CoSense:
Enhancing Sensemaking for Collaborative Web Search

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ABSTRACT
Making sense of the information found during an investigational Web search task can be daunting. With the recent emergence of tools to support collaborative Web search, the associated sensemaking task has become even more complex, requiring sense to be made not only of the *products* of a search (*i.e.*, results found) but of the *process*, as well (*i.e.*, group division of labor and decision-making).

We present the findings of a formative study illustrating the sensemaking challenges posed by collaborative search tools. Based on these findings, we created CoSense, a system that supports sensemaking for collaborative Web search tasks by providing several rich, interactive views of a group's search activities. We describe an evaluation of CoSense, reflecting on how its features supported different aspects of sensemaking, and how future collaborative search systems can benefit from these findings.

Author Keywords
Collaborative search, sensemaking, trajectories, awareness.

ACM Classification Keywords
H5.3. Information interfaces and presentation: Group and organizational interfaces – computer-supported cooperative work.

INTRODUCTION
The term "sensemaking" has been used in various fields such as organizational science [22], education and learning sciences [18], communications [4], military command and control [9], human-computer interaction (HCI) [16], and information systems [17]. Broadly speaking, sensemaking is *finding meaning* in a situation. In HCI, sensemaking refers to the cognitive act of understanding information [24]. Today, with the Web emerging as the main research tool in professional and personal life, we are constantly required to make sense of vast amounts of information. We engage in sensemaking when we look up reviews on the Internet before buying a digital camera, or when we are preparing a presentation for management on the company's quarterly sales. Thus, sensemaking is an important activity in our information-rich lives. One of the important problems facing HCI research today is the design of computer interfaces to enable us to make sense of the vast amounts of information we encounter every day [24].

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Figure 1. CoSense offers a variety of views of collaborative search data to enhance sensemaking. One such view, the interactive query history timeline (above), provides insight into how users' keyword choices are influenced by vocabulary and queries from other group members.

Not only is sensemaking important for individuals, but groups collaborating on information-intensive tasks are often required to make sense of information to achieve shared goals. However, most of the current research on sensemaking has been at the individual level, with little understanding of how sensemaking occurs in groups. As a result, most tools developed to support sensemaking have been aimed at enabling individual users to make sense of complex information spaces. Such tools have been focused on providing better information representation [15], visualization [8], and organization of search results [2] for individual users. These tools are not designed to support the collaboration and communication that occurs between people when they make sense of information together.

We studied collaborative sensemaking within the domain of collaborative Web search. There are many scenarios where groups collaboratively search the Web to find information – for instance, school students jointly writing a report go online to conduct research [1]. Several tools (*i.e.*, [1, 6, 12, 14]) have recently been developed to support such

collaborative search tasks. However, it is not clear whether these tools support group members' sensemaking. To understand the sensemaking challenges of collaborative Web search tasks, we conducted a formative study of users performing collaborative Web search using SearchTogether [12], a free browser plug-in available from http://research.microsoft.com/searchtogether. From the findings of our study, we derived design requirements for features that would help users make better sense of the information found using such collaborative search tools. We then built CoSense, a tool for collaborative sensemaking. CoSense takes information about group members' search process and products and provides visualization and contextualization of that information to enhance sensemaking. We then conducted an evaluation where we observed participants using CoSense.

In this paper, we present the findings of our formative study, the resulting CoSense tool, and the outcome of our evaluation of CoSense. We present findings about how sensemaking takes place in collaborative information seeking tasks and which features of CoSense were most beneficial to users for understanding information during different phases of such tasks.

BACKGROUND

The term "sensemaking" has been used in a variety of fields and has been mostly examined for single-user tasks. In communications and information science, sensemaking is broadly 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 "Sense-making" [4]. 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 education literature, sensemaking has been explored in the context of how it applies to teaching and learning [5], and in online communities [20]. In this context, sensemaking refers to how students derive meanings about their learning experiences and how they identify particular ideas as important [5]. Weick [22], has explored sensemaking in the context of organizations. According to Weick, 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. In HCI, sensemaking has focused on how users understand complex information spaces [16]. When interacting with large amounts of information, people create representations to organize information in order to make sense of it. Sensemaking is the process of encoding information into external representations to answer complex, task-specific questions.

Sensemaking Support Tools

Tools for supporting sensemaking in information seeking tasks have been focused on individual users. Sensemaker [2] was designed to support information exploration 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 lets users bundle returned search results into topics of interest and search within these topics. Entity Workspace [3] is a tool that 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 automatic highlighting of important terms, note-taking with an electronic notebook, importing text from documents, adding comments, and organizing information.

The Sensemaking-Supporting Information Gathering (SSIG) [15] system, provides tree structures to represent information found during Web search. 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 [8] was developed as an extension to the standard browser interface to assist users in making sense of information found on the Web. It helps capture both user-generated content and user-created insight. ScratchPad defines an algorithm for calculating and conveying the relevance of previously captured information to a user's current browsing behavior.

Few tools have been developed to support sensemaking in groups. EWall [10], a visual analytics environment, was developed to support remote-collaborative sense-making activities. It enables individual users to navigate shared information and helps remote team members combine their contributions. A computational agent infers possible relationships among collaborators' information items.

Collaborative Web Search

There are many situations in which small groups of users (*i.e.*, colleagues, family, or friends) collaborate on Web search tasks, such as researching group projects or reports, arranging joint travel, or planning shared entertainment opportunities [11]. Although most search tools are designed for individual use, several collaborative search tools have recently been proposed by the research community [7]. While these tools vary in their details, they tend to offer two classes of support proposed by Morris & Horvitz [12]: *awareness* features (*e.g.*, sharing of group members' query histories, browsing histories, and/or comments on results) and *division of labor* features (*e.g.,* chat systems, the ability to manually divide search results or URLs among group members, and/or algorithmic techniques for modifying group members' search results based on others' actions).

For example, CoSearch [1] supports group awareness through use of a specialized browser containing features such as a "query queue" and the ability to associate notes with individual Web pages, and supports division of labor by enabling group members to download distinct subsets of search results to their individual mobile phones. SearchTogether [12] supports awareness through group

query histories and a group "summary" displaying group members' comments and ratings of web pages, and it supports division of labor through chat and split result lists.

Collaborative search tools are relatively novel and thus not widely available. We used SearchTogether, which is publicly available as a free browser plug-in, to study the challenges of sensemaking in collaborative search. Although our study uses SearchTogether as a jumping-off point, descriptions of other collaborative search tools in the research literature (*e.g.*, [1, 6, 12, 14]) indicate that the level of sensemaking support in SearchTogether is representative of (or better than) the status quo for such systems.

FORMATIVE STUDY

We first examined if and how collaborative Web search tools like SearchTogether support sensemaking. The goals of our formative study were to understand 1) how SearchTogether currently supports sensemaking during collaborative search tasks, and 2) what additional features can enhance support for collaborative sensemaking. Some questions we were interested in answering through our formative study were:

- How do group members collaborating on a Web search make sense of the information found by others, the group's task strategies, and the task state?
- How do group members share the *process* and *products* of their sensemaking during a collaborative search task?

Participants and Task

We recruited six, three-member groups to perform a collaborative Web search task. Participants were members of our organization who volunteered in groups (*i.e.*, group members were all acquainted with each other). Participants were proficient with basic Web search, but had not used collaborative search tools.

The task for each group was to plan a weekend of activities to explore the local metropolitan area and to come up with a joint plan for the weekend, since travel planning is a realistic collaborative search activity [11]. The task rules stipulated that group members could only "spend" $50 per person, and that of all the activities chosen for the weekend, one had to be an arts or cultural activity, the other an outdoor activity, and the third a dining activity. Group members were free to choose any other activities in addition to these three. Each group member was provided with a computer connected to the Internet with SearchTogether installed. They were free to use other standard software like the Microsoft Office suite as well as pen and paper. Before they started the task, all participants were given a tutorial of SearchTogether's features.

The studies were conducted in two phases. In phase 1, two members of each group were online simultaneously (but in different physical locations) and worked on the search task for 20 minutes. Then, in phase 2, the third group member went online and continued the task for an additional 20 minutes. All of the query terms, comments, and chat from phase 1 were made available in phase 2 via SearchTogether's asynchronous collaboration features [12]. This two-phase study design gave us a chance to observe sensemaking not only during synchronous collaboration but also during handoff of the sensemaking when collaboration was asynchronous.

Participants were asked to "think aloud" during the task and tell the researchers about any issues or problems they faced. We observed the participants' search strategies, usage of the tool, and creation of any electronic and non-electronic artifacts during the search. Also, we audio- and video-recorded the sessions, and SearchTogether automatically saved all the information found by participants during the task. Finally, we conducted semi-structured interviews with participants after they had completed the task.

We analyzed the data using a grounded theory [21] approach and looked for themes related to how group members understood the information (*e.g.,* websites) found during the task as well as information related to division of labor, group members' task strategies, and task state.

Findings

The formative study revealed several themes regarding the sensemaking challenges of collaborative Web search.

Awareness

Although SearchTogether was designed to provide awareness of others' search activities [12], 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*.

Participants 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.

Temporality and Sensemaking Trajectories

The temporality of the search process was important for participants' sensemaking. Many participants wanted to see a unified chronological ordering of all events in the search process. 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.

Sensemaking Handoff

Persistence of both the process and products of sensemaking was deemed to be important during the collaborative search task. With respect to the sensemaking process, participants wanted to understand *how* others had found information, and their motivations behind viewing and recommending web pages. Phase 2 participants 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 sense that was made. For instance, they wanted to make 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."

From the findings of our study it was clear that while SearchTogether helped collaborators to jointly search the Web, it did not adequately support sensemaking. Based on our findings, we designed the CoSense prototype.

COSENSE

In designing CoSense, we chose to include several alternative representations of information, in order to address the many sensemaking challenges faced by participants in our formative study – CoSense includes features to support action and context awareness, understanding temporal relationships and trajectories, and enabling sensemaking handoffs. We chose to implement design elements that would maintain consistency with the way information is already presented in SearchTogether.

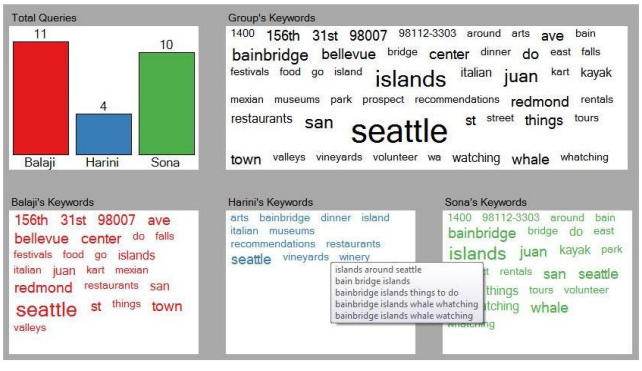

Figure 2. The search strategies view provides an overview of how many queries each group member executed, as well as displaying tag clouds of the group's and individuals' keywords. Hovering over a keyword ("islands" in this example) reveals the list of queries using that term.

CoSense can be used to support synchronous or asynchronous sensemaking. When a user logs into CoSense, that user's data from SearchTogether (*e.g.*, query terms, urls, chat, and comments) are exported to a database, from where they are read and processed by CoSense. Additional data generated through the use of CoSense is also written to this database. Use of this networked database architecture permits CoSense to update its views in real time in response to new data from any instances of SearchTogether and/or CoSense (*i.e.*, changes made by group members are reflected by CoSense in real time).

CoSense consists of four views—the search strategies view, timeline view, chat-centric view, and workspace view—each of which provides a different representation of information about a given search session. In the following sub-sections, we describe each of these views in detail.

Search Strategies View

The search strategies view provides information about roles and skills of group members. It provides aggregate data about the group's search process as well as the search process of individual group members, in order to facilitate

Figure 3. The search strategies view also provides an overview of how many web pages each group member has viewed, and shows interactive tag clouds of the domains visited by the group and each member. Hovering over a domain ("sanjuansafaris.com" in this example) reveals the URLs visited within that site, and clicking a domain in a tag cloud will open all visited sites in separate browser tabs.

our design goals of supporting action awareness, clarifying sensemaking trajectories, and enabling sensemaking handoffs. Visualizations from the search strategies view can be seen in Figures 1, 2, and 3 (this view's contents were divided among several figures to increase legibility).

The search strategies view contains two graphs – one for the total number of URLs visited by each group member in the search session and the other for the total number of queries issued by each group member. These graphs provide an approximation of the level of involvement of each group member in the task, and of each member's balance of search vs. browsing activity.

The query history (Figure 2) and browsing history (Figure 3) of group members are also represented via interactive tag clouds. There are tag clouds of the websites the group visited as well as tag clouds for websites individual group members visited, with the size of each domain name proportional to the number of visits. Similarly, there are tag clouds of the query keywords for the group as a whole, as well as for individual members; keywords used in a large number of queries appear more prominently within the clouds. These tag clouds offer an at-a-glance impression of which websites and keywords were associated with the overall task and with each group member.

The tag clouds are interactive in that hovering over a site name in the web sites tag cloud provides a tooltip displaying all the URLs of that website that were visited by group members. Clicking on the site name opens all the URLs in separate tabs of the current browser window. Similarly, hovering over the terms in the keywords tag clouds shows all queries having those keywords. Clicking on a keyword issues all the queries having that keyword and opens the results in separate browser tabs.

The search strategies view also has a "query history timeline" (Figure 1), which shows color-coded, interleaved timelines of each group member's query history. This timeline is intended to make group members' *query evolution trajectories* more apparent, by showing not only how queries evolved over time (as in a per-user query history), but also how they evolved across group members (by allowing side-by-side, temporally aligned comparisons). The search strategies view also contains an option to display "advanced graphs". Choosing this option reveals additional visualizations inspired by information retrieval literature on techniques that distinguish expert and novice searchers [23], such as the average number of words per query for each group member, the advanced operators used by each group member, and the average time between queries issued by each group member.

Timeline View

The timeline view provides an integrated chronological representation of the actions of all group members during the entire search session. This view aims to support our design goals of improved context awareness and understanding temporality and trajectories.

The timeline view has two regions. The left region (Figure 4) shows a timeline of all group members' queries, web pages visited, comments associated with web pages, and chat. Color-coding reflects which user issued a query or visited a URL, and group members' photos appear adjacent to the comments and chat messages they authored. The timeline is interactive, and its content can be filtered by type (queries, web pages, comments, chat), as well as by user. Clicking a query node in the timeline re-issues that query in the user's preferred search engine and displays the results in a new browser tab. Clicking a web page node in the timeline provides additional context about that page, in addition to opening the associated URL in a browser. A "preview" of the web page appears in the rightmost region of the timeline view. The preview shows a thumbnail of the web page, a list of group members who visited that web

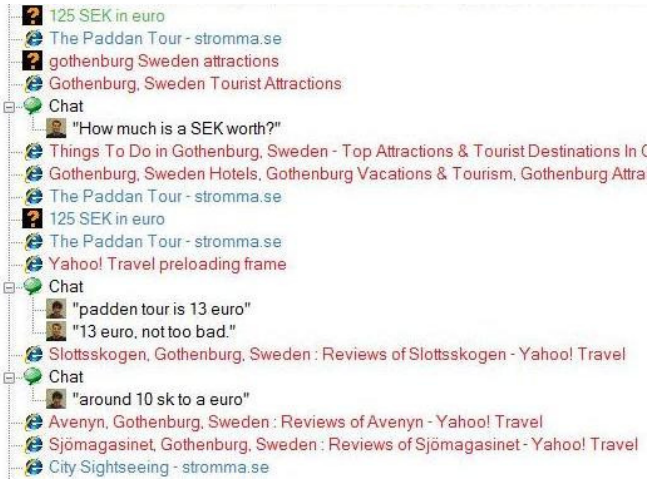

Figure 4. The timeline view provides a unified, chronological depiction of all queries executed, web pages visited, page comments, and chat messages, color-coded according to user. The timeline can be filtered to show only certain activities or certain users' actions.

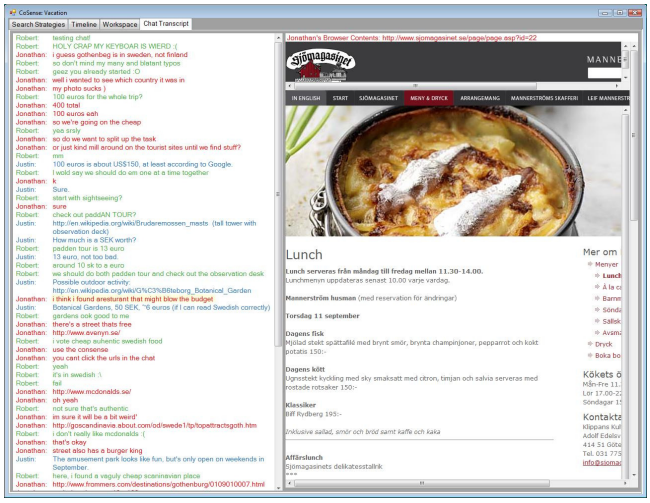

Figure 5. The chat-centric view shows the group's color-coded chat conversation (left). Clicking any chat message shows the webpage that message's author was viewing at the time that message was sent (right).

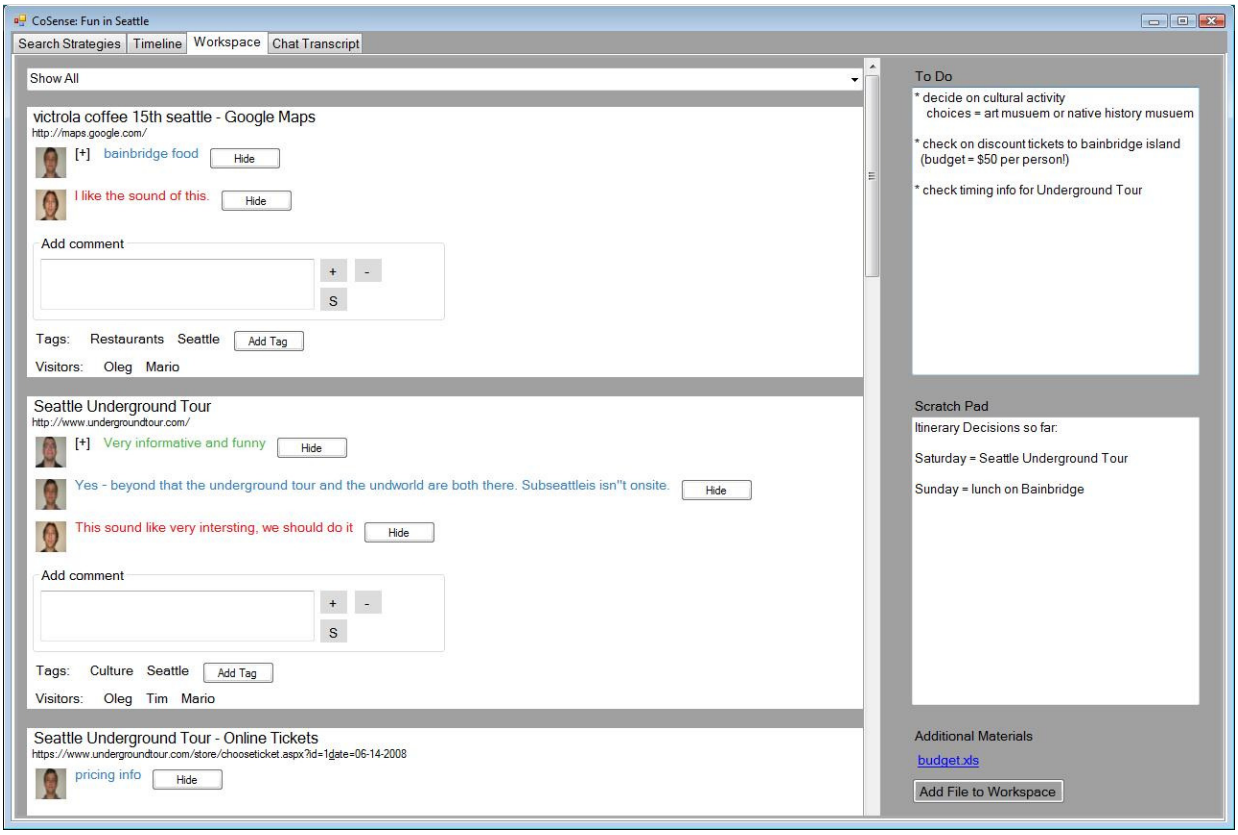

Figure 6. The workspace view depicts a list of "summary items", *i.e.*, webpages that have been commented on by group members. Each summary item shows the page title and url, associated comments, which group members have viewed the page, and any tags that have been applied. These tags can be used to filter the view. The right-hand portion of the workspace provides "to do" and "scratchpad" areas, as well as links to external documents associated with the task.

page, the chat associated with that web page (*i.e.*, the chat that took place within two minutes before and after that web page was viewed), and comments and ratings associated with that web page. The preview also allows users to add additional comments to the current web page.

Chat-Centric View

The chat-centric view (Figure 5) aims to facilitate context awareness by showing the connections between group members' instant message conversations and their search process. It shows the group's chronologically-ordered chat transcript (imported from SearchTogether), color-coded by user. Clicking on a chat item displays the web page that was active in the browser of the group member who authored that chat message, at the time the message was sent.

Workspace View

The workspace provides a place for explicitly storing the products of sensemaking by imposing structure on collections of links and comments, creating to-do lists, and noting decisions (Figure 6). The workspace aims to support our design goals of enabling persistence of the products of sensemaking and facilitating sensemaking handoff.

Associating comments with specific web pages, such as in collaborative search systems like CoSearch [1] and SearchTogether [12], facilitates these design goals to a small degree. However, our formative study found that page-level comments were not adequate for representing evolving sense, and that sensemaking handoff was still quite challenging for our participants. CoSense's workspace thus uses page-level comments as a jumping-off point for supporting richer sensemaking features.

The left portion of the workspace view displays summaries of web pages that group members have commented on. Each summary contains the title of the web page, a hyperlink to the associated URL, comments and ratings associated with that page, and a button to add additional comments or ratings. Also, each summary provides action awareness by showing which group members have viewed that web page (even if they have not commented on it). Users can assign tags to the web page in each summary item; tags associated with a page are then displayed as part of the summary. These tags provide a means of organizing the workspace—a menu allows the workspace to be filtered by tag, in order to display only a subset of the summary items. Individual comments can also be hidden from view, in order to reflect changed opinions that come about with evolving sense.

The right portion of the workspace provides two areas for taking free-form notes. These areas are labeled "scratchpad" and "to do" and provide basic text editing functionality. This area of the workspace also provides a

button for adding digital artifacts to the search session. External files such as text documents, photos, spreadsheets, or emails can be associated with the workspace, and are represented in a list of hyperlinks. Files added to the workspace are copied to a shared network location to facilitate access by group members running copies of CoSense on different computers.

EVALUATION

We conducted a study to evaluate whether CoSense enhanced sensemaking during collaborative Web search. We were specifically interested in evaluating how well CoSense helped the handoff of sensemaking between group members who searched asynchronously, since this was the most challenging sensemaking scenario uncovered by our formative study. We were also interested in understanding which features of CoSense were most valuable to the sensemaking process, and in what ways the tool could be further improved.

We decided that an observational study of CoSense's use, rather than a formal comparative experiment, would enable us to answer these questions. A comparative experiment seemed inappropriate, for lack of other collaborative sensemaking tools to compare against. Similarly, comparing against collaborative search tools such as SearchTogether seemed unnecessary as our formative study had already revealed that tool's shortcomings with respect to supporting collaborative sensemaking.

Study Design

We recruited 18 participants from our organization. Participants were in the age range 20-60 years, and their expertise in Web search ranged from "average" to "expert," with a majority reporting "above average" expertise. Participants had not used collaborative search tools before.

Evaluation tasks used in the sensemaking literature include problem solving [19], topic comprehension [3], understanding large document collections [16], and information retrieval tasks such as shopping for products online [19]. We chose a collaborative information retrieval task which was designed to require handoff. To maintain consistency with our formative study, our evaluation task scenario involved vacation planning. As in our formative study, this study comprised two phases. An observer took notes during all sessions, and all interactions with CoSense were automatically logged.

Phase 1 entailed having two groups (group A and group B, having three members each), synchronously conduct a collaborative Web search to plan their vacation itinerary per budget and activity constraints analogous to those in the formative study. Participants were told that a fourth group member would be joining them on the trip, and would log in at a later point in time to complete any unfinished itinerary planning. Group members were located in separate rooms, and each had access to a computer running both SearchTogether and CoSense. After a brief tutorial on those two tools, groups worked on their search task for 20 minutes. Participants then completed an online questionnaire containing questions that probed the extent of their sensemaking. To increase task variety, group A and group B performed the same task but with different vacation destinations.

Phase 2 entailed having the remaining twelve participants play the role of the fourth group member, who, after tutorials on SearchTogether and CoSense, asynchronously logged in to the search sessions started by groups in phase 1. Phase 2 participants' job was to complete the vacation planning task (half of the participants continued group A's session and the other half used group B's). After 20 minutes, participants completed the online questionnaire regarding the extent of their sensemaking, followed by a semi-structured interview to elicit feedback about the handoff experience and about the CoSense prototype.

FINDINGS

The results of our evaluation show that CoSense enhanced sensemaking during collaborative search, as compared to the sensemaking challenges noted during our formative study. The different views in CoSense supported different modes of search (asynchronous vs. synchronous), different stages of the search (initial search vs. handoff), and different sensemaking styles which varied across individuals. In this section we present our findings in detail.

CoSense Feature Use

Participants made use of CoSense's features both during the main vacation-planning task, as well as in answering the "sensemaking measurement" questions at the end of the study. Here, we describe which features were most relied upon for these different activities.

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, 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.

Questionnaire

Across both phases of the study, time-stamped logs created while participants completed the post-task online questionnaire enabled us to analyze 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 Robert 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 felt that the tag cloud of each group member's query keywords reflected 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 used most frequently; frequency of use did not necessarily indicate that these websites were more useful. Some participants (28%) realized this and used the timeline to view the chronological ordering of everything done during the session in relation to websites group members had viewed. The more comments and chat associated with a website, the more useful it was judged.

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 by 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.

Sensemaking Handoff

Through semi-structured interviews, we tried to understand how phase 2 participants had tackled the challenge of resuming a task that had been "handed off" to them, and which features of CoSense had helped them in this respect.

In resuming the search task, phase 2 participants reported that they predominantly used the views provided by CoSense, rather than SearchTogether. Participants reported using the search strategies view for an at-a-glance overview of the queries issued and websites visited by other group members. One of the participants said that when he started the search, he found the search strategies view useful because "the tag clouds and statistics on how many queries had been done, what were the group's sites, and what is their popularity, helped me immensely…I was able to plan it [my search] better using the websites and keywords." The chronological flow of events in the timeline was important for people to understand not only the history of the previous search but also where to pick up the task. One participant said "I looked at the timeline and at what were the final things that people were searching on." Another participant said, "The flow of the search was hard to tell [by looking at SearchTogether]. The timeline in CoSense helped because of the information about order of queries. I identified what had already been done."

We asked phase 2 participants how they understood what group members had already done in phase 1. We found participants had two approaches to understanding what had happened before. One approach, taken by 6 out of 12 participants, was to dig into the details of what had happened in phase 1 so as to get the whole picture of the search history before starting their own search. Participants who had this approach said that they found the chat-centric view and the timeline most useful. In the timeline, participants liked being able to filter content to understand

the nuances of the search process. One of the participants said, "I liked the integration of chat and web pages in the timeline. The chat was hard to follow in SearchTogether. The timeline was helpful because filtering content gave context to queries. It was good to see the flow of things." Another participant mentioned that he liked the ability to filter the timeline based on user. However, some participants found the chat transcript and the timeline had too much detail to follow. A disadvantage they found to the timeline was that it captured everything that happened and there was no way of telling the "good" content from the "bad" content. An alternate approach to understanding what group members had found, taken by the remaining 6 participants, was to look at high level information instead of getting bogged down with the details. Such participants mostly looked at the workspace. The summary items in the workspace gave a high level overview of the kinds of activities the group members had been interested in pursuing on the vacation.

DISCUSSION

Overall, our evaluation found that using CoSense helped participants understand the collaborative search process and avoid many of the challenges encountered during our formative study. CoSense particularly helped participants hand off their sensemaking to asynchronous collaborators. Observing participants use CoSense provided insight into how sensemaking takes place in collaborative search tasks and what kinds of features can support this process.

Participants' tendency to use different views offered by CoSense during the two phases of the study indicates that the representations useful for sensemaking may differ during synchronous and asynchronous collaboration.

During synchronous search, group members looked at each others' search strategies to understand division of labor and refine their own task strategy. Also, as they chatted, group members frequently needed to contextualize the chat with respect to the rest of the search process and hence used the chat-centric view to open web pages associated with chat messages. Since this was the initial part of the collaborative search, group members were concerned with making sense of *how* information was being found.

During asynchronous search, group members wanted to know *what* information had already been found so they could do the remaining parts of the task. The workspace view offered a useful way to see what the important web pages were and what the group's decisions and to-do items were. The timeline view provided another valuable way to explore web pages found by the group.

Some of our findings were contrary to our expectations. For instance, in answering the question about which aspect of the task each group member worked on (Q3), we expected the search strategies view to be used most, but more often participants used the workspace view. Another example is that, in figuring out which websites the group found most useful for the task (Q4), we expected participants to use the workspace view to see websites that had been commented on; although some participants did so, it was more common for them to check indications of visitation frequency in the tag clouds of the search strategies view. These examples suggest there is benefit in offering multiple representations of the same information, since people's sensemaking strategies may vary with individual styles, collaboration modes, and task types.

Our formative study had found that SearchTogether users wanted better support for awareness, visibility of temporality and sensemaking trajectories, and sensemaking handoff. CoSense was designed to facilitate awareness though the search strategies view, the visitation information in the timeline and workspace views, and the chat-centric method of accessing page history. The unified timeline was designed to make temporal trajectories clearer, and the organizational and note-taking affordances of the workspace view were designed to facilitate sensemaking handoff. Our initial evaluation suggests that these designs were successful, and that the redundancy of functionality offered by some views proved beneficial in accommodating different sensemaking approaches.

Our findings provide important implications for the design of collaborative search tools. As our formative study demonstrated, offering collaborative search tools is a good, but not sufficient, step toward supporting group information seeking. Sensemaking is an integral part of the information seeking process; for groups, this sensemaking encompasses both the need to make sense of found information as well as the need to make sense of the collaboration process, such as group members' roles and task state. This sensemaking support becomes particularly important for asynchronous collaborative search tasks, when handoff poses an extra sensemaking challenge. Integrating rich data representations to support action- and context-awareness, temporality and trajectories, and handoff can enhance collaborative search tools. Tools aimed at synchronous collaboration scenarios may want to consider integrating features such as those found in CoSense's search strategies and chat-centric views, while those focused on asynchronous scenarios should especially consider features from CoSense's timeline and workspace views. Including a variety of data representations can help collaborative search tools better support the integration of the intrinsically related search and sensemaking cycles.

Note that additional sensemaking support, beyond what is offered by CoSense, may be needed for collaborative search tools that rely on algorithmic mediation to distribute content among group members, such as Cerchiamo [14], iSpy [6], and groupization-based systems [13], since it is likely that additional sensemaking support may be necessary to help users understand the underlying algorithms and their consequences. The question of how algorithmic mediation impacts users' ability to make sense of the collaborative search process is left to future work.

CONCLUSION

In summary, this paper contributes to our understanding of sensemaking in collaborative Web search in three ways:

1. Our formative study provided insight into the sensemaking challenges faced during collaborative Web search tasks.

2. Our new tool, CoSense, introduced several interactive views of information designed to support sensemaking of both the process and products of collaborative search tasks.

3. Our evaluation of CoSense showed that it enabled group members to understand the strategies, roles, and contributions of group members in a collaborative search task. Our analysis indicated that different types of features were used to support sensemaking during synchronous and asynchronous collaborations.

One of the challenges of developing collaborative Web search tools has been the lack of models of collaborative information seeking behavior. Such models can be built either through field observations or through the design of tools like CoSense. Logging users' behavior within CoSense helped us understand the complex intertwining of sensemaking and information seeking during collaborative Web search. In future work, we intend to further analyze the data about CoSense feature use to develop models of users' behavior, which in turn can help us provide recommendations for improving tools like SearchTogether.

Designing interfaces to facilitate sensemaking remains a challenging problem in HCI. Tools like CoSense can help provide insight into the nature of sensemaking, and these insights can be applied to the design of tools in a variety of domains where collaborative sensemaking takes place, such as hospitals, libraries, and classrooms.

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