Understanding Together: Sensemaking in Collaborative Information Seeking

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ABSTRACT

An important aspect of collaborative information seeking (CIS) is making sense of the information found, i.e., collaborative sensemaking. We conducted an ethnographic study of the CIS practices of healthcare providers in a hospital emergency department to gain a conceptual understanding of when and how collaborative sensemaking occurs during CIS activities. We present occasions and characteristics of collaborative sensemaking and design implications for collaborative information retrieval tools to support sensemaking.

Author Keywords

Collaborative sensemaking, collaborative information seeking, healthcare, emergency department.

ACM Classification Keywords

H5.m. Information interfaces and presentation: Group and organizational interfaces – computer-supported cooperative work.

General Terms

Design, Theory.

INTRODUCTION

Collaboration is an essential aspect of many types of daily activities. One daily activity that is central to people's personal and professional lives is information seeking. In the last decade, there has been growing interest in understanding and supporting people's *collaborative information seeking (CIS)* practices [5, 9, 10]. For instance, researchers have explored how friends and family members collaboratively search the Web to plan a vacation [17] or how healthcare providers collaboratively search for information to diagnose and treat patients [23]. Recently several tools (e.g., SearchTogether [18], Cerchiamo [20]) have been designed to support CIS activities. However, researchers still do not have a clear understanding of people's collaborative information seeking behavior. CIS is often viewed as a single activity, but it is actually composed of many different activities, such as seeking, sharing,

understanding, and using information together. Identifying and understanding these different collaborative activities is important for developing effective CIS tools. In our study we address this lack of understanding of CIS behavior. We specifically focus on how collaborative *sensemaking* takes place during CIS activities.

Collaborative information seeking has been defined as "the study of systems and practices that enable individuals to collaborate during the seeking, searching, and retrieval of information" [10] (p. 330). Thus, studies of CIS have focused on how people find and retrieve information together, with little attention paid to how people work together to *synthesize* and *understand* the different pieces of information that are shared during a CIS activity. This collaborative sensemaking activity is an integral aspect of CIS practice that has not been studied much. While sensemaking has been studied in a variety of fields [8, 14, 25, 33], most studies of sensemaking have examined it in the context of individual information seeking tasks. Although some researchers [33] have mentioned the social and interactional aspects of sensemaking, there has been little empirical exploration of how sensemaking takes place in collaborative work, especially within CIS activities.

We examined the CIS practices of healthcare providers in a hospital Emergency Department (ED) in order to gain a conceptual understanding of collaborative sensemaking. The ED is a highly collaborative and information-intensive environment that requires healthcare providers to find information quickly and efficiently in order to provide care to critically ill patients. Researchers have examined a variety of information activities in hospital settings such as the use of digital and non-digital artifacts for collaboration [2], information flows and their effect on collaboration [30], and supporting awareness via shared displays [3]. In these and other studies, information seeking has been found to be an intrinsic aspect of collaborative work but it has not been studied in detail. In this paper, we present a field study of the CIS practices of healthcare providers in the ED. We specifically focus on when and how collaborative sensemaking takes place during these CIS activities. The following section describes previous work on sensemaking and CIS. We next present our study methods and field site, followed by a description of CIS activities in the ED. We highlight the occasions for collaborative sensemaking during these CIS activities and the important characteristics

of collaborative sensemaking. Finally, we conclude with some design implications for supporting sensemaking in CIS tools.

BACKGROUND

The term 'sensemaking' has been used in a variety of fields. In the information and communication sciences, Dervin's [8] "Sense-making" methodology examines how people overcome 'gaps' in reality by constructing bridges consisting of ideas, thoughts, emotions, feelings, and memories. In the field of HCI, sensemaking has focused on how users understand complex information spaces or large document collections [25]. Here, sensemaking is the process of encoding information into external representations to answer complex, task-specific questions. Sensemaking has been examined in a number of other domains ranging from education [26] to organizational sciences [33]. Weick [33] defines sensemaking as 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 situations and enact this sense back into the world.

In spite of the varied perspectives on sensemaking, there are three salient characteristics of the sensemaking literature. First, 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 [14]. 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. For instance, Dervin's [8] Sense-making methodology has been applied to a variety of information seeking studies and prominent models of sensemaking, (e.g.,[25]) are based on information seeking activities of information workers. Third, 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; refining the representations used based on new information found; and changing representations or frameworks in use to fit new information [15, 25].

Sensemaking in Collaborative Environments

Sensemaking is an important aspect of collaborative work, especially in time-critical, high-reliability domains such as military command and control [13], firefighting and rescue operations [32,16], and healthcare [1]. In such domains, work is typically information-intensive and the information relevant to joint tasks is distributed across group members who may each have a different understanding of the information they possess. It is important to create a shared understanding of the information available to achieve shared goals. A handful of studies have examined sensemaking in collaborative work. Jensen [13] conducted a study of sensemaking in Army teams and found that neither the quality of information presented to team members nor

the ability to meet face-to-face affected the sensemaking process. However, the better the sensemaking process, the better were the plans produced. Weick [32] examined how sensemaking broke down in a team of smoke-jumpers during a huge forest fire in Montana. He proposed four sources of resilience that makes groups less vulnerable to disruptions in sensemaking – improvisation, virtual role systems, the attitude of wisdom, and norms of respectful interaction. Landgren [16] studied patterns of mobile phone interactions among police patrol units and firefighting crews during emergency response operations. He showed that the dyadic exchange of mobile phone numbers between the actors helped sensemaking during the emergency.

Though medical work is rife with occasions for sensemaking, there have been few studies of sensemaking in this domain. Albolino et al. [1] conducted an ethnographic study of sensemaking among healthcare providers working in the intensive care unit (ICU). They found two kinds of sensemaking occur in the ICU – '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.

While sensemaking is an important aspect of collaborative work, it has not been examined in collaborative information seeking studies [11, 23, 31]. Collaborative information seeking (CIS) occurs when "a group or team of people undertakes to identify and resolve a shared information need." [21] (p. 239). Some studies of CIS have focused on the *process* of collaboratively finding and sharing information, such as collaborative formulation of information needs [21], sharing information needs and information seeking strategies, and communicating during information seeking [27]. Other studies have explored the *characteristics* of CIS such as temporality [23], triggers [28], and situational awareness [27]. However, none of the studies have examined how people together understand information found during CIS activities. Similarly, models of collaborative information behavior do not account for sensemaking. For instance, the behavior axis of Reddy et al.'s [24] collaborative information behavior model includes information searching, seeking, and use but not sensemaking.

While empirical studies of CIS have rarely focused on sensemaking as part of this process, these studies have often found that sharing the understanding of information is an important aspect of such activities. For instance, Harper & Sellen [12] conducted a study of information workers at the International Monetary Fund and found that social interaction taking place during information seeking activities was "not as important to the sharing of *objective* information as it is to the sharing of *interpreted* information". Collaborators often shared their interpretation of information in the form of notes and annotations.

Similarly, Hansen & Jarvelin [11] 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 enhance group members' understanding during information seeking activities.

Due to its conception as a cognitive activity, most theories and models of sensemaking have not examined its social aspects. At the same time, the collaborative information seeking literature suggests that people not only share information but also their *understanding* of the information found during CIS activities to build a shared understanding. Consequently, we argue that sensemaking in collaborative environments is not merely a cognitive activity that occurs inside the sensemaker's head; but is a social and interactional activity that takes place between multiple people. Although some researchers [7, 33] have emphasized the social character of sensemaking, most of these descriptions have been theoretical. In this paper, we provide an empirical understanding of the collaborative sensemaking phenomenon.

METHODS

Research Site
We conducted an ethnographic study of the CIS activities of healthcare providers in a hospital ED. Our study site was the ED of a 500-bed teaching hospital, HMC. HMC is one of seven academic health centers in Pennsylvania, USA and serves about 1.5 million people living in Central Pennsylvania. It sees nearly 26,000 admissions and 800,000 clinic visits each year. HMC provides pioneering medical techniques and therapies and state-of-the-art technologies and facilities, including a nationally recognized electronic medical record, the region's only comprehensive cancer institute, and one of the nation's best children's hospitals.

The 32-bed ED at HMC sees nearly 50,000 patients a year. It contains 27 private rooms, 8 observation beds, and 2 trauma resuscitation rooms. In addition to these beds, there are 'hallway beds', i.e. beds placed in hallways to accommodate patients when rooms are full. The ED is served by emergency medical services (EMS) consisting of medically-equipped helicopters and ambulances. The EMS transport critically ill patients into and out of the ED.

Participants
Participants were clinical and non-clinical ED staff. The clinical staff comprises attending physicians, residents (i.e., physicians-in-training), physicians' assistants, nurses, and nurse practitioners. The non-clinical staff includes emergency department technicians (EDTs), inpatient access associates (who perform administrative jobs such as patient registration and billing), support assistants, and housekeeping staff. These personnel are distributed across three teams; each team has physical coverage of a different part of the ED and consists of an attending physician, 1-2 residents, and 3-4 nurses during any given shift. Also, during each shift, there is an ED charge nurse who coordinates patient care and resource allocation for the entire ED. The responsibilities of the charge nurse include assigning nurses and rooms to patients, distributing the patient caseloads evenly across nurses; and adjusting staff according to changing workloads. Bed management is an important responsibility of the charge nurse; she moves patients between rooms and hallway beds based on the resources available.

Information and Communication Tools in the ED
ED care providers utilize a variety of digital and non-digital information artifacts during their work. The HMC ED has an electronic medical record, Eclipsys, which is integrated with a computerized provider order entry system, FirstNet (Figure 1). FistNet is used by clinical staff to order medications and lab tests for patients.

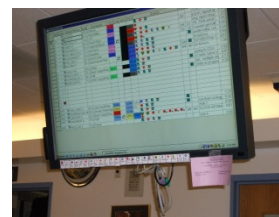**Figure 1(a): Care providers using FirstNet in the ED**

Figure 1(b): FirstNet on overhead displays in the ED

Figure 1(c): The spread-sheet view of patient information in FirstNet.

It shows a spread-sheet like view of the following information for each patient in the ED: bed number; physicians, residents, and nurses assigned; tests ordered; level of acuity; chief complaint; length of stay; and comments. A more detailed view of each patient's information contains a history of medications ordered, procedures performed, nurses' narratives, and physician's assessment. Apart from Eclypsis and FirstNet, the ED uses traditional information tools like whiteboards and paper forms. Communication devices included phones and pagers.

Data collection and analysis
We collected data at the HMC ED using ethnographic techniques during Feb 2007 – Nov 2008 for a total of 170 hours of fieldwork. The first author collected data using observations, informal and formal interviews, 'shadowing' of participants, and critical incidents collection. Since examining the interactions of care providers as they collaborated to understand information was central to this study, observations were the main data collection technique. We conducted observations 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 computers) were in use. We noted interactions between providers as they searched for, shared, and made use of information. During observations, we conducted informal interviews asking participants about their work, information needs, and information sources.

We also shadowed participants while noting their information seeking activities. For instance, we observed charge nurses during handoff activities and then followed the incoming charge nurse on her rounds. We also followed certain events and 'critical incidents' in the ED and observed how different care providers interacted to share and understand information during these events. Critical incidents were unexpected incidents (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). We observed 17 critical incidents, where these incidents spanned 30 minutes to several hours.

Finally, we conducted formal semi-structured interviews to gain richer insights into observed information seeking and sensemaking activities. It is hard to ask people how they make sense of situations because people are often not aware of their sensemaking or may not be able to articulate how they make sense of information. We asked two kinds of questions to gain insight into participants' sensemaking. First, we asked post-hoc questions about instances where we had observed participants collaborating with others to understand information about a particular situation. Second, we asked participants to explain how they understood typical situations (e.g., the arrival of trauma patients) that frequently arise in the ED. We conducted 12 formal interviews: 4 with nurses (including charge nurses), 4 with physicians (including residents), 3 with administrative staff, and one with a support assistant.

Data collected during observations, shadowing, and informal interviews were noted using pen and paper, while formal interviews were audio-recorded. All data were transcribed into electronic form. We used a grounded theory approach [29] to analyze our data. We identified instances of collaborative information seeking by drawing on previous work [22] and then using an open coding technique, we coded "sensemaking moments" as instances where group members were unable to perform their work due to their inability to understand the information found during CIS activities. We further categorized sensemaking moments as instances of "collaborative sensemaking" if group members collaborated to gain a better understanding of the situation. "Sense" was deemed to be made when care providers were able to continue their work again.

COLLABORATIVE INFORMATION SEEKING IN THE ED
In this section, we provide a brief description of the CIS activities in the ED to contextualize our discussions of collaborative sensemaking. Work in the ED is collaborative, time-critical, and information-intensive. 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 scarcity. 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.

We observed CIS during two main categories of collaborative work activities in the ED – clinical and organizational. These two types of activities were conducted in parallel during a patient's stay. Clinical activities related to providing medical care to the patient, including diagnosis, stabilization, and treatment of his condition. Organizational activities typically included resource allocation tasks (such as bed management and allocation of nurses and medical equipment) and administrative tasks (such as patient registration, charting, and billing). Here we provide vignettes from our data to illustrate how information was found and used collaboratively during clinical and organizational 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.

> 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, 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"

This example illustrates how care providers collaboratively diagnose a patient by finding and understanding different types of information. 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.

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, 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 section we focus on the sensemaking part of this process and describe when and how it occurred during CIS activities.

OCCASIONS FOR COLLABORATIVE SENSEMAKING

Making sense of information was closely intertwined with information seeking activities of care providers. We found that collaborative sensemaking occurred for three main reasons – ambiguity of available information, role-based distribution of information, and lack of expertise.

Ambiguity of Information

Ambiguous information is information that is unclear or that can be interpreted to have multiple meanings. Care providers often collaborated to understand ambiguous information, as highlighted by the following vignette:

RA2, a registration associate, is registering a patient and finds that the patient has two different medical record numbers, one that she found in Eclipsys and the other provided by the patient. RA2 is looking in Eclipsys, trying to figure out which one is correct. The EMS member, EM2, who brought in the patient, is standing next to her. RA2 asks EM2 whether he knows why the patient has two different medical record numbers.

EM2: "Is that because she went to [another hospital] for a while?"

RA2 (looks through Eclipsys): "Ah, I found it. It seems she hasn't come to us in a while. What is the address you picked her up at?"

EM2 tells her where he picked up the patient. RA uses the address information to verify that she has the correct record number and makes a note of it in Eclypsis.

In this 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 finds that this is indeed the case. To confirm her understanding, she asks EM2 for the patient's address information.

Role-Based Distribution of Information
Another reason why care providers felt the need to engage in collaborative sensemaking during their information seeking activities was that information was not distributed equally among group members; rather the information was distributed based on group members' roles. Different group members having access to different pieces of information had different understandings of the situation. The vignette below illustrates how role-based distribution of information led to an occasion for collaborative sensemaking:

> An emergency medicine technician, EMT1, brought a patient in a wheelchair up to the charge nurse CN1 and asks her, "Do you know what happened to 25? I took her to CT and when I brought her back, her room was being cleaned?"
>
> CN1 looks at the patient's information in FirstNet. The 'comments' column for the patient's record says 'CT scan then dispo'. CN1 has no idea why the patient's room is being cleaned out before she was brought back from CT scan. She asks the nurse in-charge of this patient, RN1: "Hey, what happened to 25? Her room is being cleaned."
>
> RN1 looks at her notes in FirstNet and tells CN1: "Looks like she was moved to hallway 1. I don't know why. I didn't move her." (apologetic)
>
> CN1 (sounds a little angry): "I know what happened. It wasn't you. It was the people in triage. This is the third time they've moved patients today without letting me know."

In this example EMT1 and CN1 are faced with a situation where a patient's room is being cleaned even though she has not been discharged. In order to understand the situation CN1 asks RN1 what happened to the patient's room. As the nurse in charge of the patient, RN1 should have known about any changes to the patient's care plan. RN1 doesn't know either but finds the patient was moved to a hallway bed. Given this information, CN1, who has been monitoring the ED all day, sees a pattern. She has experienced such situations earlier in the day when the triage nurses moved patients from room beds to hallway beds without informing her. It was CN1's experience gained due to her role as a charge-nurse that helped her make sense of the situation.

Lack of Expertise
Lack of expertise has been found to be an important trigger for collaboration during information seeking [22] and we found that it often led to collaborative sensemaking. 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 support staff are involved in caring for patients. In the following vignette 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:

> 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. We found that 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. Collaborative sensemaking arose from lack of expertise during non-clinical activities too. For instance, during bed management activities, charge nurses would 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.

COLLABORATIVE SENSEMAKING CHARACTERISTICS
In this section we highlight three important characteristics of collaborative sensemaking: prioritization of information, sensemaking trajectories, and activity awareness:

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 their information need. We found that during CIS, 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 was often a crucial decision made by each group member and this decision had consequences for collaborative sensemaking. Thus, an important aspect of collaborative sensemaking was the *prioritization* of certain shared pieces of information as relevant. Prioritizing the 'right' pieces of information as relevant enhanced group sensemaking, but it was often challenging for providers to judge what these 'right' pieces of information were. On the other hand,

failing to prioritize certain information as relevant led to undesirable consequences, as seen below.

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 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.

Thus, one of the challenges in collaborative sensemaking is for the group to prioritize information as relevant to understanding a particular situation or fulfilling a shared information need. This is challenging because different group members (based on their roles and expertise) might assign different priority to information. This affects which pieces of information are shared, which in turn affects group sensemaking. An important aspect of individual sensemaking is noticing and bracketing of cues from a stream of experience [33]. 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. We 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). What makes collaborative sensemaking challenging is that the bracketing of cues is a social process and it is important for group members to agree on priorities assigned to cues.

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. We found that knowing the "path" that a group member followed to make sense of a situation helped other group members' sensemaking. We 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. We observed that during handoffs, not only was information passed on to others, but also the *interpretation* 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 vignette below illustrates this:

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 vignette 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.

Trajectories have been seen to play an important role in medical work and have been applied to the study of temporal rhythms in information seeking [23]. Our finding of sensemaking trajectories emphasizes the temporal nature of 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.

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?). We 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 [4]. 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)" [6] (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 [4].

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 is important for collaborative sensemaking.

Care providers often shared action awareness information during their information seeking activities. However, we 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 vignette illustrates how understanding the relationship between various actions pertaining to a patient was important for sensemaking:

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 is 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 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.

We found that 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. We 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 to understand what the actions of group members meant in light of the long term care plan for the patient.

IMPLICATIONS AND CONCLUSION

Information seeking has been conceptualized as identifying, seeking, and retrieving needed information [10]. However, as we have highlighted in our study, in collaborative environments an important aspect of information seeking is sensemaking, i.e., understanding the information together. Our findings make important contributions to the conceptual understanding of collaborative sensemaking by providing insight into the occasions and characteristics of collaborative sensemaking. Weick [33] has discussed ambiguity of information as a key reason for individual sensemaking in organizational contexts. We found that in addition to ambiguity of information, the different roles and expertise of group members make sensemaking in groups more challenging. Also, group members not only need to understand task-related information but also other kinds of information such as the relative relevance of information

available with others, others' sensemaking trajectories, and activity awareness information.

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 [20] or UI-level mediation [18] 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 by different group members. Our findings can be used to design sensemaking-support features for such tools. For instance, one way of disambiguating information, especially by taking advantage of the expertise of others, is to provide the ability for group members to comment on and annotate information found by others. 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. In other domains, like Web search, comments on information found during CIS activities have been found to be useful for enhancing group sensemaking [19].

Based on our findings, we propose two design principles for CIS tools. First, tools should support persistence of the process and products of sensemaking by visualizing sensemaking trajectories. One way of visualizing such trajectories is through timelines [19] which show chronologically the information found by different group members and the sense made of the information. Users can 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). Timelines can help users deal with the challenges of role-based distribution of information by allowing information to be filtered based on roles. Comments made on information can be made part of the timeline so that the sense made of the information is shown along with the information itself. Sensemaking trajectories, though a powerful concept, is in its early phase of conceptual development and needs further exploration. Other ways of representing sensemaking trajectories in CIS tools will be explored in future work. Second, 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. These design principles can be adapted for CIS tools in domains where people collaboratively search for information such as hospitals, libraries, and Web search.

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