident assigned further importance to the surgery information by adding that the patient had a thyroidectomy scar. AP1 prioritized the patient’s low Calcium level. At this point AP1 and R3 negotiated the importance of these different pieces of information and reached the conclusion that both were important to the diagnosis. Based on this, they ordered ECG tests and found evidence to strengthen their understanding that the patient’s back pain was due to low Calcium levels resulting from hypoparathyroidism.

An important aspect of individual sensemaking is noticing and bracketing of cues from a stream of experience (Weick, 1995). People extract familiar structures from ongoing experiences as “cues” and these cues become seeds from which they develop a sense of what might be occurring. Noticing is the process by which cues are extracted for sensemaking. Once cues are extracted, sensemakers categorize or “bracket” these cues such that action may be taken. I found that prioritization of information during collaborative sensemaking was akin to noticing and bracketing of cues during individual sensemaking. Group members made relevance judgments on information pieces that were important enough to share with
others (i.e., they “noticed” the right pieces of information) and then the group as a whole negotiated the meaning or significance of the shared information (i.e. they “bracketed” the cues to create a shared understanding). This bracketing of cues was a social process and it was important for group members to reach agreement on the priorities assigned to cues.

5.2.3 Activity awareness

CSCW research has long examined the role of different types of awareness during collaboration such as social awareness (who is collaborating?) and action awareness (what are collaborators doing?). I found that for making sense of information shared during CIS activities, there was need for group members to maintain a higher level of awareness, i.e., activity awareness, rather than mere social and action awareness. Activity awareness emphasizes the need to maintain awareness about the “big picture” during collaborations (Carroll et al., 2003). It draws on activity theory to conceptualize an activity as “a sequence of actions, directed towards a goal or object, mediated by tools, and situated in many embedded contexts (e.g. work practices, culture, organizational structures, interpersonal relations)” (Convertino et al., p. 315). Activities take place over extended periods of time. While action awareness provides information about the actions of group members on short-term tasks, activity awareness is awareness of creation and changes in shared plans, evaluations, and task dependencies over time.

Since collaborative sensemaking has a temporal aspect in that information about past sensemaking aids the future sensemaking of the group, activity awareness, i.e. awareness about longitudinal endeavors, was found to enhance group sensemaking much more than just awareness about group members’ current actions. In the ED, actions were short-term tasks, such as ordering tests for a patient, administering medication to the patient, moving a patient
from one room to another etc. Activities, on the other hand, were long-term endeavors, (such as planning the patient’s care over his entire stay in the ED), which were composed of a sequence of actions. For example the activity of diagnosing the patient’s condition was composed of several actions such as triage (by the triage nurse), moving the patient to a room (by the charge nurse), recording the patient’s history and vitals (by the nurse), physically examining the patient (by physicians), ordering tests and x-rays (by physicians), and interpreting the results of tests to determine the diagnosis (by physicians). Thus, in a collaborative environment, the multiple actions that comprise an activity are performed by different actors over time and hence understanding the relationship between these actions was important for collaborative sensemaking.

Care providers often shared action awareness information during their information seeking activities. However, I found that awareness about others’ actions failed to enhance sensemaking unless group members could contextualize the actions in terms of longer-term activities. This indicated that mere action awareness was not sufficient for collaborative sensemaking, rather activity awareness was required for helping collaborators make sense of information. The following example illustrates how understanding the relationship between various actions pertaining to a patient was important for sensemaking:

**Vignette 8:**

The emergency medicine technician EMT2 comes up to the charge nurse CN5 saying she is confused because she was instructed to take the patient in room 9 to EKG but the patient she is looking for is not in that room, instead a different patient is there. She asks CN5 if she knows what is going on.

The housekeeping staff member who hears this exchange tells CN5, “But 9 is still here”, meaning that the patient in room 9 had not been discharged yet.

CN5: “Yes, I know but they are going upstairs. I have re-assigned room 9”

RN1: “Have they called transport.”

CN5: “Ask RN2 about it, she’s in 12.”
RN1 asks RN2, who is the nurse in-charge of patient in room 9, whether she had called transport to move the patient from the ED room to the floor bed upstairs. RN2 confirms that she has called transport and is getting the discharge papers ready.

EMT2, after hearing all these exchanges realized that the patient she was looking for was not in room 9 because the previous occupant had still not been vacated. She concluded that the patient she was looking for was still in the waiting area.

This vignette illustrates how collaborative sensemaking involves connecting information about the actions of several group members pertaining to a single activity. The activity of moving a patient to a room comprises several actions by different group members taking place over a period of time. The nurse in charge of the patient must call transport and prepare the discharge papers, the housekeeping staff must clean the room, the charge nurse must reassign the room and the EMT staff must go and bring the patient from the waiting room to the newly assigned room. In order to make sense of this situation it was not sufficient for EMT2 to be aware of the actions of CN5, RN2, and the housekeeping staff; she had to find the relationship between all these actions carried out by multiple group members over time. She also had to trace the sequence of these actions to understand that the patient she was looking for was still in the waiting area.

Action awareness information was frequently exchanged between team members in the ED. For instance, when the triage nurse completed the triage of a patient in FirstNet, she called the charge nurse on the phone and told her to assign a room to the patient. Similarly, when the charge nurse allocated patients to nurses on the whiteboard, she immediately called the nurses to let them know which patients had been assigned to them. Often care providers informed each other verbally before leaving the ED (e.g. to take a break or to accompany a patient to a floor bed). I found that while such information exchanges were sufficient for maintaining awareness about others’ actions, they failed to enhance sensemaking. This was because collaborative sensemaking depended on being able to contextualize individual
actions of different care providers with respect to broader activities. However, maintaining activity awareness was a challenge to group sensemaking. Often long discussions took place, triggered by short verbal communications like the ones described above, to understand what the actions of group members meant in light of the long term care plan for the patient.

5.3 Goals vs. outcomes of collaborative sensemaking

The previous sections described the occasions and characteristics of collaborative sensemaking along with instances from the data. Having described these instances of collaborative sensemaking, I’d like to re-visit the working definition of collaborative sensemaking which was used to identify these instances:

“Collaborative sensemaking occurs when two or more people create a shared understanding of information by 1) interacting with others to share individual understandings of information and 2) interpreting other’s interactions with information.”

As mentioned in Chapter 2, as an observer it is often difficult to tell that a “shared understanding” of information has been created among a group of people. Hence, in my observations, I looked for situations where breakdowns in work occurred because care providers were unable to continue their work due to a lack of understanding of the information available. When such breakdowns occurred, care providers interacted with each other to gain an understanding of the information. A “shared understanding” was deemed to have been achieved when care providers’ information needs were fulfilled such that they were able to continue their work activity.

The working definition of collaborative sensemaking above states that a shared understanding is achieved as a result of collaborative sensemaking. In my study, the goal of collaborators was to achieve a shared understanding; whether the outcome of their
collaborative sensemaking efforts was indeed a shared understanding (and to what extent that understanding was “shared”) is not something that was possible for me to measure or record.

This chapter highlighted why group members collaborate to understand the information found during information seeking activities. It also presented three important characteristics of collaborative sensemaking. The importance of preserving and passing on the products and process of individual sensemaking across group members shows that sensemaking trajectories are important during collaborative sensemaking. Also, awareness information about the actions of different group members associated with a given activity needs to be contextualized with respect to that activity. Finally, the different roles of group members might lead them to assign different priorities to different pieces of information, leading them to selectively share information with others. Collaborative sensemaking requires the group as a whole to prioritize the “right” pieces of information as relevant to the given task. The next chapter discusses these findings and their implications for the design of features that can enhance sensemaking in collaborative information retrieval tools.
6. Study 1: Discussion

In this chapter, I first discuss the findings from the study of sensemaking in the ED, in particular, the importance of sensemaking trajectories, activity awareness, and shared representations. Next, I organize the findings into a framework of collaborative sensemaking in CIS activities. This framework contributes to our conceptual understanding of collaborative sensemaking and can be used to inform the design of sensemaking-support features in CIS tools. Finally, I discuss the implications of these findings for supporting sensemaking in collaborative information retrieval tools.

6.1 Trajectories and sensemaking

As group members find and share information during CIS activities, they make sense of the information and pass on the products of their sensemaking to others. Sensemaking trajectories, as illustrated in the previous chapter, consist of the steps in the sensemaking process and the sense made at each step. Sensemaking trajectories extend across time and group members. In order to understand the conceptual implications of sensemaking trajectories, I draw on Strauss et. al’s (Strauss et al., 1985) notion of trajectories in medical work. Strauss defines a trajectory as the total organization of work done over the course of a patient’s illness and the impact on those involved in that work. Strauss’s trajectories have three characteristics that make them an important analytical lens through which to understand collaborative sensemaking in the ED – the temporal nature of the trajectory, the information work associated with a trajectory, and the arc of work that constitutes a trajectory.

Strauss et al. (1985) proposed the concept of trajectories to describe the work involved in caring for a patient, along with the people and technology involved in that work.
Trajectories are temporal in nature and there is information work associated with them. As doctors, nurses, and various other healthcare providers work on a patient during the course of his illness, they pass on information to each other. Information is passed on in the form of talk (verbal communications), reports (both verbal and written), forms and documents, and entries in information systems (such as data entered into FirstNet). Reddy (2003), in his examination of CIS activities in the intensive care unit, extended Strauss’ notion of trajectories to highlight the temporality of the information work associated with trajectories. He proposed the notion of *temporal trajectories* which emphasize that the timeline of patient care activities is intimately intertwined with information seeking. Further, Reddy and Dourish (2002) emphasized how patterns of CIS are tied to rhythms of work. Work rhythms guide when individuals will need and seek information and being aware of the work rhythms’ of others helps group members seek and anticipate information from them. Their research helps us understand how information seeking activities and events iterate and re-occur over time.

The results of my study further emphasize the temporal nature of CIS activities in organizations; however, my focus was different from Reddy et al. because I focused on the temporal nature of a specific aspect of the CIS activity, namely sensemaking. Neither Strauss nor Reddy have explicitly discussed sensemaking as part of the information work associated with trajectories, though it is implicit in their descriptions. Also, while sensemaking during CIS activities might be iterative, my focus was not on the iterative nature of sensemaking. Instead, I was interested in examining how sensemaking progressed over time across multiple group members engaged in finding and using information.
CIS activities observed in the ED were intricately tied to patient trajectories and hence extended over time. The sensemaking that took place during those CIS activities also extended over time. Thus, collaborative sensemaking had a strong temporal component. Furthermore, during CIS activities, the sensemaking of one group member influenced that of another group member. The sensemaking of group members was not isolated, but connected such that the sensemaking of one person led to further information seeking or sensemaking by another person “down the line”, i.e., there was a temporal connection between the sensemaking of individual group members. The temporal connections between individual group members’ sensemaking had important implications for the outcome of the CIS activity. As sensemaking progressed during a CIS activity, an understanding of the information associated with the trajectory was built up cumulatively across time by group members. Thus, a “sense” of the information associated with a trajectory was attached to the trajectory and this sense evolved with each group member who participated in the CIS activity.

When individual sensemaking of group members was successful, along with the information, the “correct” sense of the information was passed on, resulting in group members successfully addressing their shared information need. However, when individuals made “incorrect” sense of the information found, this incorrect sense was passed on and negatively affected others’ sensemaking, often leading to undesirable outcomes (as seen in vignette 5). Thus, sensemaking trajectories highlights that during CIS activities, ‘sense’ accumulates and evolves over time across multiple group members. If the sense made of information is inaccurate at the individual level, it leads to inaccurate sensemaking at the group level and this can result in an unsuccessful outcome for the CIS activity.
6.2 Activity awareness

The importance of activity awareness further emphasizes the temporal nature of collaborative sensemaking. My findings about activity awareness highlight that the sequence of actions pertaining to an information seeking task as conducted by various group members is important for others’ sensemaking. This relates to Strauss’s notion of trajectories. An integral aspect of trajectories is the arc of work associated with the trajectory. This arc of work is the overall work that needs to be done to control the patient’s illness and get him back into good enough shape to go home. In the ED, the arc of work associated with a patient’s trajectory was the work done by various healthcare providers to stabilize the patient enough to either get him discharged or admitted to a hospital unit. The arc of work that constitutes a patient’s trajectory is composed of separate tasks performed by different group members across time.

Strauss et al (1985) points out that:

“Since trajectories extend over time, they have phases… during each phase, it is decided that certain things need to be done such as monitor cardiac output, get another X-ray, continue the dialysis session, monitor the post-surgical condition, and so on. Any point at which it is decided to do those things we call a trajectory sequence point. The term is apt because at each point, a different cluster of tasks is required; they will change partially or totally at the next sequence point. … cluster of tasks have both a sequential ordering and an organizational base that allows their being carried out.”
(p. 30)

Thus, the trajectory of patient care is composed of clusters of tasks that are performed by different role players. In CSCW literature, a parallel to Strauss’s clusters of tasks is the concept of activities (Hayashi et al, 1999). Activity theory states that human endeavors can be analyzed in terms of activities motivated by the pursuit of a specific objective. Further, activities are carried out through a series of actions oriented towards goals. Activity theory does not view an activity as carried out by an individual, rather activities are often carried out collaboratively by distributing the actions pertaining to an activity among different actors.
Hospitals work is an example of activity-based work as the overall treatment of a patient in a hospital is carried out through a series of actions – such as examination, consultation, prescription, medication, testing, medication administration, and care – carried out by different care providers like physicians, nurses, technicians, and pharmacists (Bardram, 2009). Thus, Strauss et al.’s (1985) concepts of ‘cluster of tasks’ and ‘tasks’ map to the CSCW concepts of ‘activities’ and ‘actions’, respectively.

The sequential ordering and organizational context surrounding clusters of tasks (or activities) are important to the information work in trajectories. “Trajectory work requires an information flow before and after each task or task sequence.” (Strauss et al., 1985) p. 255). This information flow takes place in the form of decisions and negotiations about what tasks are to be done, in what order, and to what purpose. Thus, along with the information sharing that occurs in trajectories, sense is made about tasks (or actions) of group members and their order. Consequently, an important aspect of sensemaking during trajectory work is understanding the relationship between actions performed by different actors with respect to an activity. Activity awareness, that is how actions of group members are related in terms of long-term activities, is essential to collaborative sensemaking.

In the ED it was common for individual group members to maintain awareness of others’ actions via verbal communications. The following exchange between two nurses illustrates this:

Nurse: “Hey, do you know where Johnson went? I’m filling out his paperwork. I need to know what’s going on with him.”
Charge nurse: “Yeah, I sent him to x-ray. Also, Dr G changed his medication. You should talk to her.”

It took only a short verbal exchange for the nurse and the charge nurse to exchange action awareness information. The charge nurse let the nurse know that she had sent the patient to
x-ray and that the doctor had changed his medication. However, such action awareness updates were not sufficient for sensemaking because it was important for group members to not only know what others’ actions were, but to understand the sequence and context of those actions with respect to a long-term activity. From the short exchange above, it is not clear to the nurse why the patient was sent to x-rays, whether this was linked to the change in medication, and what the current status of the patient was. Activity awareness emphasizes that understanding the temporal and sequential connections between the actions of multiple group members, and the contexts surrounding those actions with respect to a long-term activity, are important for sensemaking in groups (as illustrated in vignette 9).

6.3 Shared representations

In observing how various information and communication tools were used during CIS activities in the ED, I found that shared representations played an important role in enhancing sensemaking. Studies of individual sensemaking have found that people create external representations (Russell et al., 1993) such as diagrams, maps, and tables to organize and make sense of information. Studies of group cognition have found that ‘meaning’ of a situation is often distributed in a network of external artifacts (Stahl, 2006) and representations (Hutchins, 1995). External representations have also been found to mediate collaborative knowledge construction (Suthers, 2005) in computer supported collaborative learning environments. In such environments, manipulation of external representations is ‘conversational’ in a manner similar to verbal interactions, and helps the creation of shared meaning.

In the ED, common or shared representations were used to organize information that was critical to the functioning of the group. These group representations were provided by
the whiteboard and FirstNet. Creating, manipulating, and referring to these common representations during CIS episodes enabled group members to create a shared understanding of information. For instance, the most widely used shared representation in the ED is FirstNet. It provides a common framework for entering and reviewing information about patients; each patient is reviewed along the dimensions corresponding to the fields in FirstNet. For instance, during patient handoff, incoming and outgoing charge nurses together go through the list of patients in the All Beds tab (Figure 6) in FirstNet and discuss each patient’s chief complaint, recent events, lab and radiology test results. This activity helps the outgoing charge nurse pass on her understanding about the current state of the ED to the incoming charge nurse. Similarly, physicians and charge nurses often work together using the All Beds tab to review each waiting patient and decide which patients to move to available rooms. The whiteboard is another important shared representation. Studies of public access boards have demonstrated the importance of displaying status information in facilitating collaboration around information (Xiao, 2005). Bardram (1997) found that even when using a computerized patient scheduling system, users maintained a whiteboard to re-represent the information in the computer system so that it could be publicly shared and manipulated. Similarly, in the HMC ED, the whiteboard is used to create an alternate representation of the information available in FirstNet; a representation that is tailored to be used by the nurses. The whiteboard provides a summary view of nurse assignments and information on the whiteboard can be easily changed to reflect new assignments.

Though there were different views of patient information in FirstNet, the spread-sheet like view of the All Beds tab (Figure 6) was used most often by different role players. It provided a common representation to view and discuss patient information along various
dimensions during information seeking activities. The structure provided by this view helped
enhance sensemaking but it also sometimes constrained care providers when they needed to
add or view additional information about the patient. In those cases, the comments field was
used to add short comments about the patient (or to note products of sensemaking). When
additional information was to be viewed or noted, care providers switched to other more
detailed, *role-specific views* in FirstNet. Thus, the All Beds tab in FirstNet as a shared
representation did not support role-specific viewing and encoding of information, instead it
provided a generic structure that could be used by different role players.

In contrast to the generic spread-sheet like view of information in FirstNet that was
used by multiple role players, the whiteboard was used only by nurses. The representation of
information on the whiteboard (Figure 9) was used by nurses to look up information about
patient assignments, room availability, and nurse caseloads. The nurses often referred to the
whiteboard even when discussing the medical condition of patients. An interesting
observation here was that unlike FirstNet which provided a fixed representation of
information, the whiteboard provided flexibility to modify representations of information.
This allowed nurses to easily adapt the shared representation to fit their individual working
styles and needs by making small changes to it. For instance, charge nurses leveraged the
flexibility of the whiteboard by making a variety of annotations (Figure 8). One charge nurse
used the whiteboard to keep track of shift changes so she could plan ahead and assign new
nurses before current shift nurses left. She did this by writing the letters a, A, e, E, (which
stand for different shifts) next to the names of the nurses (Figure 8). Another charge nurse
wrote “NEW” next to every new room magnet that she placed on the whiteboard when she
assigned a new patient to a nurse. This let nurses know at a glance that a new patient was
waiting for them. Thus, the flexibility provided by the whiteboard as an external representation enabled it to be used differently by different nurses. The different uses of FirstNet and the whiteboard show that one of the challenges in designing technology to support collaborative sensemaking is the tension between providing a fixed structure versus providing flexible representations that can be modified by role players.

6.4 Framework for collaborative sensemaking

Based on the findings from my study in the ED, I present a conceptual framework of collaborative sensemaking in CIS activities (Figure 10). This framework highlights why collaborative sensemaking occurs during CIS activities and how it is characterized. The framework is divided into three parts: part I represents the CIS activity, part II contains the factors which trigger collaborative sensemaking, and part III highlights the activities that take place during a collaborative sensemaking episode.

The framework presented is descriptive and does not prescribe how collaborative sensemaking should progress for a given CIS activity. Also, it draws together the concepts that emerged from my findings about CIS in a particular context, namely the ED. Therefore, not all the triggers/activities described in this framework will always be present during a given collaborative sensemaking episode, rather the framework describes possible factors that might trigger collaborative sensemaking and the possible activities that might take place during a given collaborative sensemaking episode.
Figure 10: A framework for collaborative sensemaking during CIS activities
6.4.1. Part I: Collaborative information seeking activity

Part I of the framework represents a CIS activity where multiple people engaged in work must fulfill a shared information need in order to continue their work. CIS can occur in various ways: group members may be co-located (such as in a hospital) or remote (such as during inter-organizational intelligence analysis tasks) and may search for information synchronously or asynchronously. Furthermore, the CIS task may be split such that different group members look for different pieces of information or the CIS task may be conducted such that all group members look for the same piece of information simultaneously. In Figure 10, Part I of the framework describes how CIS activities were conducted in the ED, however, this part of the framework can be modified to represent different types of CIS activities.

CIS activities are initially split into tasks/sub-tasks and each sub-task is often performed by a different group member, depending on their roles and expertise. Roles can be organizational (as in the case of a hospital) or might be assigned more informally by the group members based on their expertise (as in the case of a generic Web search task). Each group member finds information pertaining to her sub-task and makes sense of this information. During this individual sensemaking, action awareness information is shared, i.e., group members keep each other aware of what they’re doing. In other domains than emergency care, CIS activities might be conducted differently. Part I of the framework simply highlights that CIS activities often involve individual information seeking and sensemaking, but due to the factors stated in Part II, lead to collaborative sensemaking which is conducted via activities described in Part III of the framework.
6.4.2 Part II: Triggers for collaborative sensemaking

This part of the framework highlights some important factors that trigger collaborative sensemaking during a CIS activity. As individual sensemaking progresses, group members might encounter ambiguous information that is hard to understand. Also, if information is distributed according to roles, each group member may not have access to all the information needed to make sense of the given situation. Individual group members might also lack the domain and/or search expertise needed to find and make sense of information, thus needing to collaborate with those who have the required expertise. These factors lead to group members collaborating to make sense of information.

6.4.3 Part III: Collaborative sensemaking activities

The triggers described in Part II lead to collaborative sensemaking. Part III of the framework lists some of the activities that take place during collaborative sensemaking. During collaborative sensemaking, group members share the information they each have access to, along with the sense they’re made of that information. When sharing different pieces of information, group members prioritize the pieces of information that they each feel is relevant and important to the CIS activity. This may lead to negotiations about which pieces of information are important and what those pieces of information mean. They also try to contextualize action awareness information with respect to long-term activities which involve multiple people performing sequences of actions. They try to understand how others had made sense of the information available and they also try to trace the sequence and context of others’ actions pertinent to the CIS activity. As group members share and make sense of information, they create and manipulate shared representations to store the information found and the sense made of that information. During the CIS activity, and after it is over, the
products of sensemaking are handed off to other group members who might continue the activity or utilize the results in other work activities.

It must be noted that none of the parts of the framework are all-inclusive. Part I does not represent the only way in which CIS activities take place, nor does Part II include all possible triggers for collaborative sensemaking. Similarly, Part III does not list all possible activities that can occur during collaborative sensemaking. Also, the framework does not assume that these activities take place in any fixed sequence; in fact most of the activities noted in Part III occur simultaneously and iteratively throughout the CIS task. Also, as noted before, the framework is based on the context of information seeking in a time-critical, role-based, information-intensive organization like the ED. In other collaborative information seeking contexts (like intelligence analysis or Web search), all the factors, steps, and activities shown here may not be present.

This framework helps describe why and how sensemaking occurs during CIS activities and how collaborative information retrieval tools can enhance the sensemaking of users. The following section draws on the discussion of the characteristics of collaborative sensemaking to provide design implications for collaborative information retrieval tools.

6.5 Supporting sensemaking: Design implications for collaborative information retrieval tools

The findings and discussion of the characteristics of collaborative sensemaking provide implications for the design of collaborative sensemaking tools. Dourish (2007) has provided insightful commentary on how ethnographic accounts can inform the design of technologies. Ethnographies are powerful means of providing detailed and rich accounts of aspects of human experience that reach beyond the specific sites at which research engagements took
place. The implications for design that can result from ethnographic accounts do not need to be of the “requirements capture” variety. Instead, these implications can be in the form of consequential, profound, and direct guidance for how to think about the design issues in question. Implications of design arising from ethnographic accounts open up the design space and bring to surface the role of design and technology in that space (Dourish, 2007).

Understanding when and how collaborative sensemaking takes place during CIS activities enables us to think about the design features that can be incorporated into collaborative information retrieval tools. Currently, such tools support collaborative querying and algorithmic (Pickens et al., 2008) or UI-level mediation (Morris & Horvitz, 2007) of search results. Thus they focus on helping users retrieve information and do not have much support for helping them make sense of the information retrieved. These findings can be used to design sensemaking-support features for such tools. In thinking about the design space of sensemaking-supporting features in collaborative information retrieval tools, I examined whether previous literature had addressed the conceptual ideas arising from my study – especially the role of sensemaking trajectories, activity awareness, and shared representations in information seeking. The following sub-sections tie background literature with my findings about collaborative sensemaking to propose some high-level design features for collaborative information retrieval tools.

6.5.1 Supporting sensemaking trajectories

Since sensemaking progresses across group members with time, it is important for group members to be aware of the sensemaking path of others. The “path” followed by information seekers during an information seeking activity has been studied in various contexts ranging from organizational settings to Web search. Literatures on information foraging and Web
search have explored the trails that users follow during information seeking activities. For instance, White & Drucker (2007) examined the search logs of Web searchers to investigate post-query navigation trails which consisted of the Web pages viewed by searchers after issuing a query to the search engine. Search trails were characterized by amount of time spent on the trail, number of queries submitted, number of pages viewed and re-visited, and the number and length of branches in the trail. Similarly, Pirolli (2007) studied the effect of information scent, i.e. the visual and linguistic cues pertaining to a distal object’s information value, on searchers’ navigation behavior. While these studies focused on the ‘information’ aspect of trails, they did not examine how sense made of the information evolved during the information seeking process.

Also, studies of information trails have rarely examined how sharing such trails affects the information seeking behaviors of others. The few studies that examined sharing of information seeking trails, found that sharing the sensemaking process was also important. For instance, Gorman et al. (2002) studied how physicians navigate the information about a patient’s case and found that as they navigated through the complex collection of information artifacts about a patient, physicians were interested in knowing how a previous physician had navigated the documents in relation to the same patient (Foster, 2006). This observation led them to focus on “the trace left by an expert as she explores the collection of documents” pertinent to a patient (Gorman et al., 2002, p.1246). They designed SLIMpad, a tool that makes explicit the traces left by other physicians in navigating information about a patient. Similarly, in their study of collaboration during library-use, Twidale et al. (1997) found that people often shared the process and products of their search. They suggest that information retrieval systems should facilitate such sharing by allowing annotation and rating of
documents to reflect the sense made by others. Documents should be ‘history-enriched’, that is, they should record and display a history of edits and reading patterns. Also, saving a graphical representation of the search process can help users see the broader logical structure of the search and focus on sub-tasks within the process, detect and repair errors, and reflect on their own performance of the search.

These studies, as well as my findings, indicate that along with sharing the information found during CIS activities, sharing the history of others’ interactions with information enables group sensemaking. Thus making the temporality of the information seeking process persistent is important for supporting sensemaking during collaboration. Thus, collaborative information retrieval tools should support persistence of the process and products of sensemaking by visualizing sensemaking trajectories. One way of visualizing such trajectories is through timelines (Paul & Morris, 2009) which show chronologically the information found by different group members and the sense made of the information. Users should be able to view information in such timelines by group member (e.g., all actions performed by nurse X on patient Y) or by type of information (e.g., all tests ordered for patient X in the last 24 hours). Comments made on information can be made part of the timeline so that the sense made of the information is stored and shown along with the information itself.

6.5.2 Supporting activity awareness

While some studies have proposed design ideas to support activity awareness in shared workspaces, none of these systems have been specifically designed for collaborative information retrieval. Hayashi et al. (1999) proposed that activity awareness can be supported by providing awareness of a set of interrelated activities, each of which is executed within an
individual workspace. Their tool Interlocus implements activity awareness through a *temporally threaded workspace* model. In this model, a workspace is provided for each activity of an individual and contains the information necessary to perform the activity and to record the progress of the activity. Activity awareness is achieved by providing a *collective activity perspective* which shows a synthesized view of the collaborative activity, created dynamically from component individual activities. Thus, the temporal connection between the activities of different individuals pertaining to a collaborative task is maintained. This is an important design feature for CIS systems since understanding the temporal connections between actions of group members is important for sensemaking.

Another approach to supporting activity awareness is Bardram et al.’s (2009) activity-based computing. Activity-based computing represents activities as computational entities which are aggregations of services, resources, artifacts, and users relevant to a real world human activity. Systems implementing activity-based computing allow activity-centered resource aggregation, suspension and resumption of activities from various computers and by various actors, sharing of activities, and activity awareness. An important aspect of such systems is that the state of activities are made persistent and saved by the system. Such a feature would also be a useful addition to a CIS system since it would help make explicit the temporal connections between actions of different group members with respect to a long-term activity.

The design ideas discussed above can be extended in the design of collaborative information retrieval systems to support activity awareness during sensemaking. Activities can be represented as a sequence of actions by various actors (similar to the temporally threaded workspace model of Hayashi et al. (1999)) and can incorporate the characteristics of
activity-based computing that help preserve and make explicit the temporal aspects of the activity. Activity representations, called *activity timelines*, can store the information found and used by actors during various actions performed during an activity, along with the sense made of that information (in the form of comments or annotations). Thus, collaborative information retrieval tools should provide not only action awareness via notifications but also activity awareness by visualizing timelines of all actions pertaining to a particular activity. For instance, a system like FirstNet can show activity timelines of the actions performed by various care providers with respect to a particular activity like diagnosis of the patient’s condition. This would enhance sensemaking of group members by situating action awareness information within the context of larger activities.

**6.5.3 Supporting roles and expertise**

Here I address two related aspects of collaborative sensemaking with respect to design – the importance of roles and expertise. As discussed earlier (Section 5.1.2.) group members often have to collaborate for sensemaking because information distributed across role players needs to be synthesized to understand the “big picture”. Different group members might have access to different pieces of information due to their varied organizational roles and often have to pool together the information available with others to make sense of it. Furthermore, different role players might make sense of the situation differently based on this fragmented information. Few studies of CIS have addressed how roles can be supported during such activities.

Drawing on the findings from my study, one way to support sensemaking in the face of role-based information distribution is to provide visualizations of information by roles in the timelines for different activities. For instance, within FirstNet, timelines can show all
information available about a particular patient for each category of role-players such as doctors, nurses, etc. Doctors have access to diagnosis and medication information while nurses have information about the patient’s past history and current condition. Sensemaking can be enhanced by allowing users of FirstNet to filter timelines by type of role player (e.g., enabling users to see all information available to doctors) and by type of activity (e.g., enabling users to see all information available to doctors and nurses pertinent for diagnosing the patient’s condition). Along with the information, role players should be able to note the sense made of the information (e.g., in the form of comments) and this should be visualized along with the information. In other domains, like Web search, comments on information found during CIS activities have been found to be useful for enhancing group sensemaking (Paul & Morris, 2009).

Another aspect of roles that needs to be addressed in design is related to the discussion of shared representations (Section 6.3). Group representations provided by tools must be designed to be flexible enough to support role-specific information encoding. This can be done by providing the flexibility to change group representations to fit specific roles or by providing alternative representations of the same information for different roles.

Related to role-based information distribution is the role of expertise in collaborative sensemaking. Lack of expertise has been found to be a trigger for collaboration during information seeking activities (Reddy & Jansen, 2007). Studies of information seeking and sharing have explored how people find experts who can help them fulfill their information needs. These studies seek to answer the question “how do people determine whom to ask for information during information seeking activities?” (Allen, 1977; Borgatti & Cross, 2003). For instance, McDonald & Ackerman (1998) found that there were two steps in seeking
expertise in an organization – *expertise identification*, which is knowing what information or special skills others have, and *expertise selection*, which is choosing among people with the required expertise. Shami et al. (2009) note that searching for experts is ‘people sensemaking’ as it often involves sifting through a variety of information.

Collaborative sensemaking involves identifying that there is a need to find an expert as well as selecting the right experts to make sense of the information. Not being able to understand information leads group members engaged in a CIS task to find someone who can either help them understand that information (i.e. a domain expert) or help them understand how to find the information (i.e. a search expert). Group members seek others’ help to not only understand the information associated with the task but also to understand information pertaining to the search process itself, such as the relative reliability and value of information sources, the steps in the information seeking process, and group dynamics information. One way of enabling experts’ contribution to the sensemaking process is to provide the ability for them to comment on and annotate information found by others based on their expertise. However, a challenge of seeking out the expertise of group members is that different group members might prioritize different pieces of information as important to the CIS activity (as discussed on Section 5.2.2.). This challenge can be addressed by letting group members rate each others’ expertise and weighting comments from experts based on their expertise rating. For instance, in FirstNet, the ‘comments’ field allows care providers to make notes about the information contained in a patient’s record. Hence, the comments field was frequently used to store the products of sensemaking, but due to its very basic functionality (for instance, it does not show the time or the author of comments) it is not very effective in supporting sensemaking. To be more effective in supporting group sensemaking, the ‘comments’ field
can show the comments on each patient’s record ranked according to the expertise of the expert who provided that comment.

6.6 Summary of Study 1

This chapter concludes my discussion of study 1. The findings from this study provided insight into the nature of collaborative sensemaking and helped lay a conceptual foundation for when and how sensemaking takes place during CIS activities. I found that in CIS tasks, the products of sensemaking are often re-used by different group members and passed on over time. Also, the awareness of activities was more important than mere action awareness. The shared external representations help group members to build a shared understanding but can sometimes hamper group members’ sensemaking by not allowing role-specific information encoding. Based on these findings, I described some high level design implications that we need to think about in supporting sensemaking during collaborative information seeking tasks.

The findings from Study 1 lead to the conceptualization and design of Study 2. I wanted to explore the design implications arising from this study by developing a tool to enhance collaborative sensemaking in CIS activities. I chose to do this in the domain of Web search. There is growing evidence (Morris, 2008) that people collaborate during Web search activities and collaborative Web search is a ripe area for tools to support CIS activities. Hence, several tools (Morris & Horvitz, 2007; Pickens et al., 2008) have been recently proposed for helping users perform joint Web search tasks. However, there is little understanding of how sensemaking occurs in such tools and hence I found the area of collaborative Web search to be ideal for testing out the design ideas arising from Study 1.
The next three chapters of this thesis cover Study 2. Chapter 6 provides background about collaborative Web search and the design of the tool CoSense. Chapter 7 describes the evaluation of CoSense and findings from the evaluation while Chapter 8 discusses those findings.
Some of the content presented in the following chapter is based on research conducted at Microsoft Corp. during an internship with Meredith Ringel Morris and is the intellectual property of Microsoft Corp.
7. Study 2: Study Design and Methodology

The second study that I conducted to examine sensemaking in collaborative information seeking activities was in the domain of collaborative Web search. Web search is a domain of information seeking where the focus has traditionally been on the individual searcher. However, recently there has been growing evidence that people collaborate on Web search tasks in both their personal and professional lives (Morris, 2008). For instance family members might collaboratively search automobile websites to look for information before buying a new car, or healthcare providers in a hospital might search online medical databases to find the best drug to prescribe to a patient. A few tools have been developed to support such collaborative search tasks (Amershi, 2008; Freyne & Smyth, 2006; Morris & Horvitz, 2007; Pickens et al., 2008). However, researchers still do not have a clear understanding of users’ behavior during collaborative Web search tasks. Furthermore, studies of Web search behavior have focused mostly on how users retrieve information online with little attention paid to how they make sense of the retrieved information.

Since I was interested in examining how sensemaking could be supported in CIS tools (RQ3), I undertook study 2 in the technical domain of collaborative Web search. While study 1 focused on gaining a conceptual understanding of collaborative sensemaking during CIS activities, study 2 focused on the technical aspects of collaborative sensemaking. I examined how people make sense of the information found during collaborative Web search tasks. To investigate this, I conducted a formative study of users’ sensemaking during collaborative Web search tasks using SearchTogether, a collaborative Web search tool. I found that though SearchTogether helps users collaboratively search for information, it does not adequately support their sensemaking. Based on the findings of the formative study, I
built a new tool called CoSense to enhance sensemaking in SearchTogether. I evaluated
CoSense and found that it significantly enhanced sensemaking during SearchTogether-use.
The evaluation of CoSense not only helped understand what design features can enhance
sensemaking in CIS tools but also provided insight about users’ collaborative sensemaking
behavior.

In this chapter, I provide background about collaborative Web search, followed by a
description of the formative study to examine sensemaking during the use of SearchTogether. Next, I describe the findings from the formative study and the design of CoSense.

7.1 Collaborative Web search

Since Web search is an area of information seeking which has primarily focused on
individuals, most Web search tools, like browsers and search engines, are designed for
individual users. However, recently there has been growing evidence that people
collaboratively search the Web, both implicitly and explicitly. In a survey of 204 knowledge
workers, Morris (2008) found that over half of the respondents had cooperatively searched
the Web with others for activities ranging from travel planning to looking for medical
information. Survey respondents reported collaborating on the search process both
synchronously (e.g. watching over someone’s shoulder as they searched) as well as
asynchronously (e.g. emailing collaborators links to information pertinent to a joint task).
Evans & Chi (2008) surveyed 150 people about their experiences with searching for
information in their personal and professional lives, focusing specifically on the role of social
interactions in search activities. They found that people frequently interacted with others
before, during, and after a search activity and that social interactions were specifically
important in exploratory searches.
Collaboration during Web search can be classified along three dimensions – intent, concurrency, and location (Golovchinsky et al., 2008). In terms of intent, collaborative Web search can be implicit or explicit. Implicit collaboration encompasses collaborative recommendation and filtering systems, such as Amazon.com, in which the behavior of people searching for particular content is used to inform the search results of others searching for similar content. Explicit collaboration, on the other hand, occurs when people form task-based groups (Morris & Teevan, 2008) to search for information for completing a joint task, such as travel planning. Usually implicit collaboration occurs on large scales, such as over the Internet, while explicit or task-based collaboration occurs on smaller scales, such as in groups of three to four collaborators. Additionally, collaboration in Web search tasks can be synchronous or asynchronous, and co-located or distributed. While sensemaking is important for all kinds of collaborative Web search tasks, in our study we focused on sensemaking in distributed, task-based groups where group members conducted the search task both synchronously and asynchronously.

7.1.1 Collaborative Web search behavior

In spite of the evidence that collaboration occurs during Web search, there are very few studies which have investigated users’ search and sensemaking behavior when engaged in collaborative Web search or when using Web search tools. Most extant studies of Web search behavior have focused on individual searchers (Chi et al., 2001; Granka, Joachims, & Gay, 2004; White & Morris, 2007). Such studies have examined how interaction styles and queries differ within users and between users (White & Drucker, 2007) and how the use of different kinds of query syntax affects navigation behavior and search success (White & Morris, 2007). Few of these studies have focused on sensemaking within search. Information
foraging theory (Pirolli & Card, 1999) explains human information seeking and sensemaking behavior in Web search at the individual level; users forage for information by navigating from page to page along Web links. The content of pages that a user navigates is represented by snippets of texts or graphics called *proximal cues*. Foragers use these proximal cues to assess the *distal content*, which is the Web page at the end of the search.

Since collaborative Web search is a new area, very few studies have closely examined users’ behavior during collaborative search. Joho et al. (Joho, Hannah, & Jose, 2008) conducted a study to compare concurrent and independent search conditions in terms of the strategies used by searchers and the effectiveness of the search process. They designed experiments where participants worked on finding as many relevant documents as possible for a given topic. Participants did the task under three conditions – 1) an independent condition where two members of the team worked on the same topic but independently, 2) a shared condition where a team members performed a concurrent search using an search interface with instant messaging, and 3) a communication condition which was the same as the shared condition but participants could also communicate verbally. The researchers found that there was a lot of redundancy in documents marked relevant by team members in the independent condition. They also found that the size of the search vocabulary diversified in the collaborative condition as compared to the independent condition. However, the improvements in vocabulary and decrease in redundancy did not lead to more efficient retrieval of documents in the collaborative condition. The researchers speculated that this was because the costs of collaboration on their study were higher than the benefits due the way the communication channels were devised. For instance, teams that spent more time discussing documents they found and the relevance of the documents, spent less time finding
relevant documents. Also, participants avoided viewing documents viewed by team members and hence did not learn everything about the topic space. Their incomplete knowledge of the topic space led them to mark fewer documents as relevant. This study, while not specifically designed to study sensemaking in collaborative search, provides important insights into how participants understand the information found by others in concurrent search conditions. It also shows that there is still much to learn about collaborative search behavior and how effective tools can be designed to support it.

7.2 Supporting sensemaking in Web search

A significant part of the research on Web search has been focused on developing tools to make the search more efficient, rather than helping users make sense of the results. Chapter 2 described some sensemaking-support tools for Web search tasks, such as the Sensemaking-Supporting Information Gathering (SSIG) system (Qu, 2003) and ScratchPad (Gotz, 2007). Though not explicitly designed to enhance sensemaking, several other tools have been designed to help users organize information found during Web search sessions. Some of these tools have focused on supporting efficient management of bookmarks. WebBook (Card, Robertson, & York, 1996) helps users visualize their bookmarks collection as pages in a book which can be quickly “flipped through”. Data Mountain (Robertson et al., 1998) helps users arrange bookmarks as pages of thumbnails in a 3D space. TopicShop (Amento et al., 2000) provides an interface to help users organize and evaluate collections of Web sites and lets users organize sites both spatially and by creating subfolders and moving resources into subfolders; thumbnail images serve as memory aids to support re-use and sharing of Web pages with others.
While these tools help users manipulate entire Web sites, The Hunter-Gatherer interface (schraefel et al., 2002) helps organization of smaller-than-page-sized information components extracted from Web pages. Users can collect content from within Web pages, represent those components in a collection, and edit the component collection. Some tools have been designed to help users summarize personal Web browsing sessions. Dontcheva et al. (2006) designed a system to help users select Web page elements and label them with pre-defined keywords. The selected content is used to create an extraction pattern that can be applied to automatically select more content from similar pages. SearchBar (Morris, Morris, & Venolia, 2008) helps users manage information across multiple Web sessions by storing query histories, browsing histories, and users’ notes and ratings in an inter-related fashion. Though these tools were not explicitly designed to support sensemaking in Web search tasks, their ability to help users select, organize, evaluate, and re-visit information found during Web search makes them important examples for consideration when designing sensemaking support for Web search. However, these tools have all been designed for individuals.

Similarly, Web search tools like browsers and search engines have also traditionally been designed for single users, but have recently been taking into account collaborative aspects of this activity. Researchers have developed collaborative search tools which provide either UI-level (Morris & Horvitz, 2007) or algorithm-level mediation (Freyne & Smyth, 2006) of search results. Tools that mediate at the UI level (e.g. SearchTogether (Morris & Horvitz, 2007), CoSearch (Amershi, 2008)) provide features such as division of labor and increased awareness to group members so they can coordinate their searches. Tools that mediate at the algorithmic level (e.g. Cerchiamo (Pickens et al., 2008)) record and re-use search histories of like-minded users. Finally, some search engines are incorporating social
aspects of search by allowing users to vote on link relevance (e.g. Wikia search www.wikia.com).

At the community-level, websites like Many Eyes (Viegas et al., 2007) allow users to upload data, create visualizations of that data, and leave comments on both the visualizations and data sets. While the comments, annotations, and discussions on visualizations helps people make sense of the data together, they do not collaborate on generating the data itself. Other Web 2.0 sites like del.icio.us (www.del.icio.us.com), Mag.nolia (www.mag.nolia.com), and CiteULike (www.citeulike.com), augment solo search and browsing by facilitating link sharing with friends.

In summary, most sensemaking-support tools have been designed for individuals searching over document collections and the Web. Recently there has been emergence of tools that allow UI-level or algorithmic mediation of search results for collaborative search. Also, some search engine sites allow social augmentation of Web search results to allow community-level collaboration. However, these tools are still new and we have very little understanding of how they support sensemaking in Web search tasks.

One of the tools that have been designed to support collaboration during search, and that was used in our study, is SearchTogether. In the next section I describe SearchTogether, and the formative study of sensemaking in SearchTogether.

7.3 Research design

Study 2 began by conducting a formative study of sensemaking within SearchTogether. The goals of the formative study were to examine

- how sensemaking is currently supported in SearchTogether, and
- what additional features could enhance the current level of sensemaking support.
Findings about sensemaking in SearchTogether are generalizable to other CIS tools since descriptions of other tools in the literature suggest that the level of sensemaking support in SearchTogether is representative of the status quo for such collaborative search systems.

7.3.1 SearchTogether

SearchTogether\(^6\) is a UI-based collaborative Web search tool. It is a publicly-available, free plug-in for the Internet Explorer 7 Web browser, whose feature set is based on the system described in (Morris & Horvitz, 2007). There are currently 1,312 registered users. SearchTogether is meant to facilitate synchronous and asynchronous remote collaboration on Web search, among small, task-oriented groups.

Figures 11(a) and 11(b) show the SearchTogether plug-in. In the example depicted, three family members are conducting a joint search to plan a vacation to Disney World. SearchTogether’s collaboration features include shared Web browsing support (through the “peek” and “follow” actions), shared awareness of group members’ query terms, the ability to “split” a search results page by distributing the results among group members, the ability to associate a rating or comment with a page (which is then visible to the group through the “summary” view, see Figure 11(b)), and integration of chat with the browsing application. All data from a SearchTogether session are automatically saved and stored on a central server, in order to facilitate asynchronous collaboration and re-use of search results over extended periods of time. SearchTogether’s features are explained in detail at http://research.microsoft.com/searchtogether/tutorial.html.

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\(^6\) For more information about SearchTogether see http://research.microsoft.com/searchtogether/
Figure 11(a): The SearchTogether browser plug-in’s “Contacts” view fills the left-hand portion of the Web browser, and the integrated chat runs across the browser’s bottom. These features provide some basic support for collaborative sensemaking around the process of searching by providing shared awareness of query terms and associating context (conversation from the integrated chat) with the search topic.
Figure 11(b): The “Summary” view of the SearchTogether plug-in can be switched to in place of the “Contacts” view, and provides some basic support for collaborative sensemaking around the *products* of a search, such as creating a collection of links and associating comments with them.

SearchTogether provides some facilities to support collaborative sensemaking. The storage of chat transcripts together with the queries and search results, for example, helps provide
additional context surrounding the search task. Group query histories support awareness of the process and strategies used by other collaborators in approaching the information seeking task. The summary view, Figure 11(b), with users’ comments and ratings on found pages, reflects the groups’ efforts to triage found content.

7.3.2 Formative study of sensemaking in SearchTogether

I conducted a formative study to understand how well SearchTogether currently supports sensemaking and what additional features might enhance sensemaking in SearchTogether. The study had six three-member groups participate in a vacation planning task using SearchTogether. Participants were employees of Microsoft and were proficient in basic Web search, but had not used the tool before. The task was to find fun activities for a weekend in Seattle given the constraints that each group member could spend only $50, and that the activities chosen should include one each of cultural, outdoor, and dining activities. The task was conducted in two phases – in phase 1, two members from each group were online synchronously (but in different locations) and searched together, knowing that their third group member would log in later to complete the task at a later time. The information they found was automatically stored in SearchTogether. In phase 2, which occurred at a later time, the third group member logged into the group’s SearchTogether session alone and was instructed to continue the task in order to come up with the final vacation itinerary. This study design helped me observe sensemaking during both synchronous and asynchronous collaborative search, and also enabled me to observe the “handoff” between group members who searched searched synchronously (in phase 1) and those who searched asynchronously (in phase 2).
I use the term “asynchronous” to refer to collaboration in which the third group member alone continued the search task started by the others and the other group members did not re-visit or resume the search task after the third group member had worked on it. In other words, the actions of the phase 2 participant were not fed back to the phase 1 participants and “influence” (Pickens & Golovchinsky, 2007) flowed only in one direction – from the phase 1 searchers to the phase 2 searcher. Such kind of collaboration has also been referred to as “non-synchronized” in the literature (Pickens & Golovchinsky, 2007).

I observed participants as they conducted the task and also asked them to “think aloud” and tell us about their experience using SearchTogether. I also audio and video recorded the sessions and conducted semi-structured interviews with participants after they had completed the task to understand what sensemaking challenges they had faced while using SearchTogether. I analyzed the data using a grounded theory approach (Strauss & Corbin, 1990) to find themes related to sensemaking challenges during SearchTogether use.

Participants felt that collaborative Web search necessitated support for sensemaking beyond what was offered by SearchTogether. Participants faced important challenges in making sense of information found during their collaborative search task, as discussed below.

### 7.3.2.1 Sensemaking trajectories

Understanding the temporality of the search process was important for group members’ sensemaking. Many participants wanted to see a unified chronological ordering of all events in the search process (such as comments and ratings associated with web pages, query terms, and links followed). Persistence of the process of collaborators’ sensemaking was important. Group members wanted to be able to view the path that others had followed during the search; this was not supported currently in SearchTogether. One participant said about
making sense of other group members’ search process, “I didn’t have an idea of what route they [group members] were taking.” The persistence of the products of sensemaking was also important. SearchTogether allows group members to comment on Web pages, but participants said that they wanted to be able to note meta-comments and decisions that were not associated with particular Web pages, but rather with the task itself. They also wanted to be able to edit these meta-comments as the group’s sense evolved over time. They wanted to see the complete information path that was followed by other group members, and hence would have liked SearchTogether to make the browsing (in addition to searching) behavior of others more visible.

The concept of query evolution seemed important to participants’ sensemaking; that is, participants wanted to take others’ queries and build upon them. A related concept was of evolving sense, that is, as more sense was made of the search task, participants wanted the state of the collaborative search tool to reflect this, such as by modifying and deleting comments and links which were not considered important anymore and editing the summary in SearchTogether as the task progressed and more sense was made of the task space. Thus, it was important to be able to view not only others’ search trajectories, but also their sensemaking trajectories, i.e., the steps in their sensemaking process and the “sense” made at each step.

### 7.3.2.2 Awareness

Awareness played a key role in group members’ sensemaking. Although SearchTogether was designed to provide awareness of others’ search activities (Morris & Horvitz, 2007), our participants wanted even more awareness of what others were doing during the search task. There were two kinds of awareness that participants considered important for making sense
of the search task: *action awareness* and *context awareness*. Group members wanted awareness of others’ actions; while SearchTogether provided awareness of others’ actions with the search engines (through query histories and ratings of pages), our participants also wanted awareness of actions that occurred in the collaborative tool itself, such as who had viewed comments and ratings they added, visited the pages they’d suggested, or re-used terms from their history. Participants also wanted to be able to draw context from others’ search queries and instant messages, and to be able to connect these to the search results they had found. Being able to contextualize the web pages, chat messages, and comments of other group members was key to participants’ ability to tell what decisions the group was working toward.

7.3.2.3 Sensemaking handoffs

I found that sensemaking was particularly difficult for phase 2 participants to whom the search task had been “handed off”. These participants were overwhelmed with all the information in the search session and felt that there was no quick way to get an overview of “what others were thinking”. They found it difficult to correlate the different kinds of information (web pages, comments, ratings, chat) and determine what decisions had been made by others. They also found it hard to distinguish “old information” from “new information.” Due to this, persistence of both the process and products of sensemaking was deemed to be important during the collaborative search task. Participants wanted to understand *how* others had found information, and their motivations behind viewing and recommending web pages. Phase 2 participants searched asynchronously and felt that while the query history and comments showed the highlights of the search, there was no way to “drill down into everything” that was done in phase 1. In collaborative sensemaking, the
product of the sensemaking process (i.e. the “sense” that is made) is passed on not only over time but across multiple individuals. Phase 1 participants wanted to be able to explicitly note the products of their sensemaking to pass on to phase 2 participants. For instance, they wanted to be able to note meta-comments about the state of the search task, not just comments about specific web pages. Phase 2 participants wished group members had left them notes about “what they were thinking.” They would also have liked a place to record their “final decisions.” Thus, it was challenging to hand-off the sense made in phase 1 of the task to members who resumed the task in phase 2.

From the findings of my study it was clear that while SearchTogether helped collaborators to jointly search the Web, it did not adequately support sensemaking. Based on our findings, I designed the CoSense prototype. The features I decided to include in CoSense were guided by my findings from the formative study as well as literature on Web search behavior.

### 7.4 CoSense

CoSense is an extension of SearchTogether that enables users to understand the information found during a collaborative Web search task, as well as the process group members used to find that information. CoSense is integrated with SearchTogether as shown in Figure 12.

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7 CoSense was designed with the help of Meredith Ringel Morris, my internship mentor at Microsoft Research. Merrie and I together brainstormed about the design features CoSense and I implemented them through C# code. Merrie wrote some of the code for implementing the Search strategies and Chat transcript views.
When users perform a search using SearchTogether, the queries issued, Web pages opened and commented on, comments made on Web pages, and the chat messages exchanged in a given search session are stored in a database. CoSense reads that data from the database in real-time and provides alternate views of this data to enhance group members’ sensemaking.

Users log into CoSense along with SearchTogether. When a user logs into CoSense, the tool reads the user’s SearchTogether search session data from the database and displays this data in four views – the search strategies view, the timeline view, the workspace view, and the chat-centric view. Data added via CoSense are reflected in SearchTogether and vice versa. CoSense updates its views in real-time in response to new data from any other group.
member’s instances of SearchTogether and CoSense (that is, changes made by any group member are reflected in all group members’ copies of CoSense in real-time).

As suggested by the findings of the formative study, the views of information in CoSense were designed to make explicit the temporal nature of the search, to provide action and context awareness, and to support sensemaking during handoffs. The following subsections describe the four views of CoSense.

### 7.4.1 Search strategies view

The search strategies view (as shown in Figures 13(a) and 13(b)) visualizes the query and browsing activity of individual group members and of the group as a whole. The formative study revealed that it is often challenging for participants to understand the searching and browsing behavior of others. This view is designed to help group members make sense of the search process and of the roles and skills of each group member during the search task. The view shows three kinds of information about users – query history, browsing history, and search skills and strategies.
Figure 13(a): The search strategies view shows individual and group tag clouds of the query keywords and the websites used in the search. It also shows graphs for the number of URLs visited and the queries issued by group members. The cursor is placed over the keyword “Gothenburg” and shows a list of queries which contained the word “Gothenburg”.

Query history is depicted by graphs showing, for each group member in a search session, the total number of queries issued. It is also made explicit through tag clouds of the keywords used in group members’ queries, and through a timeline that shows group members’ queries side-by-side in a chronological view. The query tag clouds are interactive in that hovering
over a keyword will show all queries which contained that keyword and clicking on the keyword will re-issue all queries containing that keyword and display the results of those queries in separate tabs of the current browser window.

Figure 13(b): The search strategies view also shows the ‘query history timeline’ which shows a chronological side-by-side view of group members’ queries and “advanced” graphs which make explicit the search skills of group members.

Browsing history is made explicit via graphs that show the total number of URLs visited by each group member, and tag clouds of the websites visited by each group member and the group as a whole. The website tag clouds are interactive too; hovering over a website name
in the website tag cloud shows all the URLs associated with that website. Clicking on the website name in the tag cloud opens up all the URLs in tabs of the current browser window.

The query and website tag clouds provide at-a-glance information about each group member’s search strategy and help users make sense of the similarities and differences between the roles and search strategies of different group members. Additionally, the skills and strategies of group members are made explicit through graphs for each group member that show the advanced operators used in their queries, the average number of keywords in their queries, and the time between queries. These graphs are inspired by prior literature (White, Dumais, & Teevan, 2009; White & Morris, 2007) on what makes someone an expert searcher since understanding the levels of expertise of other searchers seems necessary for making sense of group members’ search process and roles.

7.4.2 Timeline view

The formative study found that making the temporality of the search process explicit was important for participants’ sensemaking. The timeline view (Figure 14) makes explicit the browsing and search history of the group and allows users to inter-relate different kinds of content (such as Web pages viewed, chat messages, comments and ratings). It shows chronologically all the actions performed by group members during a search session in the form of an integrated timeline. The timeline contains queries issued, web pages visited, comments and ratings associated with web pages, and chat messages. Content is color-coded by user. This timeline is interactive — clicking on a website in the timeline opens it in the browser window. Also, a “preview” of the webpage appears in the right side of the timeline tab. This preview shows a thumbnail of the web page, group members who visited that page, chat messages exchanged when that page was being viewed, and any comments and ratings
associated with that web page. The timeline can be interactively filtered by group member or action type. For instance, the checkboxes can be used to show only the Web pages or the chat and comments along with the Web pages. The Web pages can also be grouped by domain to make the timeline more concise.

Figure 14: The left-side of the timeline view shows a chronological, color-coded listing of Web pages viewed, chat messages exchanged, and comments and ratings on Web pages. Clicking on a Web page in the Timeline view shows a “preview” of the Web page on the right-side.

7.4.3 Workspace view

The workspace view (Figure 15) is designed to support categorization and organization of search results. The left side of the workspace contains summaries of web pages group members have commented on. The summary for each web page contains a link to the webpage, comments and ratings associated with that web page, and a list of group members who visited that web page. Group members can tag summary items and then filter the
workspace by tags. The workspace view also supports storing of the products of sensemaking, such as meta-comments associated with the search session and files or other electronic artifacts group members might create. The right side of the workspace contains areas for free-form note-taking (allowing group members to note to-do items or decisions reached). It also allows uploading of text files, spreadsheets, photos, or email that group members might have created during their search. The notes and artifacts in the workspace are accessible to all group members.

Figure 15: The workspace provides a place to store the products of the sensemaking process. It shows Web pages that have been commented on, “to do” and “scratchpad” areas, as well as links to external documents associated with the task.

7.4.4 Chat-centric view

The chat-centric view is designed to provide context awareness by allowing searchers to inter-relate the Web pages viewed with the chat messages exchanged. This view (Figure 16)
shows a transcript of the chat conducted during the search session, color-coded by user. Clicking on a chat message in this transcript shows the web page that was open in the browser of the person who authored that chat message, at the time that chat message was typed.

Figure 16: The chat-centric view shows the group’s color-coded chat conversation (on the left). Clicking any chat message shows the Web page associated with that chat message (on the right).

The different views of CoSense present different ways of visualizing and interacting with the information found during a collaborative Web search task. The views are designed to help searchers face the sensemaking challenges identified in our formative study. After designing and implementing CoSense, we conducted an evaluation of CoSense to see how well it alleviated the sensemaking challenges faced by participants in using SearchTogether. The next chapter describes the evaluation study and findings from the evaluation.
Some of the content presented in the following chapter is based on research conducted at Microsoft Corp. during an internship with Meredith Ringel Morris and is the intellectual property of Microsoft Corp.
8. Study 2: Findings

This chapter provides details about the evaluation of CoSense and findings from the evaluation. I first describe the methodology used for evaluation, including the search task and experimental design as well as the questionnaire used to measure participants’ sensemaking at the end of the evaluation task. Then I discuss findings from the evaluation such as how the different features of CoSense helped support sensemaking during the evaluation task and participants’ sensemaking behavior during different parts of the task and while answering the questionnaire.

8.1 Evaluation of CoSense

I evaluated CoSense to investigate whether it helped participants overcome the sensemaking challenges found in the formative study. This section describes the evaluation study in detail.

8.1.1 Participants

For the evaluation, I recruited 18 participants who were employees of Microsoft to perform a collaborative Web search task using SearchTogether and CoSense. Participants were recruited by emailing Microsoft employees using various internal listservs. Participants were in the age range 20-60 years and their self-reported expertise in Web search ranged from “average” to “expert”, with a majority having “above average” expertise. Participants had not used collaborative Web search tools before.

8.1.2 Task

Evaluation tasks used in the sensemaking literature include problem solving (N. Sharma, 2007), topic comprehension (Billman & Bier, 2007), understanding large document
collections (Russell et al., 1993) and information retrieval tasks like shopping for products online (N. Sharma, 2007). I chose a collaborative information retrieval task which was designed to require handoff (in order to study whether CoSense helped participants overcome the sensemaking challenges associated with handoff, as uncovered in the formative study). To maintain consistency with the formative study, the evaluation study task was also a vacation planning task. Appendix A contains the instructions provided to participants about the task.

The task was conducted in two phases again to allow me to observe the sensemaking challenges associated with handoff. In phase 1, three group members performed the search task synchronously (but in different physical locations) and in phase 2, the remaining group member went online later and continued the task alone. The task required planning a vacation in a European city given certain constraints that were included to make the task more realistic. The constraints were that participants could spend only 100 Euros per person and they had to plan at least four different vacation activities – sightseeing, outdoor, cultural, and dining. To avoid bias error, I designed two versions of the task which were identical except for the vacation location.

Phase 1 consisted of two three-member groups (i.e., a total of 6 participants) completing one of two versions of the task. Phase 1 participants worked on the task for 25 minutes and were told that a fourth group member would log in later to complete the task. In phase 2, each of the remaining 12 participants played the role of the fourth group member and continued either task 1 or task 2. Each phase 2 participant logged into the search session of a given phase 1 group and continued the task for 25 minutes. Figure 17 shows the experimental design for the evaluation task.
8.1.3 Data collection and analysis

All participants’ actions in SearchTogether and CoSense were logged automatically while they were conducting the search task. SearchTogether automatically logged Web pages opened by participants, queries issued, comments on Web pages, and chat messages exchanged. Appendix B shows an example of a participant’s log file generated during SearchTogether use. In CoSense, I logged a variety of actions for each participant, such as changing tabs, clicking on buttons and labels within tabs, checking off radio-buttons and check-boxes, and notes made in the free-form text-entry areas in the Workspace tab. All actions were saved as times-stamped entries in log files. Appendix C shows an example of a
participant’s log file generated during CoSense use. Thus, combining the log files from SearchTogether and CoSense for each participant gave me a complete chronological history of all actions taken by the participant during the search task.

After completing the task, both phase 1 and phase 2 participants answered an online questionnaire (Appendix D). The questionnaire was designed to measure participants’ sensemaking about various aspects of the task, as explained in detail in Section 8.2.1. I logged participants’ answers to the questions in the questionnaire, as well as which features of CoSense were accessed when answering each question. I also conducted semi-structured interviews with phase 2 participants (Appendix E) after they had completed the task as I was interested in how they had handled the handoff of the search task.

I analyzed data from both SearchTogether and CoSense logs to examine how search and sensemaking took place both during the task and when answering the questionnaire. I was interested in examining how participants switched between search and sensemaking and how these patterns of search and sensemaking varied across individuals and between synchronous and asynchronous search.

In the next section, I first present quantitative assessments of CoSense tab usage during the task and during answering the questionnaire. Then I provide a detailed qualitative analysis of the results of the evaluation of CoSense, in order to provide insight into users’ sensemaking behavior during collaborative Web search.
8.2 Results of the evaluation

8.2.1 CoSense Feature Use

Participants used CoSense’s features both during the main vacation-planning task, as well as in answering the “sensemaking measurement” questionnaire at the end of the study. Here, I describe which features were most relied upon for these different activities.

8.2.1.1 CoSense use during the search task

During the main search task, participants tended to rely on different CoSense views depending on whether they were participating in phase 1 (initial, synchronous search) or phase 2 (handoff, asynchronous search).

In phase 1, the most frequently accessed view was search strategies (accessed by 83% of participants), followed by the chat-centric view (accessed by 67% of participants). The most frequently used features in the search strategies view were viewing tag clouds (all participants) and clicking on website tag cloud items (33% of participants). In the chat-centric view, 67% of participants looked at the web pages associated with individual chat messages. Although the workspace was not frequently used during phase 1, 50% of participants visited the workspace, and all edited the “to do” space.

In contrast, during phase 2 the most frequently accessed view was the workspace view (accessed by 92% of participants), followed by the timeline view (accessed by 83% of participants). Several features within the workspace view were relied upon – editing the “scratchpad” area was common (42% of participants), as was the use of hyperlinked URLs to open web pages associated with summary items (58% of participants). 42% of participants used the timeline view, mainly to open web pages.
8.2.1.2 CoSense use during the questionnaire

During collaborative search participants need to make sense of information relevant to the task and information about group members’ actions. I designed a post-task online questionnaire (Appendix D) to test how well participants had made sense of both these types of information. The questionnaire contained questions to test participants’ understanding of task-related information, such as websites and queries, and how useful that information had been to the search process (Q4, Q6, & Q7); questions to test participants’ understanding of others’ task performance, such as search strategies and division of labor (Q3 & Q5); questions to test participants’ understanding of others’ skills and contributions to the task (Q1 & Q2); and questions to test participants’ understanding of the task-state and progress on goals, such as decisions reached and progress made with the itinerary (Q8 & Q9).

The questionnaire was taken by participants from both phases after they had completed the search task. Time-stamped logs were created while participants completed the questionnaire. These logs showed which views of CoSense participants had switched to while answering each question in the questionnaire. An analysis of the logs revealed which features of CoSense were used while answering each of the questions.

The search strategies view was useful in helping participants understand skills and strategies of group members. This view was used by 44% of participants to answer which group member was the most skilled searcher and why (Q2). Participants judged their group members’ skills based on 1) the quality of their queries (average length, keywords used) 2) the quality of the search results returned by their queries, and 3) how much attention they paid to the task categories and constraints as they searched. For instance one of the participants thought that R was the best searcher in his group because he had a “high number
of search types with low average number of words per query.” Participants indicated that the tag cloud of each group member’s query keywords helped reflect whether that member had taken constraints such as categories of activities or budgeting into account. The search strategies view was also frequently used (by 50% of participants) to answer the question about which websites the group found most helpful (Q4); the tag clouds, in particular, were used to answer this question. However, the tag clouds only show which websites had been most frequently used; frequency of use did not necessarily indicate that these websites were more useful. A few participants (28%) realized this and used the timeline view to look at the chronological ordering of everything done during the session in relation to websites group members had looked at. The more comments and chat associated with a website, the more useful it was judged to be.

The timeline view was used in understanding connections between various kinds of content. Participants (33%) typically used the integrated timeline view (rather than the special query history timeline in the search strategies view) to understand how group members’ search strategies influenced each other (Q5), since this view gave a more holistic view of the search process including results found as a consequence of each query. The most common approach (taken by 44% of participants) was to use the timeline (rather than the chat-centric view) to decide which pages generated the most discussion (Q6), since they felt that both chat messages and comments applied to web pages were relevant to consider when answering this question, and the unified timeline showed both. The timeline view was also the most common choice (33%) for determining which queries were most successful (Q7), since this view enabled them to connect queries with subsequently visited web pages, and thereby judge the success of queries based upon the quality of the pages they led to.
The chat-centric view was used most often (by 39% of participants) when answering questions about which group member contributed the most to the task (Q1). The other main use of the chat-centric view (by 11% of participants) was understanding what decisions were reached (Q8). For Q1, participants clicked on chat items to view the associated web page, but for Q8 participants merely read the chat transcript without clicking on any messages.

The workspace view was useful to participants when answering questions regarding group members’ contributions and roles with respect to the task, as well as for understanding what decisions had been reached by the group. This view was used by 33% of participants to answer the question about which group member contributed most to the task (Q1), primarily by counting how many URLs and comments each group member had posted to the workspace. It was also used by 22% of participants to answer (Q3), regarding what aspect of the task each group member worked on; again, the summary items were used to formulate the answers. 17% of participants relied on the workspace to answer Q8 which asked what, if any, decisions the group had reached regarding the itinerary; the “to do” list was used for this purpose.

8.2.2 Qualitative analysis of CoSense use

In order to understand how sensemaking takes place in collaborative search, I analyzed participants’ patterns of search and sensemaking. I found that patterns of search and sensemaking differed during synchronous (phase 1) and asynchronous (phase 2) search. For our analysis, we categorized participants’ actions as follows:
In addition to analyzing how participants switched between search and sensemaking, I was interested in qualitatively examining how sensemaking took place and the role that CoSense played in supporting sensemaking. For this, I examined when and why participants switched from SearchTogether to CoSense and how the different views in CoSense were used. Here I present our findings for both synchronous and asynchronous search.

**8.2.2.1 Sensemaking during synchronous search**

*Sensemaking-lead strategy*

During synchronous search, searching and sensemaking were intimately intertwined. I found that there were two strategies adopted by phase 1 groups in starting the search task. Before looking for information about activities to do on their vacation, one group (task 1) started with making sense of the task and the strategies that they would apply in performing the task. I call this approach the *sensemaking-lead* strategy. Figure 18(a) shows for task 1, what proportion of the group’s actions was sensemaking (red line) and search (black line) at any given time. It was seen that during the first five minutes of the task, more than 50% of the group’s actions were sensemaking. In the middle of the task, search took precedence over sensemaking, but again during the last 7 minutes of the task, sensemaking took precedence over search.
Figure 18(a): Proportion of search and sensemaking activities for synchronous search (during task 1). The group had a sensemaking-lead strategy.

Figure 18(b): Categories of search and sensemaking actions during synchronous search (task 1) for the sensemaking-lead group.

Figure 18(b) shows a breakdown of what the search and sensemaking actions for the group were across time. The group started by using SearchTogether’s chat feature to discuss their
strategy for searching. They decided that they would all work simultaneously on each of the
four activities (sightseeing, dining, outdoor, and cultural) one by one, instead of splitting up
the activities between group members, and that they would start with the sightseeing activity.
They also discussed that since 100 Euros was not much, they were “going on the cheap”.
Thus, during the first 5 minutes of the task, sensemaking took place only through the chat in
SearchTogether. After discussing their strategies and constraints, group members switched to
searching and submitted their queries to SearchTogether; two group members used the query
“Gothenburg Sweden” while the third used “Gothenburg”. Depending on the search results
returned, each group member then diverged in a different direction. Group member A visited
Web sites like goscandinavia.com, travel.yahoo.com, and wikipedia.com; group member B
visited stromma.se, wikipedia.com, and tripadvisor.com; and group member C visited
wikipedia.com, stromma.se, and goscandinavia.about.com.

As they searched, sensemaking took place in the form of chatting and adding
comments to interesting Web pages in SearchTogether, such as “possible sightseeing
destination”. CoSense wasn’t used at all during the first five minutes of the task. However,
as more search took place, group members started using CoSense to understand what aspects
of the task others were working on. However, they continued to use the chat in
SearchTogether to express their opinion on things they found. For instance, group member B
switched to the search strategies view of CoSense and saw that group member A was looking
at McDonald’s as a dining option. B told A via chat that he didn’t want to eat at McDonald’s
and re-directed his own search to look for cheap dining places in Sweden. In the last 7
minutes of the task, group members spent more time on making sense of the information
found than on searching for new information. Most of their sensemaking during this time was using CoSense.

**Search-lead strategy**

The other group (performing task 2) used a different strategy for approaching the search task. They did not start by discussing or making sense of the task, instead they started by searching for information. I call this the *search-lead* strategy. Figure 19(a) shows the proportion of search and sensemaking activities for the group performing task 2. This group started with searching and consistently performed more search than sensemaking; during the entire duration of the task more than 75% of the group’s actions were search. Figure 19(b) shows the breakup of the search and sensemaking actions of the group. Here again I found that during the first 5 minutes of the task, sensemaking took place only via SearchTogether’s chat. Group members did not comment on Web pages, but instead used the chat to leave comment-like messages such as “found a day long hike” or “this amusement park is around 38 euros per person”. Later, they commented on Web pages in SearchTogether but used this feature only in the middle part of the task. CoSense wasn’t used until 13 minutes into the task and overall was used much less than it was by the task 1 group.
Figure 19(a): Proportion of search and sensemaking activities during synchronous search (for task 2). This group had a search-lead strategy.

Figure 19(b): Categories of search and sensemaking actions during synchronous search (task 2) for the search-lead group.
CoSense usage

I analyzed the CoSense log files to understand which features of CoSense were used (and how) during synchronous search. I found that the most-used views in phase 1 were the search strategies view (accessed by 83% of participants and viewed 17 times across both tasks) and the chat-centric view (accessed by 67% of participants and viewed 16 times across both tasks). Phase 1 participants used the search strategies view primarily to look at tag clouds and tooltips and the chat-centric view to look at Web pages associated with group members’ chat messages. Here I provide some examples of how the search strategies and chat centric views were used during synchronous search.

Participants periodically switched to the search strategies view to keep track of what others were searching for and which Web sites were being used the most. This helped them update their own search strategies in real time. Group members said that viewing the individual tag clouds of others helped them sometimes to make sure that their searches were not overlapping and at other times to follow up on what others were searching for.

The importance of the chat-centric view was linked to the importance of chat during synchronous search. I noted that chat in SearchTogether played an important role during synchronous search. In initial stages of the search, the chat helped groups discuss their strategy for conducting the task, such as having different group members focus on different components (such as sightseeing activity, dining activity, etc.) of the task or having the whole group focus on one component at a time (as in the case of the task 1 group). The chat was also useful in helping group members share information they had found and their preferences for how they wanted to spend their vacation. However, making sense of the chat
messages in SearchTogether was difficult since group members were simultaneously searching and could easily lose context of what others were saying in the chat.

The chat-centric view in CoSense was often used by participants to contextualize the chat with respect to the Web pages found. For instance, in task 2, group members started the task by entering queries into SearchTogether such as “Helsinki Finland” and “Helsinki”. As they started exploring the results returned by the search engines, they shared what they found by typing in the chat “here’s an amusement park in Helsinki” and “found a day long hike”. But since the chat messages were devoid of context, other group members found it hard to understand which amusement park or hike the person was talking about. This is where the chat-centric view in CoSense was used by group members to make sense of chat messages. Group members clicked on these chat messages in the chat-centric view in CoSense to directly see the Web page that the person was looking at when that message was typed.

Another example of using the chat-centric view in conjunction with the chat occurred during task 2 when group member B volunteered to find a restaurant and typed a query “Helsinki dining”. From the returned search results he followed links to finnguide.fi which listed the top restaurants in Finland. Having found a restaurant he liked, B typed “aino Helsinki” and “aino Helsinki restaurant” as queries, found the website of the restaurant and looked up the menu. Next, B informed other group members of his choice by typing in the chat in SearchTogether “they serve reindeer at this restaurant aino, I’d like to go there”. In the meantime, group member C had been looking at restaurants using the query “Helsinki good cheap restaurants”. When he saw B’s chat message about the restaurant he’d like to go to, he switched to the chat-centric view in CoSense and clicked on that chat message. This
opened up the Aino restaurant menu page directly for C and he spent some time looking at the menu. After reviewing Aino’s menu, C stopped searching for restaurants.

Another example of using the chat-centric view was in task 2 when group member C wanted to share the Wikipedia article on the botanical gardens in Sweden. He wrote in the chat

“Possible outdoor activity: http://en.wikipedia.org/wiki/G%C3%B6teborg_Botanical_Garden”.

A minute later, group member B was looking at the chat-centric view in CoSense and clicked on this message which opened up the link for the botanical gardens. He wrote in the chat “garden looks good to me”. In the meantime, C browsed the Wikipedia article on the botanical garden by going back to click on his own chat message in the chat-centric view, rather than using the back or history features of his browser. Now group member A, seeing that the botanical garden was being discussed in the chat, clicked on the chat message from C in the chat-centric view and opened the Wikipedia article. Finally, C switched to the workspace view in CoSense and added “Botanical gardens” to the list of activities in their To-do list.

Finally, both groups of phase 1 participants used the workspace view the least (accessed by 50% of participants and viewed 7 times across both tasks). They primarily used the summary in SearchTogether rather than the one in CoSense, suggesting that these groups’ strategies were to read and comment on pages during the search process itself, rather than quickly building up a set of candidate pages and then reading and reflecting on them as a separate stage in the process. Also, only one group used the to-do and scratchpad free-form text entry areas to record a rough itinerary of the options they were considering for their
vacation (Figure 20). This might be because (due to time constraints) they were still in too preliminary a stage to start recording their decisions.

Figure 20: Workspace view of the phase 1 group conducting task 2 shows that they recorded four activities in the scratch-pad. The other group did not record anything in the “to-do” and “scratchpad” areas.

**Handoff in synchronous search**

Phase 1 participants were told that a fourth group member would log in later to continue the planning of their vacation. I also told them that all the information they found during the task, as well as their chat, comments, and ratings would, be automatically stored for the fourth group member to see. After working on the search task for 25 minutes, phase 1 groups had generated a lot of content as shown in Table 5 below:
Thus, it would be a daunting task for the fourth group member to make sense of all this information in order to successfully complete the handoff and continue the task.

I was interested in observing if phase 1 participants made any special efforts to ensure an effective handoff to the fourth group member such that he or she would be able to easily make sense of the information found in phase 1. I found that phase 1 participants did not make explicit preparations for handoff. They recorded the sense they had made about specific Web pages in the form of comments added to those Web pages, and one of the groups listed four activities that they were considering for their vacation (Figure 20), but neither phase 1 group left any notes or instructions specifically for the fourth group member. It would be valuable to repeat this study with a larger number of phase 1 groups, in order to verify this trend of leaving minimal information for future group members during asynchronous task handoff. However, this trend makes sense when considered in light of studies of single-user information seeking activities that suggest that many users take a “do nothing” approach toward organizing found information for their own future use (Jones, Bruce, & Dumais, 2001; Morris et al., 2008).

8.2.2.2 Sensemaking during asynchronous search

Handling Handoff: Search-lead vs. sensemaking-lead strategies

I was interested in understanding how the twelve phase 2 participants resumed the search task that was handed off to them, and whether CoSense helped with this. I found that, like

<table>
<thead>
<tr>
<th>URL visits</th>
<th>Queries</th>
<th>Chat messages</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Task 1</td>
<td>98</td>
<td>16</td>
<td>75</td>
</tr>
<tr>
<td>Task 2</td>
<td>120</td>
<td>22</td>
<td>26</td>
</tr>
</tbody>
</table>

Table 5: Content generated by phase 1 groups for both tasks
phase 1 participants, phase 2 participants used one of two strategies when resuming the search task. Four out of twelve (33%) phase 2 participants used a search-lead strategy, and started by searching for and making sense of task-related information (such as information about the vacation location, costs, currency conversion rates etc.) before looking at and making sense of the information already found by their group members. These participants wanted to first get their own sense of the information space and took between 30 seconds and 5 minutes for making sense of task-related information before trying to make sense of the information found by phase 1 group members. Figure 21 depicts the search and sensemaking actions of a participant who used the search-lead strategy.

Figure 21(a): Proportion of search and sensemaking during asynchronous search for a phase 2 participant (task 2). This participant had a search-lead strategy.
The remaining 8 participants (66%) used a sensemaking-lead strategy, and started by making sense of the information already found by phase 1 participants (such as which activities had been covered, which landmarks had been considered for each activity, what decisions had been made etc.) before starting their own search. Figure 22 shows the activities of a participant who used the sensemaking-lead strategy.
Figure 22(a): Proportion of search and sensemaking during asynchronous search for a phase 2 participant (task 1). This participant had a *sensemaking-lead* strategy.

Figure 22(b): Categories of search and sensemaking during asynchronous search for a phase 2 participant (task 1) with a *sensemaking-lead* strategy.
Those who used the search-lead strategy used generic queries for their search, such as “Gothenburg Sweden”, “Sweden attractions”, “Finland attractions wikipedia”, and “helsinki tourism”, indicating that they wanted to start by finding the most basic information about the location. However, I found that usually these participants read the top few Web pages in their search results (e.g. Wikipedia or tripadvisor sites) and then switched into sensemaking mode and started exploring the information found by phase 1 group members (as in Figure 21). The participants who used a sensemaking-lead strategy had two approaches to make sense of the information found by other group members. They either re-issued the queries of other group members by clicking on them in the SearchTogether query history and exploring the search results returned by those queries or they used CoSense views to understand the information already found. When sensemaking-lead strategists resumed search, their queries were more specific than those of search-lead strategists, such as “Ehrensvard museum” or “Brudaremossen masts”. Their search was also more focused; for instance they searched for directions to and from landmarks that had been discussed by group members in phase 1 or for the cost of tickets or meals at locations discussed by phase 1 group members.

In general, phase 2 participants performed more sensemaking than search as compared to phase 1 participants. Most of this sensemaking took place in CoSense, rather than through the chat and comments in SearchTogether. Participants used the various views of CoSense to understand what other group members had done. They moved the search task forward by summarizing the options considered, decisions reached, and things left to do before the vacation itinerary could be finalized. In order to do this, they spent a lot of time making sense of the information handed off to them.
Figures 21 and 22 show the searching and sensemaking behavior of phase 2 participants. The participant in Figure 21 had a search-lead strategy while the one in Figure 22 had a sensemaking-lead strategy. Figure 21 shows that the participant started with searching, by opening URLs and issuing queries in SearchTogether. Then he switched to sensemaking and used CoSense more as the task progressed. Figure 22, on the other hand, shows that this participant started by making sense of the information found by others through CoSense and only later searched for new information using SearchTogether. Figure 21 shows that this participant used CoSense for sensemaking throughout the task and did not use the chat or comments in SearchTogether. He also searched in the latter half of the task by submitting queries and opening Web pages in SearchTogether. Figure 22 shows that for this participant, the predominant activity was also sensemaking though he submitted more queries and opened more Web pages than the participant in Figure 21.

Phase 2 participants generally did not use the chat feature in SearchTogether, as they were searching alone. However, some of them left messages for their group members through the chat. These messages generally pertained to not only the information that they had found during their search, but also the sense that they had made of that information. Figure 21 shows some chat activity, and I found through the logs that this participant first searched for restaurants in Finland, then tried to make sense of the cost of meals with queries such as “average meal cost in Helsinki” and “currency in Finland”. He then left a message in the chat “25 euros per person for a meal”. Thus chat messages in phase 2 were comments not associated with any particular Web pages, but relevant to the task as a whole. Phase 2 participants also commented on pages added to the summary by phase 1 participants or added new pages to the summary and added comments to those pages, such as “outdoor activity can
be selected from this link”. Thus, the chat messages and comments on pages in the summary were means for phase 2 participants to pass on the sense they had made to their group members.

**CoSense usage**

I compared CoSense view usage in asynchronous search to that observed in synchronous search to see whether different views were useful during these two kinds of collaborative search. While in phase 1 the search strategies and chat-centric views were accessed the most, in phase 2 the **workspace view** (accessed by 92% of participants and viewed 67 times across both tasks) and the **timeline view** (accessed by 83% of participants and viewed 58 times across both tasks) were accessed most frequently. The workspace view was very important for phase 2 participants since this allowed them to store the “sense” that they had made in the form of comments and ratings on Web pages, to-do lists, and decisions reached. This view also allowed them to associate external files created during the search task. The summary in SearchTogether and the summary in the workspace view of CoSense served different purposes. While in phase 1 participants mostly added items to the summary through SearchTogether, in phase 2, participants used the summary in CoSense since CoSense enabled modification of the organization of the summary as they made sense of the information. For instance, participants tagged, sorted, and deleted summary items in the workspace. They also frequently used the summary to open Web pages that others had commented on.

Phase 2 participants used the scratchpad and to-do areas of the workspace to record the sense they made, as well as the group’s emerging itinerary. 7 out of 12 phase 2 participants (58%) used these free-form text entry areas to record notes. Of these, 4
participants edited the scratchpad only, 2 participants edited the to-do only, and 1 edited both the scratchpad and the to-do. All participants who edited the scratchpad created a ‘representation’ that mapped to the task categories, that is, they noted ‘sight-seeing’, ‘cultural’, ‘dining’, ‘outdoor’ (or variations of these) on four separate lines and next to each they jotted down the names of landmarks, events, or restaurants they thought should be included in that category of the itinerary. Sometimes they also added links, prices, distances, and their opinions next to each item on the itinerary. Interestingly, participants recorded only one option for each category of the itinerary instead of listing multiple options that had been considered by group members. Thus, phase 2 group members used the scratchpad to record not unfiltered information, but rather the sense they had made of the information generated in phase 1. In contrast to the scratch-pad, which was used consistently across all participants who used it, the use of the to-do area of the workspace view varied. One participant used it to leave questions for other group members (as described in the example below) while another participant noted the four vacation activities and next to each he wrote “done” as he made a decision regarding each.

In phase 1, one of the groups had recorded their emerging itinerary in the scratchpad area while the other group had not. In examining how ‘sense’ was handed off from phase 1 to phase 2, I felt it would be more interesting to observe this for the group which had not recorded any of their decisions or to-dos in the workspace (task 2). So, I analyzed how different phase 2 members made sense of the task where previous group members had not left any notes for them. Interestingly, different phase 2 participants made different notes for task 2. Figures 23(a) and 23(b) show the to-do and scratchpad of two phase 2 members from task 2.
Both participants D and E did not search much but used CoSense to create the itinerary shown. For instance, in understanding what dining activity his group members would prefer, E first saw group member A’s message in the chat-centric view “this is Norwegian, but I really want to try it: http://en.wikipedia.org/wiki/Lutefisk” and added “Dining: Lutefisk” to the to-do area of the workspace. Going back to the chat-centric view, he clicked on B’s message “they serve reindeer at this restaurant Aino, I’d like to go there”. Clicking on B’s message opened the Web page for the Aino restaurant. Knowing that A wanted to try Lutefisk (reindeer meat), E copy-pasted the address and phone number of Aino restaurant
into the to-do area. He also noted the cost of dining at Aino by writing “Aino – 40eu/person?”. The fact that he noted the name and address of the restaurant in the scratchpad and also noticed that it was an expensive restaurant (indicated by the ‘?’ in noting the price) suggests that he did not read B’s next message in the chat which was “it’s really expensive though, nevermind”.

For the outdoor activity, E used CoSense to guide him in making sense of what his group members wanted to do. When E started his search, he found a summary item in the workspace that pointed to the Fountain of Helsinki. E noted in the scratchpad “Free stuff: Fountain of Helsinki”. Later, by clicking on Web pages in the timeline, he found that a number of landmarks had been discussed in phase 1 for the outdoor activity, such as the Helsinki Central Railway Station, Suomenlinna museum, and the Ehrensvard museum. Not knowing which of these were preferred by other group members, E wrote in the To-do list “[A’s name]: Suomenlinna – 2 random picks? Ask for preferences. ~10 euros/person railway station?” Next E went to Google maps and found out the directions from Helsinki railway station to Suomenlinna museum and from the railway station to Ehrenvards museum. He found Ehrenvards to be closer and hence modified the to-do to pass on to others the sense that he had made of this information, resulting in the to-do space shown in Figure 23(b). Thus, here I saw an instance of the user using the to-do area like the chat feature, i.e. to leave messages for others.

Interestingly, participant D (Figure 23(a)) also clicked on the Web pages for Suomenlinna and the Helsinki railway station in the timeline and hence added these to the itinerary he created. However, for the dining activity, D clicked on a number of restaurants in the timeline that group members had looked at, but did not click on the webpage for the Aino
restaurant. After visiting the webpages of 4 restaurants in the timline, D decided on a restaurant called “restaurantwallah” and noted restaurantwallah as the dining activity in the scratchpad area. Later, D spent 13 minutes reading the chat transcript in the chat-centric view, and while reading he clicked on A’s chat message about wanting to try Lutefisk. However, D did not change the restaurant choice to Aino (as selected by E), since he read in the chat that it had been vetoed because it was too expensive.

The timeline view was used to get a sense of the entire search history in chronological order. I found that participants used the timeline to click on two kinds of items – Web pages and chat. They often right-clicked on Web pages to see who else had viewed that Web page and what was the chat that occurred around that Web page (as shown in the right side of the timeline view). I was surprised to find that participants frequently clicked on chat items in the timeline, since they had various ways of looking at the chat (including the actual chat as stored in SearchTogether and the chat-centric view). This was because the timeline view helped participants to connect the chat to the Web pages opened. I also found that participants often ‘reviewed’ their own search by going to the timeline and clicking on pages that they had themselves found.

**8.2.2.3 Measuring sensemaking**

One of the challenges in sensemaking research has been to measure or evaluate people’s sensemaking. Since sensemaking is intimately intertwined in everyday cognitive activities, people often don’t consciously pay attention to how they make sense of situations; they also find it difficult to articulate when asked to explain their sensemaking. So, in order to understand how participants made sense during our tasks, I designed a questionnaire and a semi-structured interview that was administered to participants after the task. The
questionnaire (Appendix D) was built to measure participants’ sensemaking in two ways – through the quality of their answers and the time taken to answer each question. The questionnaire was also designed to help us understand which features of CoSense were useful in helping participants understand different kinds of information during a search task. Thus, the software logged participants’ answers to each question, the CoSense views used by participants to answer each question, and the time taken to answer each question.

To measure participants’ sensemaking, I examined the average amount of time participants took to answer each question and the number of times they switched CoSense views to answer each question. More time and more view switches indicated that participants found it difficult to answer the question. In phase 1, participants took the longest times to answer questions related to group members’ contributions and skills with respect to the task. They took the longest time (2.08 minutes, on average) to answer the question about which group member contributed most to the task (Q1); 50% of participants said they didn’t know or that it was hard to tell. Participants also took a long time (2.03 minutes) to answer the question about which group member was the most skilled searcher (Q2). Here again, 50% of participants said that it was hard to know or that they couldn’t tell. The shortest time (0.6 minutes) was taken to answer the question about what steps remained before the itinerary was complete (Q9). The most view switches occurred in answering questions about who the most skilled searcher was (Q2, 21 switches) and which websites the group found most useful for the task (Q4, 14 switches). On the other hand, participants did not switch views at all to answer Q9. This suggests that sensemaking regarding group dynamics (skills and contributions of group members) was less important to participants than sensemaking regarding task progress and state.
In phase 2, participants again found it difficult to answer questions about contributions and roles of group members. They again took the longest time to answer Q1 (1.51 minutes), and the second longest time (1.38 minutes) to answer the question about which aspect of the task did each group member work on (Q3). The least amount of time (0.49 minutes) was again taken to answer Q9. Interestingly, in phase 2, the most view switches occurred in answering the question about which queries were the most successful (28 switches across all phase 2 participants as opposed to 8 switches across all phase 1 participants). The second highest (26) view switches occurred for Q1. Once again, participants did not switch CoSense views to answer Q9. Finally, participants in both phases took the same amount of time (0.72 minutes) to answer the question about what decisions the group had reached.

Also, judging from the quality of their answers, participants in both phases found it hard to answer the questions about group dynamics (such as contributions (Q1) and strategies (Q2) of group members) and questions about task-related information (such as which websites generated a lot of discussion (Q6) or were most useful to the task (Q4), and which queries were the most successful (Q7)). For Q1, two phase 1 participants said that it was hard to tell, all others said that all group members had contributed equally to the search task. However, phase 2 members all had different answers to this question. For Q2, 50% of phase 1 participants said they couldn’t tell who the most skilled searcher was and phase 2 participants were inconsistent in answering this question. One phase 2 participant said he didn’t know the answer to this question while all the others either answered that they themselves were the most skilled searchers or named a different phase 1 participant as the most skilled searcher.
When it came to task-related information, phase 1 participants were better at answering Q4, they were all consistent in naming “frommers.com” (in task 1) and “wikipedia.com” (in task 2) as the most helpful website. I noticed an interesting thing here with respect to phase 2 participants – they found it difficult to answer this question in the case of task 1 and all of them provided different answers, none of which was “frommers.com”, but in the case of task 2 all but one participant could answer this question correctly. This was because phase 2 participants were judging the importance of websites by the size of that websites name in the tag clouds in the search strategies view. However, the tag clouds reflected frequency of use and not usefulness of websites or query keywords. Thus, though frommers.com was more useful to phase 1 participants, they didn’t visit it as frequently as some other websites and subsequently frommers.com was less prominent that other websites in the tag clouds. In fact the only phase 2 participant who answered Q4 correctly said that he realized that group members had used wikipedia.com a lot but he thought frommers.com was more useful because he knew from prior experience that frommers.com provided pricing information. In task 2, wikipedia.com was the most useful website for phase 1 participants. It was also, coincidentally, the most visited website and hence appeared biggest in the tag clouds; therefore phase 2 participants found it easy to answer Q4 correctly for task 2.

Both phase 1 and phase 2 participants found it hard to understanding which websites generated a lot of discussion (Q6). While phase 1 participants in both tasks did not feel any particular website had generated too much discussion, phase 2 participants all named different websites as the answer to this question. Similarly, both phase 1 and phase 2 participants found it hard to tell which queries were the most successful (Q7). One phase 2
participant said “No way to figure out as there is no way for someone to mark useful results from a query”. In the next section, we discuss why participants might have had difficulty in answering these questions (see section 9.3.5 on success in sensemaking) and how interfaces can be designed to enhance their understanding of such information.

### 8.3 Summary of evaluation results

The evaluation of CoSense helped us understand which design features of CoSense aided sensemaking during a collaborative Web search task. It also provided insight into searchers’ sensemaking behavior during different parts of the search task – synchronous, asynchronous and handoff.

The different views of CoSense were useful to participants during synchronous and asynchronous search. During synchronous search, the most accessed view was the search strategies view, followed by the chat-centric view. Participants wanted to understand the skills and search strategies (such as keywords used in queries) of others so that they could tailor their own search accordingly. Synchronous searchers also wanted to be able to contextualize the chat messages with the content found, especially since they tended to lose context of the chat messages as they searched and chatted simultaneously. Hence, they relied heavily on the chat-centric view.

On the other hand, during asynchronous search, the most accessed view was the workspace view, followed by the timeline view. Asynchronous searchers were interested in what the products of the sensemaking process were in phase 1 so they could continue the task. Hence, they used the workspace to view the Web pages others had commented on, as well as the decisions associated with the task as noted in the free-form text entry areas. They
were also interested in getting a chronological history of the search process conducted in phase 1 and found the timeline useful for this.

Participants had two strategies for handling handoff. Some participants took a search-lead strategy where they approached the task by searching for information. Once they had found some information (e.g., basic information about the vacation place, prices, and fun activities in the vacation spot) they spent more time on making sense of the information found by other group members. Other participants had a sensemaking-lead strategy where they approached the search task by making sense of the information found by group members before they started their own search. Understanding what others had found and decided on helped sensemaking-lead strategists narrow their own search.

The next chapter discusses the findings from the evaluation in more detail, focusing on what we learnt about users’ sensemaking behavior and about the design features that can be incorporated in collaborative information retrieval tools to enhance sensemaking.
Some of the content presented in the following chapter is based on research conducted at Microsoft Corp. during an internship with Meredith Ringel Morris and is the intellectual property of Microsoft Corp.
9. Study 2: Discussion

In this section, I discuss the results from my evaluation of CoSense in terms of the insights gained about the nature of collaborative sensemaking. I discuss how collaborative sensemaking is different from individual sensemaking, how the different strategies of sensemaking differ, how the products of sensemaking are stored in different forms, and how success in sensemaking can be judged. I also discuss the implications of my findings for supporting sensemaking in collaborative Web search tasks. Finally, I provide a taxonomy of sensemaking in collaborative information seeking tasks drawn from our study.

9.1 Characteristics of collaborative sensemaking

I found that sensemaking in collaborative information seeking is far more complex than individual sensemaking as described by extant models and theories (Dervin et al., 2003; Russell et al., 1993). In individual information seeking, sensemakers need to only make sense of task-related information. For instance if a single user is searching for a camera to buy, he needs to only make sense of information pertaining to cameras. In collaborative search, sensemakers not only have to understand task-related information but also information about division of labor among group members, information found by other group members, and the sense other group members have made. This is specifically challenging during synchronous Web search since other group members are constantly interacting with the search space, adding to it not only new information like Web pages they found, but also their sense of the information (in the form of comments and ratings). Additional challenges arise from the need to constantly interact with others (via chat or comments) and contextualize these interactions with respect to the content being found. This is also troublesome in the case of asynchronous
search. For instance, in the example in Section 8.2.2 when D joined the search asynchronously, he had to not only make sense of good dining options for the vacation but also make sense of what other group members had found. Here, A had expressed his preference for trying out Lutefisk and B had found a web page of a restaurant Aino where reindeer meat was on the menu. D had to put together these two pieces of information and noted Aino as the restaurant where they could go on their trip. For such contextualization of information, collaborative Web search tools need to provide features that help users connect different kinds of information; the chat-centric and timeline views in CoSense are examples of how to accomplish this.

Three important characteristics of collaborative sensemaking make it different from individual sensemaking and hence make it difficult to design collaborative search tools to support collaborative sensemaking:

9.1.1 Sensemaking trajectories

During our formative study of sensemaking in SearchTogether, we found that collaborative sensemaking has a strong temporal component in that the products of sensemaking are passed on over time from one group member to another (Paul & Morris, 2009). I found that it was important for participants to view not only others’ search trajectories but also their sensemaking trajectories. In observations of CoSense use, I found that making such trajectories explicit, as in the case of the timeline and the chat-centric views, has advantages and disadvantages. While phase 1 participants did not use the timeline view much, they found the chat-centric view useful to connect the ongoing chat to the content being found. Phase 2 participants, however, were divided over the utility of the timeline and chat-centric views. While one phase 2 participant found “going through the timeline and chat transcript
to see why [other group members] were following a particular flow” advantageous, another participant found it confusing to figure out what others had found before she came on to the task. She said,

“The whole conversation that unfolded was very confusing. The signal-to-noise ratio just overwhelmed me...The timeline and chat transcript were specifically overwhelming.”

Participants who used the timeline successfully were those who used the checkboxes to filter out content from certain users in order to dig deeper into a given part of the history; those who tried to look over the whole timeline found it overwhelming. Thus, while the evaluation of CoSense indicates that search and sensemaking trajectories should be made explicit in collaborative Web search tools, the challenge for the designer is to figure out how much information to present in such trajectories such that users are not overwhelmed. I found that selective display of information in the timeline by providing options to filter out content by type (such as Web pages or chat messages), as well as by user, could be one way to make the timeline less overwhelming.

9.1.2 Prioritizing information

Another challenge unique to collaborative sensemaking was the prioritization of information from group members. When the information found and the sense made by multiple people are stored and made visible, it can be daunting to tell the “good information” from the “bad information”. One of our phase 2 participants said:

“The biggest frustration I had was jumping into the story mid-stream and being overwhelmed and not being able to tell the substantive decisions and recommendations from all the nonsense that happens when people talk online”.

Thus, one of the disadvantages of making the information found and sense made throughout the search process persistent was that participants were overwhelmed. Though CoSense
provided ways of book-marking, commenting on, rating and categorizing important web pages, the prioritization of information provided was not adequate to enable participants to quickly identify the top website for the group or the most preferred options for things to do on their vacation. Thus, another design challenge for sensemaking-enhancing tools is to figure out what the adequate level of prioritization should be. For instance, participants found tags and thumbs-up and thumbs-down ratings to be inadequate and said they would like finer-grained rating scales (such as 1-5 stars). One way prioritization of information could be facilitated in collaborative search tools is by automatically ordering the Web pages found based on the comments and ratings received on them. Prioritization based on the properties of group members (rather than properties of the content itself) would be another possibility, such as favoring content found by high-expertise group members, or content visited by a certain proportion of group members. Prioritization of information was a recurring theme in our findings and I discuss other ideas for supporting this in the next two sections.

9.1.3 Managing group representations

While group sensemaking was different and more complex than individual sensemaking, I found that there were some similarities, too. The use of representations (Russell et al., 1993) was equally important to the group scenario. Three phase 2 participants created external documents (using OneNote, Word, and Excel) to map the information they found to the structure of the task, which was that there were four activities to be planned for the vacation – sightseeing, outdoor, dining, and cultural – and task constraints, such as budget. Other participants (7) used the scratchpad and to-do for creating mappings of the information found to this task structure. These mappings were akin to Russell et al.’s (1993) notion of representations used to ‘encode’ task-related information; in this case task-related
information was the locations, prices, links etc. associated with each activity. Figures 23 (a) and (b) show two such representations. Participants likened the use of the scratchpad and to-do areas to using notepad to make notes. One participant said he used the scratchpad to “list various possibilities” while another said he used it to manage task dependencies. Thus, participants used the free-form text entry areas to create representations to map task categories to information found in each task category. Some participants expressed the need to have the tool automatically provide the structure and make it easier to create representations of information. One of the participants said,

“I don’t think synchronous communication is absolutely necessary to accomplish this type of task. That’s why the wiki is really nice because people can review what other people have found and their recommendations. I refer to the workspace as the wiki…it’s not as flexible as a wiki but structure is useful sometimes. Maybe add some kind of task feature where somebody sets this up saying ‘we have four tasks to accomplish. We need to find sightseeing, art, and outdoor thing’ …and maybe set up individual tabs for them so we don’t have overlap.”

Several other participants echoed this sentiment. Another participant said:

“…since all this is so activity-based, there could be something where we create a tab just for activities. The moment you have an activity you list it as an activity, and you have the ability to multiply that with the number of people, associate that with cost, and once you are done with the activity [the tool] can mail out directions to all the people.”

Thus, while the users in our formative study found the lack of support for free-form notetaking in SearchTogether disadvantageous, when supplied with such functionality users of CoSense wanted the tool to support representations that mapped to the task structure. So a challenge for designers is to provide the right level of structure for noting the intermediate and final products of sensemaking. I discuss some ways of doing this in Section 9.3.4.
9.2 Differences in sensemaking strategies

I found that participants had two strategies when approaching a collaborative search task – search-lead and sensemaking-lead. This was true for both phase 1 participants (when they started the task) and phase 2 participants (when they resumed the task that was handed off to them). In post-test interviews with phase 2 participants we found that there were some differences between participants who used these two strategies with respect to 1) features of SearchTogether and CoSense they preferred, and 2) ability to answer questions in the questionnaire (discussed in Section 9.3.5). Here I discuss how these strategies differed for participants who searched asynchronously, the different features SearchTogether and CoSense preferred by these strategists, and the implications for supporting both strategies in the design of collaborative search tools.

9.2.1 Search-lead strategy

Phase 2 participants with a search-lead strategy used SearchTogether, rather than CoSense, as a starting point in their search task and began by searching using generic queries. When asked how he had approached the search task, one such participant said,

“Irrespective of what had been found by other group members, I searched for things about Gothenburg first.”

Search-lead strategists found the query history in SearchTogether particularly useful as it showed what queries had previously been used so they could re-execute these queries or build upon them. They also found the chat, summary, and comments in SearchTogether useful. When they switched to making sense of information found by other group members, such participants spent a lot of time looking at the timeline view in CoSense useful; 75% of search-lead strategists started the task by looking at the timeline view. They used this view to
click on Web pages and chat items from other group members. However, search-lead strategists were not positive about the utility and usability of the timeline view. 75% of search-lead strategists found the timeline overwhelming because they felt it did not prioritize information and captured both useful and non-useful information. One participant said,

“Timeline feature was not useful because ...while doing a search there would be a lot of garbage that you would go through, I don’t want to look at all that stuff. I want to look at something useful that they found, that timeline would have been useful.”

Thus, since the timeline showed all content instead of the “useful” content, participants found it overwhelming and wanted that the tool should make explicit the useful content in the timeline. Only one search-lead strategist found the timeline useful and he filtered content out by user. Thus, in addition to providing filtering of content, another important design feature for presenting chronological information in a collaborative search tool should be visual indicators of useful content. An important question here is how to decide which content is ‘useful’ and who it is useful to (e.g., useful to the group vs. useful to the individual). One approach is to allow users to mark content as useful while another is for the tool to algorithmically determine which content is useful (i.e., by employing heuristics based on factors such as length of time spent on a page, number of times a page was revisited, and/or the number of group members visiting a particular page). All search-lead strategists found the chat-centric view useful; one of them said,

“I found the [chat-centric view] useful. I was able to associate the context when people had written a particular comment. I was able to associate what page they were looking at.”

Only 50% of search-lead strategists used the workspace view in CoSense. One participant used it to create a checklist of activities which he checked off as he worked on each, the other created an emerging itinerary. This could be because search-lead strategists were more
focused on search than on making sense of the information and recording the products of their sensemaking.

### 9.2.2 Sensemaking-lead strategy

Sensemaking-lead strategists began the task in two ways – 1) by re-issuing the queries of other group members through the SearchTogether query history and exploring the search results returned by those queries or 2) by using CoSense views to understand the information already found by other group members. Though sensemaking-lead strategists did not mention using SearchTogether much; they still found the query history in SearchTogether useful to re-execute queries of other group members. When using CoSense to understand what others had found, 50% of sensemaking-lead strategists started with the search strategies view. Participants said the search strategies view helped them gain an initial understanding of what other group members had searched for; one participant said, “The search strategies definitely brought together what keywords were working, it gave an initial view”. 62.5% of sensemaking-lead strategists mentioned that they liked the search strategies view; they particularly like the query history timeline which shows how group members’ queries have evolved over time. One participant said about the query history timeline,

“...I found this to be quite useful because it actually tells me more about the chat. I was trying to fill out the gaps, which was a little difficult, and then I saw this and thought ‘well this is great’.”

50% of sensemaking-lead strategists also mentioned that they found the chat-centric view useful. One of them said, “The chat-centric view is good because it gives you a very qualitative look at what people are interested in.” Finally, like search-lead strategists, sensemaking-lead strategists were also divided over the utility of the timeline; those who
found it useful used it to filter content to “give context to the queries”, while the others felt it contained too many details.

The sensemaking-lead participants were divided about the utility of the workspace view. While 62.5% of them used the scratchpad or to-do to take down notes relating to the itinerary, one of the participants said that he would have liked more structure to the free-form text-entry areas,

“I personally like mind-mapping...so a notepad style scratchpad is not much use to me. Having a mind-map that others can go in and edit and evolve...would be a valuable addition.”

Thus, providing structure to the workspace view was a recurrent theme in our findings and is an important consideration when designing collaborative search systems. Free-form text entry areas provide flexibility to allow participants to structure the representations used in sensemaking but too much structure was deemed invaluable. One way to deal with this tension is to provide free-form areas like the to-do and scratchpad in CoSense and also provide ways to draw diagrams, tables, mind-maps and other commonly used representations by dragging and dropping icons, for instance.

9.3 Procedural knowledge of sensemaking

Bhavnani et al. (2003) found that users who have search expertise in a particular domain also have procedural search knowledge which consists of 1) the sub-goals to organize a search in a particular domain, 2) the order in which to satisfy those sub-goals, and 3) the selection knowledge to determine which information sources (websites) will satisfy those sub-goals. When searchers have expertise in a certain domain, they demonstrate knowledge of how to sequence sub-goals in a search task and of specific URLs to use, however goal sequencing and URL knowledge is absent in searchers’ behavior when they search information outside
their domain (Bhavnani, 2002). I wanted to see whether searchers exhibit similar procedural knowledge of sensemaking. Since the participants in my study were not experts in planning vacation tasks, I found that they did not exhibit procedural search knowledge by breaking up the task into sub-goals, though some participants did structure their search according to the four activities to be done on the vacation. Participants also did not show special knowledge of URLs that they typed directly into the browser, but instead used generic search engines. However, from the log files, I found that for asynchronous search, participants exhibited procedural sensemaking knowledge that consisted of satisfying sensemaking sub-goals and the order of satisfying sub-goals differed depending on whether a participant used a search-lead or a sensemaking-lead strategy.

Table 6 shows the sensemaking procedural knowledge of search-lead and sensemaking-lead strategists.
Search-lead strategy

1. Understand task-related information
1.1. Find and understand new information
   a. Issue generic queries
      e.g. “Helsinki attractions”
   b. Visit generic websites
      e.g. Wikipedia.com
      OR
   a. Issue queries specific to task categories
      e.g. “cultural activity Gothenburg”
   b. Visit Web pages specific to task categories
      e.g. Wikipedia article about Gothenburg book fair

[1.2] Record understanding of new information
   a. Comment on Web pages
      e.g. “I like it, we should do it”
   b. Leave chat messages or to-do items for others
      e.g. “25 Euros for a meal per person”
   c. Create representations to map task categories to information found
      Use the workspace in CoSense or create external documents

1.3. Understand information found by others
   a. View queries used by others
      Use search strategies view in CoSense or query history in SearchTogether
   b. Visit Web pages found by others
      Use the summary in SearchTogether or the timeline and workspace in CoSense
   c. View chat messages of others
      Use the timeline or chat-centric view in CoSense

[1.4] Record understanding of information found by others
   a. Comment on Web pages
      e.g. “It’s just a radio tower, why would you want to see that?”
   b. Create representation to map task categories to information found
      Use the workspace in CoSense or create an external document

2. Understand task state and progress on goals
3. Understand group dynamics information

Sensemaking-strategy

1. Understand task-related information
1.1. Understand information found by others
   a. View queries used by others
      Use search strategies view in CoSense or query history in SearchTogether
   b. Visit Web pages found by others
      Use the summary in SearchTogether or the timeline and workspace in CoSense
   c. View chat messages of others
      Use the timeline or chat-centric view in CoSense

[1.2] Record understanding of information found by others
   a. Comment on Web pages
      e.g. “nice restaurants here”
   b. Leave chat messages or to-do items for others
      e.g. “Suomenlinna – two random pick? Ask for preference”
   c. Create representation to map task categories to information found
      Use the workspace in CoSense or create an external document

[1.4] Record understanding of new information
   a. Issue queries specific to others preferences, suggestions, and recommendations
      e.g. “Helsinki restaurant reindeer”
   b. Visit websites returned by above queries
      e.g. hotels-helsinki.com/restaurants/
      OR
   a. Issue queries specific to task categories not covered by others
      e.g. “Helsinki museums”
   b. Visit websites returned by above queries
      e.g. Helsinki.fi article on various museums in Helsinki

2. Understand task state and progress on goals
3. Understand group dynamics information

Table 6: Procedure followed for sensemaking in asynchronous search by participants with search-lead and sensemaking-lead strategies.
In Table 6, the numbered points are sub-goals while the lettered points are steps to satisfy the sub-goals. Both search-lead and sensemaking-lead strategists had the same high level goals, which were to (1) understand task-related information, (2) understand task state and progress on goals, and (3) understand group dynamics information. Executing goals (2) and (3) did not differ with strategy, rather it was in how they understood task-related information that search-lead and sensemaking-lead strategists differed. So I focus on the procedure followed for satisfying goal (1). For a given high level goal (1, 2 or 3) smaller sub-goals were executed (e.g., 1.1, 1.2 etc.). For these sub-goals, the specific order of steps to satisfying the sub-goals (lettered points) varied across participants; for instance in sub-goal (1.3) for the search strategy, participants could view others’ Web pages (b) before viewing other’s queries (a). Also, steps indicated within [] were optional steps as not all participants performed these.

As the table highlights, search-lead strategists first focused on finding new information and then making sense of the information found by others while it was the other way around for sensemaking-lead strategists. I found that it is important for a collaborative search tool to support both these strategies, since both were common among our participants, with 50% using search-lead strategies and 50% using sensemaking-lead during synchronous search and 33% using search-lead strategies and 66% using sensemaking-lead strategies during asynchronous search. SearchTogether query history and the CoSense timeline view supported search-lead strategists while the search strategies and workspace view supported sensemaking-lead strategists. The chat-centric view supported both strategies. One implication of this could be that the different views of CoSense could be sequenced so as to encourage one strategy over the other if the designed felt that one or the other strategy was
more effective. However, my findings did not indicate any clear advantage of one strategy over the other for this kind of collaborative task.

9.4 Products of collaborative sensemaking

Participants stored the products of their sensemaking at various stages of the search task and in various forms, such as chat messages, comments and ratings on Web pages, and notes in the CoSense workspace. Here, I discuss how chat messages, comments on Web pages, and notes in CoSense were used to record the products of sensemaking.

9.4.1 Chat messages

An important theme in my findings was the importance of chat messages for communicating “sense” to other group members. During synchronous search, other than using chat to discuss their search strategies for the task, participants used the chat to pass on various kinds of “sense” such as how vacation landmarks they found fit task constraints, how tool features could be used to share information, and whether certain information they found would be of interest to the group or of personal interest. Accordingly, participants’ chat messages during synchronous search could be categorized as shown in Table 7. Chat messages in each category not only contained information, but also some “sense” about that piece of information that the author of the chat message wanted to pass on to other group members.
Chat message categories | “sense” contained in the message
--- | ---
Pointers to information sources | Description of landmark
“there’s a street that’s free: http://www.avenyn.se” | 
Constraint satisfaction | Matching cost constraints
“paddan tour is 13 euros” | 
Tool usage tips | Tool feature to use for sharing information
“use the CoSense” | 
Suggestions | Activities to consider for the task
On an activity | Information source to consider for the task
“We should do both paddan tour and check out the observation deck” | 
On an information source | 
“There is an itinerary at frommers.com” | 
Recommendations | Activity might be of interest to the group
On an activity | Information source might be of interest to the group
“The amusement park looks like fun, but only open on weekends in September” (thumbs up) | 
On an information source | 
“The itinerary [at frommers.com] is nice” | 
Preferences | Activity might be of personal interest
“They serve reindeer at this restaurant “Aino”. I’d like to go there.” | Activity might not be of personal interest
“I don’t like amusements parks” |

Table 7: Classification of chat messages during synchronous search

Chat played a central role in passing on the sense made during synchronous search. Group member preferred chat to comments for passing on the products of their sensemaking (as indicated by the low number of comments as compared to chat messages) since they were constantly monitoring the chat and were more likely to see content there than in the summary of SearchTogether or in the workspace of CoSense which they didn’t monitor as frequently as the chat.

During asynchronous search it was difficult for participants to decide whether they should note the sense that they made about an information source as a comment or pass on
the sense made through the chat. I did not expect participants to use the chat during asynchronous search since they were working on the task alone. However, I found that 2 participants used the chat to record their sensemaking. These chat messages were important meta-comments that participants wanted to let other group members know. For instance, in one example a participant left a chat message that the average cost of meals in Helsinki would be 25 Euros/person. When asked why he left the message in the chat, he said,

“I used [chat] messages a lot. I wanted to record if I felt strongly about something. For instance I wanted to pass on a message that we could just have a meal for 25 Euros per person.”

Thus, the chat was used in asynchronous search to leave messages that pertained to the task as opposed to messages specifically associated with particular information sources.

CoSense recognizes the centrality of the chat in collaborative search by allowing participants to connect the Web pages to chat in various ways. Participant can get to the chat through the Web pages (as in the timeline view which not only shows the chat inter-leaved with the rest of the information, but also shows the chat conversation that occurred 2 minutes before and after every Web page viewing) and can get to the Web pages from the chat (as in the chat-centric view which shows the web page associated with each chat message). As discussed in Section 8.2.2, the chat-centric view played an important role in both synchronous and asynchronous search. I found that the chat-centric view was useful to participants irrespective of whether they used the search-lead or the sensemaking-lead strategy. Thus, an important design implication for collaborative search tools is to store persistent chat along with the task-related information.

However, the challenge with providing persistent chat is to prioritize information in the chat transcript. Participants in phase 2 found the chat overwhelming since they couldn’t
prioritize information and tell the recommendations and suggestions from the rest of the conversation. Thus, designers must consider how to help participants make better sense of such persistent chat. One way of doing this would be to categorize the chat messages in the chat transcript (for instance by highlighting them with different colors) according to the categories in Table 7. One of the phase 2 participants who rated the chat transcript as the feature he found most useful, suggested another way to prioritize information in it; he said,

“...going back through the chat transcript it is quite hard to catch up on the conversation. Coming into any stream of consciousness is hard. Maybe weighting what you see in the chat transcript with how many people followed the links. So if there is a link, just being able to see it in [the chat-centric view] and see how many people went to it, were there three thumbs up, were there one thumbs up and one thumbs down, so you can make a judgment call.”

Thus, making the recommendations, preferences, and suggestions, along with weighting important information in the chat transcript would enhance the sensemaking of the chat conversation and make it less overwhelming.

9.4.2 Comments

Comments associated with Web pages could be placed in the same categories as chat messages. For instance, some comments were suggestions that included sensemaking related to constraint-satisfaction, such as the following comment left by a phase 1 participant on the Wikipedia article for the National Museum of Finland, “the national museum of Finland seems like it might be an option. It’s 7 euros per person”. Other comments were preferences, such as “I’d be interested in seeing this train station for the architecture”. Finally, some comments were recommendations such as the comment “this looks solid” left on a Web page about an outdoor activity.

During asynchronous search, participants used comments which again fell in the same categories as noted in Table 7. However, I found that some comments were directed toward
specific group members and were used to delegate responsibilities to them or simply to bring things to their attention. For instance, one phase 2 participant left a comment on a Swedish website, “Hey Justin, this site looks like it could have some good info, but it’s in Swedish. Can you take a look?” Later this participant said,

“I liked the idea of being able to comment on pages...to be able to assign to-do items like the person I pretended could speak Swedish to get to convert a page or to say that I converted these Kroner prices into Euros.”

In synchronous search, such task delegation could be done in real time through the chat, but not in asynchronous search. Thus, in asynchronous search the comments on Web pages could indicate sensemaking not only about a particular information source but also allowed delegation of tasks associated with that information source.

9.4.3 Notes

Finally, I examined how sense was noted in the workspace and how the use of notes in the workspace was different from using chat and comments. I found that the workspace was used mainly to record the emerging itinerary. It contained the more evolved products of participants’ sensemaking such as the final one or two options for each activity and phone numbers, distances etc, to and from landmarks. But I saw instances where the workspace was also used to leave notes directed at specific individuals. If messages directed at individuals are included in the comments and the workspace, it will be difficult for participants to find and make sense of all the content directed at them and this problem would become more complex in subsequent rounds of handoff. One way to design for this, again, could be to provide more structure to the workspace; perhaps one section of the workspace could be designed to leave messages directed at specific individuals.
9.5 Success in collaborative sensemaking

The questionnaire results showed that different views of CoSense helped participants understand different kinds of information. Here I discuss how easy or hard each type of information – group dynamics information, information about the search skills and strategies of others, information about relative importance of information and information sources, and information about task state and progress on goals – was to understand and which views of CoSense helped participants understand each of these types of information.

9.5.1 Group dynamics

The findings indicate that it is hard or unimportant for participants to make sense of group dynamics information (Q1-Q3) in a collaborative search task. In synchronous search, this might be because participants were too engrossed in searching for information and exchanging chat messages to keep track of group dynamics. This is similar to Joho et al.’s (Joho et al., 2008) finding that during concurrent search, participants who used the chat to discuss the documents they were finding were not efficient in performing the task of marking documents relevant. In my study, the chat itself seemed to help participants understand group dynamics to some extent. Highlighting the importance of chat in understanding group dynamics, a phase 1 participant said when asked about division of labor,

“...I’d try to pay attention to what was happening in the chat window so as to not step on anybody’s toes.”

During asynchronous search, understanding group dynamics again did not seem as important to participants as understanding the information which had been found, and the suggestions and recommendations that could help finalize the vacation itinerary. Most phase 2 participants said that in continuing the task they looked at queries already done or
recommendations made by others, instead of focusing on how the search task had been divided or what, if any, roles group members had assumed.

9.5.2 Search skills and strategies of others

Though previous research (White & Morris, 2007) has suggested the importance of search skills and expertise in individual Web search, it seemed understanding other’s search skills was not an important aspect of sensemaking during collaborative search. When asked which group member was the most skilled searcher, one participant said,

“No idea, I guess I didn’t actively pay attention to what people were searching for and how successful their searches were.”

However, while understanding other’s search skills were not important, participants said that their searches were influenced by one another during synchronous search. One participant said,

“We used each other’s search to guide our own searches. For example when I searched for Elfsborg fortress, [other member] searched it as well to follow up on it.”

Another phase 1 participant said he found it hard to maintain a fixed search strategy himself since his search strategy was influenced by others. He said,

“Since we were chatting while searching, the search was heavily influenced by what others were looking at. To answer questions or to understand a chat comment, I had to immediately drop my search context and peek at what others were doing. This led me to broaden my search initially, but also made it hard to keep a definite search strategy in mind.”

9.5.3 Relative importance of information/information sources

For those engaged in asynchronous search, it was difficult to understand the relative importance of queries and websites to the search task (Q4, Q6 and Q7). From watching participants answer the questionnaire, I found that questions about the “most” useful query or website were hard to answer because participants didn’t evaluate the relative value of
information sources (i.e., Web pages and queries) in a collaborative search task. Since this was not a part of their sensemaking, participants used the search strategies and timeline views to answer questions about relative importance of information sources. However, since these views make explicit the *frequency of use* and not *usefulness* of different queries and websites, phase 2 participants answered this question incorrectly (i.e., their answer did not correspond with that of phase 1 participants). Thus, phase 2 participants ended up judging those websites and queries as important to the search task which were visited/used more frequently since they were more prominent in the tag clouds of the search strategies view (as discussed in Section 8.2.2). This leads to an important implication for design; CoSense used frequency as a proxy for importance of information, but this may not always be true. Other proxies for importance could be time spent viewing a website or useful content generated from a query. These could be made visually explicit in the search strategies view.

Instead of evaluating the relative importance of information sources, participants were interested in evaluating the relative importance of the information itself (i.e., Web pages of landmarks or restaurants that group members wanted to visit during the vacation). Several participants said that they wanted better ways to rank recommendations from phase 1 participants. Though the workspace view of CoSense enables tagging and organization of recommended Web pages, participants found this inadequate. They wanted finer-grained ratings (instead of the thumbs-up and thumbs-down ratings) and they also wanted to integrate the rating more tightly with the rest of the content, especially the chat. Hence, one participant said he would have liked the tool to highlight recommendations in the chat itself. Thus, an important design implication for a collaborative search tool would be to highlight different categories of chat messages. Again, similar to highlighting useful content in the timeline, this
can be done either manually by the user or the program can algorithmically categorize chat messages and highlight important information in the chat transcript.

9.5.4 Task state and progress on goals

Finally, participants in both phases of the task found it easiest to answer questions about what decisions had been made (Q8) and what was left to be done (Q9); this suggests that it was easier to make senses of task state and progress on goals as compared to group dynamics or importance of information and information sources to the task.

Thus, in sensemaking during collaborative Web search, the order of difficulty in understanding different kinds of information, going from hardest to easiest, was as follows – 1) relative importance of information sources, 2) relative importance of information, 3) group dynamics, and 4) task state and progress on goals. Also, making sense of task-related information was more important than making sense of information about group dynamics. But perhaps this is task-dependent; making sense of group dynamics information may not be important for vacation planning but might be important for other kinds of collaborative tasks that are more heavily-coupled, such as writing a joint report. Similarly, it could also be role-dependent; in tasks where there are separate roles, such as group leader, making sense of group dynamics information might be important.

9.5.5 Search-lead vs. sensemaking-lead strategies

I also examined whether participants with different strategies found it easier to understand these different kinds of information. I found that search-lead strategists took significantly less time than sensemaking-lead strategists to answer questions about which aspect of the task others had worked on (Q3, 45 seconds less) and how group members’ strategies had
influenced one another (Q5, 33 seconds less). However, these participants took longer to answer which group member had contributed most to the task (Q1, 32 seconds longer), and how group members’ search strategies (Q5, 12 seconds longer) had influenced each other.

On the other hand, sensemaking-lead strategists took longer to answer which websites had generated lots of discussion (Q6, 41 seconds longer), and which queries which had been the most successful (Q7, 13 seconds longer). Some of these findings were contrary to my expectations. For instance, I expected sensemaking-lead strategists to take less time than search-lead strategists in answering questions about task-related information like importance of websites and queries to the search task since they spent more time on making sense of information and less time searching. But I found search-lead participants to be quicker in answering these questions. The quality of answers for Q6 and Q7 was equally poor for all participants. When asked if they felt they had been successful in completing the task given the time they were given, search-lead strategists were more positive about their success in the task; all search-lead strategists said they thought they had been successful. In contrast, only 50% of sensemaking-lead strategists said that they felt they had been partly or completely successful in developing a vacation itinerary. Most felt they had only been successful in refining the group’s efforts rather than reaching the final decisions. My findings indicate that in terms of understanding group dynamics information, both strategies were equally unsuccessful while in terms of understanding task-related information, search-lead strategists performed better.

Thus, overall, both strategies seemed about equal in terms of actual success with the search-lead strategy appearing slightly better in terms of perceived success. The reasons for
this will be explored in future work as we expected sensemaking-lead strategists to be more successful.

**9.6 Taxonomy of collaborative sensemaking in Web search tasks**

Given the different kinds of sensemaking involved in a collaborative search task, we developed a taxonomy of the kinds of collaborative sensemaking for information seeking tasks, shown in Table 8. This taxonomy can help researchers understand sensemaking behavior in collaborative information seeking tasks and help designers develop features to support the various kinds of sensemaking occurring in such tasks.
<table>
<thead>
<tr>
<th>Category</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>What</strong> is the focus of sensemaking?</td>
<td><strong>The task</strong>&lt;br&gt;What are the task categories? What are the task constraints? <strong>Task-performance strategies</strong>&lt;br&gt;What are individual and group strategies for doing the task? What are the methods (e.g. queries) and information sources (e.g. websites) used by individuals and the group? <strong>Task-related information sources</strong>&lt;br&gt;What are the information sources (e.g. websites) and how useful are they to the search task? <strong>Task-related information</strong>&lt;br&gt;What is the information and how useful is it? <strong>The sense that has been made so far</strong>&lt;br&gt;What sense has been made by individuals and by the group as a whole? <strong>Group dynamics</strong>&lt;br&gt;Which aspects of the task are group members working on? What are their roles and skills? Are group members in agreement or not? <strong>Task status and progress on goals</strong>&lt;br&gt;What has been accomplished so far (e.g. decisions made)? What still needs to be done to complete the task (e.g. to-do items)?</td>
</tr>
<tr>
<td><strong>Who</strong> is the focus of the sensemaking</td>
<td><strong>Yourself (your own actions and the information found by you)</strong> How did I find information and how useful is it? <strong>Other group members (their actions and the information found by them)</strong> How did others find information and how useful is it?</td>
</tr>
<tr>
<td><strong>When</strong> is the sensemaking occurring?</td>
<td><strong>Synchronous or asynchronous</strong> Are the group members searching at the same time? <strong>At handoff</strong> How is sense handed off between group members who search asynchronously? <strong>During different parts of the task</strong> Is the sensemaking in the beginning, middle, or end of the task?</td>
</tr>
<tr>
<td><strong>Why</strong> is the user participating in the sensemaking?</td>
<td><strong>Active stakeholders in the group’s task</strong> Are the group members actively involved in searching and making sense of the data? (e.g. in task-based groups using SearchTogether and CoSense) <strong>External participants</strong> Are group members involved in only giving feedback and opinions on information collected by someone else (e.g. on social sensemaking sites like ManyEyes)</td>
</tr>
</tbody>
</table>

Table 8: A taxonomy of collaborative sensemaking in Web search tasks
Current sensemaking support tools have been mostly designed for individual users and help make sense of task-related information (e.g. SSIG (Qu, 2003), ScratchPad (Gotz, 2007) etc. which allow organization and annotation of information) and of their own actions (e.g. Sensemaker which allows users to see how their queries are evolving over time). Most tools designed to manage and summarize personal Web browsing sessions (e.g. Hunter-Gatherer (schraefel et al., 2002) and SearchBar (Morris et al., 2008)) also fall into this category. The collaborative sensemaking tool EWall (Keel, 2007) automatically infers relationships between information found by multiple users, but does not support sensemaking of others’ task strategies, division of labor during the task, and task status. Also, few current tools help sensemaking of during asynchronous collaboration.

CoSense helps group members understand task performance strategies and task-related information sources through the search strategies and timeline views, group dynamics through the search strategies and chat centric views, and task status through the workspace and chat centric views. However, I found that CoSense could be improved to better support sensemaking in some categories of the taxonomy. For instance, CoSense does not adequately support participants’ understanding of relative importance of information sources and information. Thus, it was hard for participants to understand which websites had been most useful to the task or what content taken from the various websites was the most relevant. Also CoSense can be improved to better prioritize information that is relevant to final decisions. CoSense does not support collaborative sensemaking of the task itself (except through the chat) and this could be important for more complex tasks with greater task categories and constraints. CoSense also does not explicitly support making sense of your own actions or information found by you but this could be important to users; one participant
mentioned in the interview that it would have been useful to go back through his own search process. While participants can filter out their own content in the timeline or look at their own tag clouds in the search strategies view, a summary of the participant’s personal search process could be useful.

CoSense supports sensemaking during different parts of the task and for both synchronous and asynchronous collaboration, but could be improved to support sensemaking during subsequent rounds of handoff. Also, as one participant mentioned, some features of CoSense like the timeline and chat-centric views might not scale well to support large groups (with more than 4-5 group members). He said that he had used the different colors to distinguish the different users when reading through the chat or timeline but it would have been difficult to keep track of the colors if thirty people had been collaborating instead of three.

Finally, CoSense supports active stakeholders in the task, i.e., those who create the information that they need to make sense of; we believe that while there are other tools available to support sensemaking by external participants (e.g. Many Eyes (Viegas et al., 2007)), the our findings with CoSense could be used to provide insight into the design of those tools as well.

### 9.7 Summary of Study 2

The design, implementation, and evaluation of CoSense provided insight into the collaborative sensemaking behavior of Web searchers as well as ideas about what design features can help support such behavior. In summary, there were three important themes that emerged from the evaluation of CoSense.
First, making the sensemaking trajectories of group members persistent and explicit is important in collaborative information retrieval tools. CoSense makes sensemaking trajectories explicit in multiple ways, most prominently through the timeline and chat-centric views. However, the challenge in making such trajectories explicit is to decide how much information and sense made should be recorded in these trajectories so as not to overwhelm users.

Second, prioritizing relevant and important information to help users’ sensemaking is important. The timeline and chat-centric view in CoSense made trajectories persistent but it was problematic that they showed “all content” instead of the “useful content”. While the ability to filter, annotate, and organize content (as in the timeline and workspace views) provided some ways to prioritize information, these were not adequate mechanisms. There are multiple challenges in prioritizing information during collaborative Web search such as how to provide visual indicators of what information is important for others’ sensemaking, how to mark this information as useful and who marks it (i.e., whether the tool should do this or users should), and deciding who the information is useful for (i.e., the individual or the group).

The third important theme was the issue of providing support for recording the products of sensemaking. Sensemaking products are recorded by participants in various forms and the design challenge is to decide how to support such recording and how much structure to provide for representations used to record such products. In CoSense, the products of sensemaking were stored in the form of chat, comments, and notes. Chat plays an important role in both synchronous and asynchronous search but the challenge in making chat persistent in the tool is to be able to prioritize information. Comments were used to
record sense make not only about the information but also about the quality of information sources. They were also used for delegating tasks to group members. Finally, notes were primarily used for recording meta-comments about the task (e.g., the final itinerary), but sometimes used to leave messages for others. Thus, chat, comments, and notes are used in different ways for multiple purposes and the design challenge is to provide support for these multiple uses.

Apart from these three themes, the emergence of the two strategies for handling handoff of collaborative search tasks – search-lead and sensemaking-lead – was an important finding of our study. Procedurally, search-lead strategists focused on finding and understanding new information about the task before they tried to understand information found by other group members. Sensemaking-lead strategists, on the other hand, focused on understanding the information found by others before they began their own search for task-related information. The two kinds of strategists found different features of CoSense useful. Search-lead strategists used SearchTogether heavily, relying on the query history, summary, and comments. In CoSense, they used the timeline view to guide their own search but found it hard to distinguish useful content from non-useful content. Sensemaking-lead strategists again found the query history in SearchTogether useful but focused more on CoSense during their search. They found the search-strategies view useful to gain an initial understanding of what others had found and also found the chat-centric view useful for making sense of others’ search process.

In measuring participants’ sensemaking via the post-test questionnaire, I found that understanding the search skills and strategies of others was not so important as understand the relative importance of information sources and the task state and progress on goals. The
taxonomy of collaborative sensemaking resulting from this study helps designers understand the kinds of information that need to be made sense of during collaborative information seeking tasks so that they can consider the various ways of supporting these kinds of sensemaking.

This chapter concludes the description and discussion of Study 2. The next chapter brings together the findings from Study 1 and Study 2 using the framework of the socio-technical circle and highlights what the two different methodologies used afforded for helping me gain a conceptual and technical understanding of collaborative sensemaking in information seeking activities.

This thesis presented two studies of collaborative sensemaking in diverse domains – healthcare and Web search – using different methodologies. The ethnographic field study in the emergency department allowed me to gain an understanding of how collaborative sensemaking takes place in a real-world setting and led to conceptual and technical implications. The design, development, and evaluation of CoSense helped me understand the design challenges in supporting collaborative sensemaking during CIS activities and also provided insight into collaborative search and sensemaking behavior. These two studies encompass the socio-technical design approach (O'Day, Bobrow, & Shirley, 1996) used in CSCW to understand how technology can support work in social contexts. In this chapter I discuss the socio-technical design methodology, highlighting how the two studies fit in this methodology, and what was gained from following this methodology. I also bring together the findings from the two studies to highlight the contribution of this thesis to our understanding of sensemaking in CIS tasks.

10.1 The socio-technical circle

The organizational and social contexts in which technology is used has been an important and recurring theme in CSCW literature (Grudin, 1996). Studies of work and technology have emphasized that it is important to understand the social implications of technical design choices as well as the technical implications arising from the social contexts of technology-use (O'Day et al., 1996). McDonald (2000) presented the socio-technical design circle as a methodology for designing a technical system taking into account the social aspects of the
setting. Figure 24 shows the socio-technical circle and how the studies conducted in this thesis aligned with the different phases in this circle.

Figure 24: Socio-technical design circle (adapted from (McDonald, 2000)) as applied to the this thesis

There can be variations in how researchers and designers follow this circle, including where they start, the number of iterations of the circle needed to achieve their goal, and where they end (McDonald, 2000). While developers might start with building a system and then introducing it into the social setting, researchers often start with a study of the social setting to see how the technology might fit in it. The two studies presented in this thesis followed the socio-technical circle. I started with an empirical study of sensemaking in a real world setting and collected evidence of how sensemaking takes place as part of CIS activities among
healthcare providers. This led to ideas about how technology can be designed to support sensemaking during CIS activities. Based on these ideas the second study was designed to examine how sensemaking can be supporting in a different domain, collaborative Web search. The second study started with a formative examination of how sensemaking takes place during collaborative Web search tasks and based on these findings I designed, implemented, and evaluated a system. The two studies are inter-related and complement each other, but also stand on their own. The first study was focused on gaining a conceptual understanding of collaborative sensemaking, though the findings and design implications arising from it influenced the conceptualization and design of the second study. The second study, influenced by ideas from the first study, started with a formative examination of sensemaking challenges in the domain of collaborative Web search and the findings from the formative study led to the design and evaluation of a tool. Thus, this thesis examined both the social and technical aspects of supporting collaborative sensemaking in CIS tasks.

10.2 Applying the socio-technical circle: A two-study approach

Figure 24 shows how the different aspects of the two studies conducted in this thesis fit within the socio-technical circle. This section is organized around this circle; the research conducted at each phase of the circle is discussed, along with the results, conceptual and technical implications, and contributions.

10.2.1 Empirical study

The starting point for my examination of collaborative sensemaking in CIS activities was an ethnographic field study of healthcare providers in a hospital emergency department. The aim of this study (Study 1) was to observe people in their natural setting to understand how
they collaborated to make sense of information as part of their work. The ED provided an ideal setting to observe collaborative sensemaking as the work of emergency care providers is information-intensive and highly collaborative. Through observations, informal and formal interviews, and artifact collection, I collected data about how care providers collaborated to find and understand information in their work. I found that seeking, sharing, and making sense of information was an iterative process during CIS activities in the ED. There were three important reasons why care providers collaborated for sensemaking – ambiguity of the information found, role-based distribution of information, and lack of expertise.

I also found that collaborative sensemaking has three important characteristics – prioritization of relevant information, sensemaking trajectories, and activity awareness. During CIS activities group members often share pieces of information available to them to fulfill a shared information need. Due to their varying roles and expertise, group members might assign different priorities to the information pieces relevant to a CIS task and this affects what information they decide to share with others. Therefore, prioritizing relevant information often entails negotiations between group members and this is challenging as prioritizing the wrong pieces of information might lead to undesirable consequences. Also, collaborative sensemaking has a strong temporal aspect in that the process and products of sensemaking are passed on over time from one group member to another in the form of sensemaking trajectories. Thus, understanding the temporal connections between the sensemaking of different group members is essential during a CIS activity. Also, understanding the sequence and context of other group members’ actions with respect to long-term activities is important for group sensemaking. Thus, activity awareness that is awareness of group members’ actions pertaining to long-term endeavors (such as taking care
of a patient from the time he is admitted to the time he is discharged from the ED) is important for collaborative sensemaking.

The empirical study in the ED provided insight into the occasions and characteristics of sensemaking during CIS activities. These findings were organized into a conceptual framework for collaborative sensemaking and also led to implications for technology design, as described in the next section.

10.2.2 Analysis/Requirements

The analysis/requirements phase of the socio-technical design cycle is used to analyze the data from the field study to develop requirements for a system or tool (McDonald, 2000). This phase was covered by an analysis of the findings from the ED (Study 1) as well as a formative study of sensemaking during collaborative Web search (Study 2).

The findings about occasions and characteristics of collaborative sensemaking in the ED led to a conceptual framework of sensemaking in CIS activities. This framework has three parts: part I represents the CIS activity, part II describes the triggers for collaborative sensemaking, and part III highlights the characteristics of collaborative sensemaking. Although the framework is based on findings from a particular setting, it begins to lay out a conceptual foundation for understanding how and why collaborative sensemaking takes place in CIS activities.

The conceptual findings arising from Study 1 led to several implications for the design of tools that can support sensemaking in collaborative information retrieval. First, sensemaking trajectories imply that the process and intermediate products of collaborative sensemaking need to be made persistent in collaborative information retrieval tools. Such tools can provide timelines that show chronologically the information found and the sense
made by different group members during the CIS task. Second, the importance of activity awareness indicates that collaborative information retrieval tools should not only provide action awareness updates via notifications, but also activity awareness information in the form of activity timelines which show all actions performed by different group members with respect to a long-term activity. Third, prioritization of information, based on roles and expertise, can be provided by allowing group members to rate, comment on, and annotate information found by others. Finally, since the creation and manipulation of shared representations helped group sensemaking, tools should support not only generic information representations but representations tailored to group members’ roles. The conceptual framework and technical implications arising from Study 1 formed the first part of the analysis/requirements phase of the socio-technical circle.

The findings of Study 1 led to the conceptualization and design of Study 2. In Study 2, I was interested in exploring further the design ideas that resulted from Study 1 and hence chose to study collaborative sensemaking in the technical domain of collaborative Web search (Morris, 2008). Even though I had some ideas about the design challenges for sensemaking-support features based on Study 1, I still conducted a formative study of sensemaking during collaborative Web search tasks using the tool SearchTogether. This formative study formed the second part of the analysis/requirements phase of the socio-technical circle.

The formative study consisted of three-member groups of friends searching the Web for planning a vacation using the collaborative Web search tool SearchTogether. Two group members searched synchronously while the third group member logged into the saved search session of the others to complete the task asynchronously. An analysis of the findings from
the formative study revealed that users of SearchTogether faced three important sensemaking challenges – sensemaking trajectories, awareness, and sensemaking handoffs. Findings from the formative study were similar to those from Study 1. As in Study 1, making the temporal aspect of others sensemaking persistent was important to Web searchers. Group members wanted to see the path followed by others during their search as well as the products of their sensemaking, in the form of comments and ratings. Awareness was an important theme again. Participants wanted awareness about others' actions during the search (such as which Web pages they looked at) as well as context awareness about how the different kinds of information (such as Web pages, comments, ratings, chat messages) generated during the search were inter-related. Finally, participants found it hard to hand off the products of their sensemaking to group members who searched asynchronously.

Based on these findings, I designed and implemented the sensemaking-support tool CoSense. CoSense is integrated with SearchTogether and visualizes the information found in SearchTogether in various ways to help users deal with the sensemaking challenges identified in the formative study.

10.2.3 System design and implementation

The design and implementation of CoSense was based on the findings from the formative study of sensemaking in SearchTogether. To aid sensemaking during collaborative Web search tasks, CoSense provides four views of the information found during a search – the search strategies view, the timeline view, the workspace view, and the chat-centric view.

The search strategies view is designed to help users make sense of the search process and roles and skills of other group members via interactive graphs and tag clouds. The timeline view supports sensemaking trajectories by showing all the information generated
during the search session, such as Web pages found, comments and ratings on Web pages, and chat messages, chronologically. The workspace view helps users store the higher level products of sensemaking such as the most important links, decisions and to-do items for the search task. It provides a summary of the important Web pages and the comments and ratings associated with them as well as free-form text entry areas for note-taking. It also allows users to associate external files (e.g. an Excel sheet of cost calculations for the vacation) where they might have stored the products of their sensemaking. Finally, the chat-centric view allows users to contextualize the chat messages with respect to the Web pages opened.

CoSense is integrated with SearchTogether in that the views of CoSense are refreshed in real-time as group members search the Web using SearchTogether. CoSense was developed as a research prototype to test the design implications arising from both the ED study and the formative study of sensemaking in SearchTogether. I evaluated CoSense to see whether it enhanced users’ sensemaking during SearchTogether use.

10.2.4 Evaluation/Adoption

The evaluation phase of the socio-technical circle ties the system design to prior phases to examine if the designed system helps users achieve their work. I evaluated CoSense to examine if the sensemaking-support features helped group members overcome the sensemaking challenges faced in the formative study. The findings from the evaluation study helped me understand not only the pros and cons of the various design features of CoSense in enhancing group sensemaking but it also provided insight into the collaborative Web search behavior of users.
Three important themes emerged from the evaluation of CoSense. First, making the sensemaking trajectories of group members persistent and explicit is important in collaborative information retrieval tools. Second, prioritizing relevant and important information to help users’ sensemaking is important. Third, the products of sensemaking are recorded by users in different ways and forms and this needs to be supported in the collaborative information retrieval tool.

From a technical perspective, I learnt how the various design features incorporated in CoSense helped group members’ sensemaking during synchronous search, asynchronous search, and handoff of the search task. I also learnt that there were important design challenges in addressing the three important themes mentioned above. The challenge in making sensemaking trajectories explicit (as in the case of the timeline and chat-centric views in CoSense) is to decide how much information and sense made should be recorded in these trajectories so as not to overwhelm users. Similarly, prioritizing relevant and important information found during the search is a design challenge. While the ability to filter, annotate, and organize content (as in various CoSense views) provided some ways to prioritize information, these were not adequate mechanisms. Finally, since sensemaking products are recorded by participants in various forms, the design challenge is to decide how to support such recording and how much structure to provide for representations used to record such products.

The emergence of two strategies for handling handoff of collaborative search tasks – search-lead and sensemaking-lead – was an important finding of Study 2. Procedurally, search-lead strategists focused on finding and understanding new information about the task before they tried to understand information found by other group members. Sensemaking-
lead strategists, on the other hand, focused on understanding the information found by others before they began their own search for task-related information. The two kinds of strategists found different features of CoSense useful.

Finally, the evaluation of CoSense helped me understand that during collaborative sensemaking not only is it important for making sense of task-related information, but various others kinds of information as well. Understanding the search skills and strategies of others is not so important as understanding the relative importance of information sources and the task state and progress on goals. The taxonomy of collaborative sensemaking resulting from this study will help designers understand the kinds of information that need to be made sense of during collaborative information seeking tasks so that they can consider the various ways of supporting these kinds of sensemaking.

10.3 Comparing the findings of Study 1 and Study 2

Study 1 provided an empirical understanding of why and how collaborative sensemaking takes place during work activities of groups. Study 2 examined design features that can support collaborative sensemaking in collaborative information retrieval tools. Comparing the findings from two studies in different domains of CIS provides important insight into the basic nature of collaborative sensemaking, as well as ideas for future work in this area.

10.3.1. Similarities in findings

Some common themes emerged from the findings of both studies regarding the nature of collaborative sensemaking. For instance, sensemaking trajectories were important for collaborative sensemaking both in the ED and in collaborative Web search tasks. In the ED, sensemaking trajectories often appeared when information was verbally passed on during
patient handoffs. In the use of CoSense, the frequent use of the timeline and chat transcript views indicated the importance of sensemaking trajectories. The use of external representations to note the emerging “sense” of the group was another important common theme from the two studies. In the ED, common representations such as FirstNet and the whiteboard provided a place for care providers to note comments and interpretations of patient information to share with others. Within CoSense, the Workspace view provided a space for collaborators to take notes and record comments pertaining to important information. Finally, the importance of prioritizing important information was evident in both studies. In the ED, it was important for healthcare providers to prioritize important pieces of information to be passed on to others. In Study 2, the ability to prioritize important content, by assigning comments and ratings, was important to Web searchers. These common themes from the findings of both studies validate the findings themselves and provide insight into the basic nature of collaborative sensemaking.

10.3.2. Differences in findings

While several common themes emerged from both studies, some themes were exclusive to each study. Due to the controlled nature of Study 2 (i.e. all participants performed the same task) and the ability to capture detailed log data, Study 2 provided insights into the information search and sensemaking strategies of users of collaborative Web search tools. In Study 1, it was not possible to examine sensemaking strategies of healthcare providers due to the variability of the instances of collaborative sensemaking. For the same reasons, Study 1 did not reveal whether healthcare providers employed any procedural knowledge of sensemaking (as seen in Study 2). These differences in the findings lead to ideas about future
work. Further empirical studies of collaborative sensemaking can focus on examining strategies and procedural knowledge of sensemaking.

10.4 Lessons learnt

The two different methodologies applied for Study 1 and Study 2 helped me gain a holistic picture of collaborative sensemaking during information seeking activities. The ethnographic approach applied in studying collaborative sensemaking among healthcare providers helped me study the details and complexities of people’s interactions and actions as they collaborated to understand information during their work. The use of observations, interviews, artifact collection, and shadowing helped me study the dynamics of interactions between people as they searched for, shared, and made sense of information in a natural setting.

Study 2 helped me gain a different, yet complementary, perspective on collaborative sensemaking in information seeking tasks. Being able to observe users of SearchTogether and log their interactions with the system allowed me a detailed view of a) how people make sense of information within a tool, and b) the sensemaking challenges faced by users of such tools. The design and evaluation of CoSense helped me test out design ideas influenced by the findings of both Study 1 and the formative study of sensemaking in SearchTogether. The detailed logs of the interactions of CoSense users with the tool during the search task, as well as their interactions when answering the “sensemaking measurement” online questionnaire, provided insight into not only the pros and cons of various design features but also into how people search and make sense of information when collaborating with others.

Thus, methodologically, the two studies helped me examine sensemaking from various perspectives in order to answer the research questions in my dissertation. The next
chapter concludes this thesis with the answers to those research questions and the contributions of my research.
11. Conclusion

While there has been growing evidence that people collaborate during information seeking activities, there is little understanding of CIS behavior. Sensemaking is an important aspect of information seeking activities but has not been explored much in studies of CIS. Recently, several tools (Amershi, 2008; Freyne & Smyth, 2006; Morris & Horvitz, 2007; Pickens et al., 2008) have been designed to support collaborative information retrieval. However, researchers building these tools have focused mostly on how to help users find, retrieve, and share information; the issue of supporting sensemaking in collaborative information retrieval tools has not been explored much.

This thesis examined collaborative sensemaking as part of CIS activities. The goals were to provide a conceptual understanding of sensemaking in CIS activities, and to provide insight into design features that can support sensemaking in collaborative information retrieval tools. Through two studies of collaborative sensemaking using different methodologies, I examined sensemaking in CIS activities in two domains – healthcare and Web search. The results of these studies make important contributions to our conceptual and technical understanding of collaborative sensemaking. This chapter lists these contributions and discusses ideas for future work.

11.1 Study contributions

I set out to answer the following research questions in my thesis:

- Why do people collaborate for sensemaking in CIS activities?
- What are the characteristics of collaborative sensemaking during CIS activities?
- How can sensemaking be supported in collaborative information retrieval tools?
In this section, I answer these research questions, highlighting the following contributions:

- Expanding our conceptual understanding of collaborative sensemaking by providing insight into the occasions and characteristics of collaborative sensemaking during CIS tasks.
- Providing insight into the design-features that can support sensemaking in collaborative information retrieval tools and also the challenges in designing some of these features.

### 11.1.1 Occasions and characteristics of collaborative sensemaking

**RQ1: Why do people collaborate for sensemaking in CIS activities?**

During CIS activities, people collaborate to find, retrieve, and share information to fulfill a shared information need. Understanding the information found can be a challenge for collaborators due to various reasons. My study of the CIS practices of healthcare providers in the emergency department found that there are three important reasons why people collaborate for making sense of information – ambiguity of information, role-based distribution of information, and lack of expertise. Ambiguous information is information that is difficult to understand because it is unclear or has multiple possible meanings. When information seekers come across ambiguous information, they collaborate with others to help them understand the information. People also collaborate for sensemaking because the different pieces of information that need to be synthesized to answer an information need are available with different role players. Finally, people collaborate because they require others’ expertise to help them understand information needed to answer their information needs. Thus people collaborate to bring together the information available with each other, and their individual expertise to disambiguate and understand the information available.
RQ2: What are the characteristics of collaborative sensemaking during CIS activities?

Three important characteristics of collaborative sensemaking emerged from my studies in both the healthcare and Web search domains, namely – prioritization of relevant information, sensemaking trajectories, and activity awareness. First, an important aspect of group sensemaking is prioritizing information as relevant to the shared information need. This is difficult in CIS activities because different group members have access to different pieces of information and might understand the information differently based on their roles and expertise. Thus, being able to assign priorities to information pieces correctly is challenging. Second, sensemaking trajectories emphasize the temporal nature of collaborative sensemaking. The products of group members’ sensemaking is passed on across time and individuals need to be exposed to the process and products of others’ sensemaking over time to enhance their own sensemaking. Finally, making sense of the connections between the actions of various group members with respect to long-term activities is important for group members’ sensemaking.

The occasions and characteristics of collaborative sensemaking can be organized into a conceptual framework (Figure 10, Chapter 6) which can enhance both researchers’ and designers’ understanding of collaborative sensemaking behavior.

11.1.2 Supporting collaborative sensemaking

RQ3: How can sensemaking be supported in collaborative information retrieval tools?

Study 1 provided broad design ideas about supporting sensemaking in collaborative information retrieval tools. Study 2, undertaken specifically to answer RQ3, helped me design and evaluate features for supporting collaborative sensemaking in collaborative Web search tools. I found that various views of the information presented to users of collaborative
search tools can provide support for sensemaking during different parts of a search task – synchronous, asynchronous, and handoff – as well as for users having different sensemaking strategies – search-lead and sensemaking-lead. Sensemaking trajectories can be supported by making the information found and the sense made persistent in the form of timelines or persistent chat. Prioritization of information can be supported by allowing users to comment on, organize and annotate information. Finally, the browsing and navigating behavior of other users can be made explicit by showing the search skills and strategies of other group members.

11.1.3 Contributions to academic communities

This research primarily contributes to three academic research communities: computer-supported cooperative work (CSCW), human-computer interaction (HCI), and information sciences.

11.1.3.1 To the CSCW community

The CSCW community has been concerned with understanding and supporting people’s collaborative activities in both professional and personal domains. Sensemaking is an important aspect of various such collaborative activities. This research extends our current understanding of sensemaking in collaborative activities by highlighting its social and interaction aspects. I provided a detailed account of how and why collaboration occurs during sensemaking activities in the context of CIS. I also presented a conceptual framework for collaborative sensemaking that highlights the occasions and characteristics of collaborative sensemaking as part of information seeking activities. My field study in the emergency department extends important CSCW concepts like trajectories and awareness by focusing on the role these play in collaborative sensemaking activities.
Another important contribution of my thesis is to the design space of tools to support collaborative information retrieval. First, the field study in the ED provided implications for the design of sensemaking-support features in collaborative information retrieval tools from my field study. Second, I synthesized the design ideas from two domains, namely healthcare and collaborative Web search, to design the sensemaking-support tool CoSense. In the past decade, CSCW researchers have developed several tools to support people’s collaborative information seeking activities. However, the research in this space is its nascent stages since researchers lack models of people’s collaborative information behavior that can be basis of such tools. This thesis moves forward the research in this space by highlighting the design features that can be used to support sensemaking in collaborative information retrieval tools. It also brings to light the design challenges that developers must face when supporting sensemaking-enhancing features in such tools.

11.1.3.2 To the HCI community

Sensemaking has been a prominent topic in the HCI community (Russell et al., 1993) and the design of interfaces to support sensemaking at both the individual and group level has been a challenging problem (Whittaker, 2008). While computers help us store large amounts of information, they are not very good at helping us make sense of this information. Most sensemaking-support interfaces developed in HCI support individual users to organize and visualize information better. Very few studies in this field have focused on sensemaking during collaboration since the predominant view of sensemaking in HCI has been that it is an individual cognitive activity. Furthermore, fewer studies have attempted to design interfaces to support the social aspects of sensemaking. My research provides valuable insight into how people interact with each other during information seeking activities and how both individual
and group sensemaking evolves during these interactions. The ideas that the process and products of an individual’s sensemaking affects that of others’, and descriptions of how this happens, helps move forward the understanding of sensemaking as a social activity. Such an understanding can help designers move beyond supporting merely organization of information as an aid to sensemaking and help them seek new ideas in this space.

Also, the evaluation of the various features of CoSense provides insight into the different ways in which information can be visualized to support sensemaking and the pros and cons of different visualizations. Furthermore, the findings about the sensemaking strategies of CoSense users will add to designers’ knowledge of collaborative information behavior.

### 11.1.3.3 To the information sciences community

Finally, this research makes an important contribution to the information sciences community. Understanding information seeking behavior has been a long-running theme in this community. Sensemaking has been an implicit aspect of information seeking studies but few studies have explicitly studied the details of people’s interactions during sensemaking activities. This research explicates this detail, bringing to light how integral a part of information seeking activities sensemaking. Also, recently, the topic of collaboration during information seeking has become prominent in the information sciences literature, but few studies of CIS have focused on sensemaking. This research highlights the important role that sensemaking plays in CIS activities and lays the foundation for further work in this area.
11.2 Future work

In future work, I am interested in moving forward the specific ideas about sensemaking in CIS arising from this dissertation, as well as generally exploring further the area of collaborative information behavior (CIB) which encompasses collaborative searching, sharing, sensemaking, and use of information.

11.2.1 Extending thesis ideas further

I am interested in further developing the concepts of sensemaking trajectories and activity awareness with respect to their role in collaborative sensemaking. For instance, sensemaking trajectories is in its initial stages of conceptual development and would benefit from being explored in other areas of CIS. I am also interested in exploring further the sensemaking strategies used during handoff, such as the search-lead and sensemaking-lead strategies observed during the evaluation of CoSense. My study did not reveal that participants benefited from using either strategy but this requires further investigation.

Finally, various design challenges remain to be addressed for supporting sensemaking in collaborative information retrieval tools. Several of the design features evaluated through the design of CoSense received mixed feedback in terms of their ability to support participants’ sensemaking. I would like to explore more effective ways to support sensemaking trajectories, awareness, prioritization of information, and sharing the products of sensemaking with others in collaborative information retrieval tools.

11.2.2 Exploring collaborative information behavior

In future work, I am interested in exploring collaborative information behavior (CIB) further in online domains at both the small group and social levels of analysis. At the group level, I
am interested in exploring further how small groups collaborate on online tasks such as Web
search and tagging, with a specific focus on how they find and make sense of information
during such tasks. Recently there has been growing evidence that friends and family
members conduct Web search tasks together such as when planning a vacation or writing a
joint report (Morris, 2008) and researchers are developing Web search tools to support users
during such tasks. Drawing on the results of my field studies of collaborative information
seeking in organizational settings and my experience with lab studies and prototyping of
collaborative sensemaking tools, I am interested in designing collaborative search tools
which employ both UI-level and algorithmic methods to mediate search results in explicitly
collaborating groups. I am also interested in supporting CIB beyond search activities.
Emerging technologies like Google Wave (Google, 2009) will allow groups to communicate
and collaborate using text, photos, videos, and maps. I am interested in supporting
information seeking and sensemaking in the use of such technologies.

Further, I want to extend my research at the small group level to community and
social levels of collaboration. For instance, I would like to extend my findings in
collaborative Web search to social search. With the rising popularity of social media sites
like Twitter (2009), Facebook (2009), Digg (2009), and Delicious (2009), social search
(Evans & Chi, 2008) is fast becoming the new paradigm of search. Supporting social
interactions during information seeking can help searchers share expertise about information
sources and search strategies. For instance, enabling Web searchers to collaborate can help
naïve searchers leverage the expertise of expert searchers on similar Web search tasks. I
envision social search to move in two directions – one in which searchers ask experts or
people with similar information needs to rank search results returned by search engines like
Google. The other direction in which I see social search growing is users directing their search queries to their social networks (e.g. Peerspective (2009)) or to experts (e.g. Aardvark, (2009)). In the latter model of social search, services will be able to mine social queries to find trends in users’ search needs (e.g. Twitter (2009)) search shows the ‘trending topics’ based on real-time analysis of users’ Tweets) and target those search needs with products or information. I want to study how trends revealed by social search queries can be targeted effectively in real-time.

At the social level, I would also like to study search and sensemaking patterns to develop models of users’ search behavior. Patterns extracted from large-scale data of users’ search, sensemaking, sharing, and tagging behavior online can be used to create re-usable ‘templates’ that can be used by other users conducting similar activity online. For instance, if we can extract patterns from the search activities of all users on the Internet searching for hybrid cars, we can possibly create templates based on these patterns (containing attributes that hybrid car owners should look for when they search online) and make such templates available to other users buying hybrid cars. We can also extract procedural search knowledge from all users who are experts at searching for cars online and present this procedural knowledge as a set of “steps” that naïve Web searchers can follow while conducting similar search tasks. Finally, I’m interested in studying non-search related large-scale collaboration online such as in Wikipedia (2009), and social tagging systems like SparTag.us (Nelson et al., 2009).

11.3 Closing remarks

Sensemaking is an important aspect of information seeking but extant research on sensemaking has focused mostly on individual sensemaking. This thesis described a multi-
method study of collaborative sensemaking during information seeking activities. Through a
field study and the development and evaluation of a sensemaking-enhancing tool, I examined
why collaborative sensemaking takes place during collaborative information seeking
activities, how it is characterized, and how it can be supported in collaborative information
retrieval tools. The insights gained in this thesis further both our conceptual understanding of
collaborative sensemaking and our technical knowledge of how to design tools that can
support collaborative sensemaking.
References


Appendix A

CoSense evaluation study: Task description

Below are instructions for the task for phase 1 participants.

You and your three friends are planning a four-day vacation in Helsinki, Finland from Sep 13th – 16th. Three of you are online now and you want to search for information about how you will spend your vacation in Finland. Assume that your flights are booked (leaving the US on the 12th of Sep and returning to the US on the 17th of Sep) and your hotels are booked too. But you have not yet planned the activities for your vacation. Your goal is to come up with a joint plan of things you will be doing on your vacation. You have certain constraints as follows:

- You can each only spend 400 Euros (100 Euros per person).
- Of all the activities your group chooses for the vacation, one has to be a sight-seeing activity, the other an outdoor activity, the third a dining activity, and the fourth a cultural activity. You are free to choose any other types of activities in addition to these three.
- Remember, you’re trying to plan a vacation as a group, so you may need to compromise to find activities that interest everyone.

Your fourth group member is not online right now, but will join in the planning at a later time. So the information you find about things to do will have to be shared with him so he can modify it or approve of it.

Below are instructions for the same task for phase 2 participants.

You and your three friends are planning a four-day vacation in Helsinki, Finland from Sep 13th – 16th. Assume that your flights are booked (leaving the US on the 12th of Sep and returning to the US on the 17th of Sep) and your hotels are booked too. But you have not yet planned the activities for your vacation. Your three friends met online and searched for things to do in Finland in order to put together a plan. You have certain constraints as follows:

- You can only spend 400 Euros (100 Euros per person) during this vacation (excluding flights and hotel).
- Of all the activities your group chooses for the vacation, one has to be a sight-seeing activity, the other an outdoor activity, the third a dining activity, and the fourth a cultural activity. You are free to choose any other types of activities in addition to these four.
- Remember, you’re trying to plan a vacation as a group, so you may need to compromise to find activities that interest everyone.

Your goal is to now look at what the others have found and come up with the final plan for your vacation.
### CoSense evaluation study: Sample SearchTogether log file

The table below shows a participant’s SearchTogether log file for the first 3 minutes of the task.

**Note:** The “Type” column indicates what type of action is logged.
- ‘1’ indicates a URL was opened in browser. In this case the ‘Action’ column contains the URL that was opened.
- ‘2’ indicates a chat message was typed. In this case the ‘Action’ column contains the chat message.
- ‘3’ indicates a query was issued. In this case the ‘Action’ column contains the query.
- ‘4’ indicates a comment was made on a URL added to the Summary tab. In this case the ‘Action’ column contains the comment.

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<th>Date</th>
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<th>Type</th>
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Appendix C

CoSense evaluation study: Sample CoSense log file

The table below shows a participant’s CoSense log file for the first 6 minutes of the task.

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Appendix D

CoSense evaluation study: Post-task Online Questionnaire

1. Which group member do you think contributed most to the task? Why?

2. Which group member was the most skilled searcher? Why?

3. Which aspect of the task did each group member work on?

4. Which websites did the group find most helpful for the task?

5. Were any group members’ search strategies influenced by the task? If so, how and why?

6. Which websites generated a lot of discussion?

7. Which queries were the most successful?

8. What decision, if any, did the group reach regarding the trip’s itinerary?

9. What steps, if any, remain before the itinerary is complete?

10. What is your name?

11. What is your age?

12. What is your gender?
Appendix E

CoSense evaluation study: Interview questions for phase 2 participants

Please answer the following questions about the search task you just completed:

1. Rate your expertise (with respect to the general population) in searching for information online
   1  2  3  4  5
   Novice  below average  Average  above average  expert

2. What was the ‘status’ of the search task when you resumed it?

3. How did you continue the task?
   a. Did you follow the links to websites found by other group members?
   b. How did you know which links or information sources to visit?

4. Are there any advantages you found in using SearchTogether and CoSense to collaborate with your group? If so, what were they?

5. Are there any features you would like to improve about SearchTogether and CoSense? If so, what were they?

6. How did you understand what your other group members had already done?
   a. What features of SearchTogether and CoSense helped you understand this?
   b. Were there aspects of what your group had done before that you found confusing or that you didn’t understand?

7. Do you think CoSense helped you better understand what other group members had done online? If so, how?

8. Did you feel the need to communicate with other group members while you were performing the task? If so, for what?

9. Did you create any artifacts (notes, diagrams) outside of SearchTogether to help you accomplish the task?
   a. Did you use any non-electronic artifacts created by the group (such as maps, diagrams etc.)? If so, how?

10. Do you think you were successful in finding things to do in Finland/Sweden given the time you were allotted? If no, why not?

11. Any general comments for us?
Curriculum Vitae
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EDUCATION

Ph.D., Information Science and Technology
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PEER-REVIEWED PUBLICATIONS

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Conference Full and Short Papers


