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Sensemaking in Collaborative Web Search

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RUNNING HEAD: SENSEMAKING IN COLLABORATIVE WEB SEARCH

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ABSTRACT

Sensemaking is an important aspect of information seeking tasks but has mostly been studied at the individual level. We conducted a study of sensemaking in collaborative Web search using SearchTogether and found that collaborators face several challenges in making sense of information during collaborative search tasks. We built and evaluated a new tool, CoSense, which enhanced sensemaking in SearchTogether. The evaluation of CoSense provided insights into how collaborative sensemaking differed from individual sensemaking in terms of the different kinds of information that collaborators needed to make sense of. In this paper we discuss findings about how sensemaking occurs in synchronous and asynchronous collaboration, and the challenges participants face in handling handoffs. We found that participants had two different strategies of handling handoffs – search-lead and sensemaking-lead, and that participants with these two strategies exhibited different procedural knowledge of sensemaking. We also discuss how complex and varied the products of sensemaking are during a collaborative search task. Through our evaluation of CoSense we provide insights into the design of tools that can enhance sensemaking in collaborative search tasks.

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1. INTRODUCTION

Recently there has been growing evidence that people collaborate on Web search tasks in both their personal and professional lives (Morris, 2008). For instance family members might collaboratively search automobile websites to look for information before buying a new car, or healthcare providers in a hospital might search online medical databases to find the best drug to prescribe to a patient. A few tools have been developed to support such collaborative search tasks (Amershi & Morris, 2008; Freyne & Smyth, 2006; Morris & Horvitz, 2007; Pickens, Golovchinsky, Shah, Qvarfordt, & Back, 2008). However, researchers still do not have a clear understanding of users' behavior during collaborative Web search. Such an understanding is essential for building effective collaborative Web search tools and can help us answer questions like:

- What do people do when they collaboratively search for information on the Web?
- How are search, retrieval, sensemaking, and use of information intertwined in collaborative Web search?
- How do people interact with a shared search space and with each other when involved in a collaborative Web search task?

Our current research focus is on understanding how sensemaking occurs during collaborative Web search. Sensemaking has been studied in a variety of disciplines (Dervin, 2003; Jacobson, 1991; Jensen, 2007; Klein, Moon, & Hoffman, 2006a; Russell, Stefik, Pirolli, & Card, 1993; Sarmiento & Stahl, 2006; Schoenfeld, 1992; Weick, 1995) but the problem of understanding and supporting sensemaking via technology remains a challenging and important one in the field of human-computer interaction (HCI) (Whittaker, 2008). Sensemaking is specifically important in information seeking tasks (Dervin, Foreman-Wernet, & Lauterbach, 2003; Russell, Stefik, Pirolli, & Card, 1993; Savolainen, 1993), and has frequently been modeled as a part of the information seeking process. However, most of the models and theories of sensemaking in information seeking have been described at the *individual* level. There has been little empirical exploration of how sensemaking takes place in collaborative information seeking, specifically in collaborative Web search, which is a new and emerging area.

Our research addresses the question “How do users make sense of the information found during collaborative Web search tasks?” To investigate this, we conducted a formative study of users' sensemaking during collaborative Web search tasks using SearchTogether (Morris & Horvitz, 2007). We found that though SearchTogether helps users collaboratively search for information, it does not adequately support their sensemaking. Based on the findings of our formative study, we built a tool called CoSense to enhance sensemaking in SearchTogether. We evaluated CoSense and found that it significantly enhanced sensemaking during collaborative search tasks. We reported on the formative study, design of CoSense, and the results from our evaluation study in (Paul & Morris, 2009). Here, we dig deeper into CoSense users' search and sensemaking behavior and provide insights into how sensemaking takes place during collaborative Web search tasks. We specifically focus on understanding how collaborative sensemaking differs from individual sensemaking, how sensemaking styles differ during collaborative search tasks, and how sensemaking differs during synchronous and asynchronous

collaborative search. Drawing on this understanding, we provide implications for designing features that support sensemaking in collaborative Web search tools.

The following section highlights the collaborative Web search and sensemaking literatures and emphasizes gaps in our understanding of sensemaking within the context of collaborative Web search. We next present our study methods, a short description of CoSense, and findings from our evaluation of CoSense. We then discuss our findings and the implications of our findings for the design of tools that can support sensemaking in collaborative Web search tools. Lastly, we conclude with ideas for future work in this area.

2. BACKGROUND

For years, information seeking models and theories focused on the individual information seeker. However, in recent years, researchers have found that people collaborate during information seeking tasks (Hansen & Jarvelin, 2005; Reddy & Spence, 2008; Reddy & Jansen, 2007; Twidale, Nichols, & Paice, 1997). Collaborative information seeking has broadly been defined as “activities that a group or team of people undertakes to identify and resolve a shared information need” (Pollock, Dumais, Fidel, Bruce, & Pejtersen, 2003). While resolving a shared information need can encompass a range of activities, most studies of collaborative information seeking have focused on how people *find* and *retrieve* information collaboratively, while overlooking the important question of how people *assimilate* and *synthesize* the information found in order to create a shared understanding. This creation of a shared understanding of information is challenging in collaborative contexts because information is often distributed unevenly among actors who might derive different meanings of the information known to them (Hertzum, 2008).

Field studies of information seeking practices in organizations have found that people often share not only information, but also their understanding of the information. For instance, Harper and Sellen (1995) studied the information seeking activities of workers at the International Monetary Fund and found that social interaction during information seeking is “not as important to the sharing of *objective* information as it is to the sharing of *interpreted* information”. Hansen and Jarvelin (2005) conducted a study of collaborative information seeking in Swedish patent work and found that in addition to sharing information, patent engineers shared working notes, annotations, representations of their information needs, decisions, and subjective opinions. (Hertzum, 2008) emphasized the importance of *collaborative grounding* in collaborative information seeking activities. Collaborative grounding is “the active construction by actors of a shared understanding that assimilates and reflects available information”. Thus, studies of collaborative information seeking have found that an important aspect of this activity is creating a shared understanding of information, i.e. collaborative sensemaking. However, these studies did not explore in detail how this collaborative sensemaking takes place.

2.1. Collaborative Web Search

Since Web search is an area of information seeking which has primarily focused on individuals, most Web search tools, like browsers and search engines, are designed for individual users. However, recently there has been growing evidence that people collaboratively search the Web, both implicitly and explicitly. In a survey of 204 knowledge workers, Morris (Morris,

2008) found that over half of the respondents had cooperatively searched the Web with others for activities ranging from travel planning to looking for medical information. Survey respondents reported collaborating on the search process both synchronously (e.g. watching over someone's shoulder as they searched) as well as asynchronously (e.g. emailing collaborators links to information pertinent to a joint task). Evans and Chi (2008) surveyed 150 people about their experiences with searching for information in their personal and professional lives and found that people frequently interacted with others before, during, and after a search activity.

Collaboration during Web search can be classified along three dimensions – intent, concurrency, and location (Golovchinsky, Pickens, & Back, 2008). In terms of intent, collaborative Web search can be implicit or explicit. Implicit collaboration encompasses collaborative recommendation and filtering systems, such as Amazon.com, in which the behavior of people searching for particular content is used to inform the search results of others searching for similar content. Explicit collaboration, on the other hand, occurs when people form task-based groups (Morris & Teevan, 2008) to search for information for completing a joint task, such as travel planning. Additionally, collaboration in Web search tasks can be synchronous or asynchronous, and co-located or distributed.

Collaborative Web Search Behavior

Most extant studies of Web search behavior have focused on individual searchers (Chi, Pirolli, Chen, & Pitkow, 2001; Granka, Joachims, & Gay, 2004; White & Morris, 2007). Such studies have examined how interaction styles and queries differ between users (White & Drucker, 2007) and how the use of different kinds of query syntax affects navigation behavior and search success (White & Morris, 2007). Few of these studies have empirically examined sensemaking within search. Information foraging theory (Pirolli & Card, 1999) explains individual information seeking and sensemaking behavior in Web search; users forage for information by navigating from page to page along Web links. The content of pages that a user navigates is represented by snippets of texts or graphics called *proximal cues*. Foragers use these proximal cues to assess the *distal content*, which is the Web page at the end of the search.

Since collaborative Web search is a new area, very few studies have looked at users' behavior during collaborative search. Joho, Hannah, and Jose (2008) conducted a study to compare concurrent and independent search conditions in terms of the strategies used by searchers and the effectiveness of the search process. They designed experiments where participants' goal was to find as many relevant documents as possible for a given topic. Participants performed the task independently and collaboratively using a search interface that allowed communication. The researchers found that there was a lot of redundancy in documents marked relevant by team members in the independent condition. They also found that the size of the search vocabulary diversified in the collaborative condition as compared to the independent condition. However, the improvements in vocabulary and decrease in redundancy did not lead to more efficient retrieval of documents in the collaborative condition. This study provides important insights into how collaborators understand the information found by others during collaborative search and highlights that there is still much to learn about collaborative search behavior.

2.2. Sensemaking

While sensemaking has not been studied much in collaborative information seeking, it has been studied in various other fields such as organizational science (Weick, 1995), communications (Dervin, 2003), military command and control (Jensen, 2007; Ntuen, Munya, & Trevino, 2006), education (Schoenfeld, 1992), and HCI (Russell, Stefik, Pirolli, & Card, 1993), and information systems (Bansler & Havn, 2006; Griffith, 1999). The common thread in these studies has been that sensemaking is about *meaning generation* and *understanding*. Most studies of sensemaking have been at the individual level, with a few field studies in recent years exploring sensemaking in collaborative work.

Individual Sensemaking

At the individual level, sensemaking is concerned with how a person understands a situation in a given context. For instance, Dervin's "Sense-making" (Dervin, 2003; Dervin, Foreman-Wernet, & Lauterbach, 2003) occurs when a person, embedded in a particular context and moving through time-space, experiences a "gap" in reality. The person facing this gap constructs bridges consisting of ideas, thoughts, emotions, feelings, and memories. While having a rich tradition of use in communication and information science studies, (Dervin, 2003; Dervin & Clark, 1987), the Sense-making methodology is limited by its focus on individual rather than collective sensemaking and is inadequate for explaining group and organizational sensemaking (Tidline, 2005).

In HCI, sensemaking research has been guided by Russell, Stefik, Pirolli, and Card's (1993) model of sensemaking, which is focused on the context of understanding large document collections. Sensemaking is modeled as cyclic processes of searching for external representations and encoding information into these representations to reduce the cost of tasks to be performed. However, Russell et al. (1993) focus on the activities that constitute individual sensemaking and do not explore how interactions between sensemakers might affect the sensemaking process. Klein, Moon, and Hoffman (2006b) have proposed the data/frame model of sensemaking. This model suggests that when people try to make sense of events, they begin with some perspective or *frame*. Frames shape and define data that is considered for sensemaking and the data itself changes the frame. Sensemaking involves elaborating a frame, questioning the frame as data is discovered, and changing the frame. The data/frame model is similar to Russell et al.'s (1993) model, in that both view individual sensemaking as the iterative process of organizing data into templates and changing templates to fit emerging data. Also, Klein et al.'s model does not consider interactions between people as they fit data into frames, nor does it consider how frames may be changed as a result of such interactions.

Pirolli & Card (2005) describe sensemaking as a process of transformation of information into a knowledge product. This process consists of two loops of activities: a *foraging loop* that involves seeking, filtering, and extracting information into schemas; and a *sensemaking loop* that involves iterative development of a mental model from the schemas that best fit the evidence.

In organizational sciences, Weick (Weick, 1995; Weick & Sutcliffe, 2005) has described sensemaking as what occurs when the current state of the world is perceived to be different from the expected state of the world. Sensemaking is grounded in identity construction, retrospective,

focused on and by extracted cues, ongoing, enactive of sensible environments, and driven by plausibility rather than accuracy. While the majority of Weick's description pertains to how individuals make sense of organizational goals, structure, and roles, he emphasizes that sensemaking is a social process and that communication is a central component of sensemaking.

Sensemaking in Collaborative Work

Though most studies of sensemaking have been about individual sensemaking, some researchers have examined the social nature of sensemaking. Weick (1993) explored group sensemaking in his analysis of the Mann Gulch disaster which led to the deaths of 13 smoke-jumpers in a forest fire. He analyzes the account of that disaster through a sensemaking lens and proposes four potential 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. DeJaegher and Paolo (2007) highlight that individual sensemakers often *coordinate* their sensemaking in social interactions and the patterns of coordination can influence the significance of the situation for individual sensemakers.

Given its social nature, sensemaking is an integral aspect of collaborative work. Some field studies have examined sensemaking in time-critical domains such as military command and control (C2), firefighting, and emergency care. Jensen (2007) studied sensemaking in teams of Army captains planning a brigade order and found that both the quality of information presented to team members and the ability to meet face-to-face failed to affect either plan quality or the sensemaking process. However, the better the quality of the team's sensemaking process, the better were the plans produced. In the medical domain, Albolino, Cook, and O'Connor (2007) conducted an ethnographic study of sensemaking among healthcare providers in the ICU. Two kinds of sensemaking were found to occur – "sensemaking-at-intervals" and "sensemaking on-the-fly". Sensemaking-at-intervals occurred during clinical rounds and its conduct was formalized. In contrast, sensemaking on-the-fly was interspersed with the care process. Other empirical studies of sensemaking have been in the domains of emergency response (Landgren & Nulden, 2007) and firefighting (Dyrks, Deneff, & Ramirez, 2008) where researchers have examined the role of artifacts like mobile phones and maps in making sense of emergent situations.

The studies discussed above have shown the importance of sensemaking in collaborative work domains. However, these studies have only begun to explore the complex and varied process of sensemaking in groups. Furthermore, few studies of group sensemaking have focused on the specific context of collaborative information seeking. Our study addresses these gaps by exploring sensemaking in collaborative Web search.

Supporting Sensemaking in Web Search

Most sensemaking support tools have been designed for individuals searching either large document collections or the Web. For instance, Sensemaker (Baldonado & Winograd, 1997) supports information exploration tasks by enabling users to search multiple, heterogeneous sources of information. Entity Workspace (Billman & Bier, 2007) helps users make sense of large document collections by enabling 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) (Qu, 2003) system supports sensemaking in Web search tasks. The user searches information on the Web and organizes the information gathered into a hierarchical tree structure. ScratchPad (Gotz, 2007), developed as an extension to the standard browser interface, assists users in making sense of information found on the Web. It defines an algorithm for calculating and conveying the relevance of previously captured information to a user's current browsing behavior.

Though not explicitly designed to enhance sensemaking, several tools have been designed to help users organize information found during Web search sessions. Some of these tools, such as WebBook (Card, Robertson, & York, 1996) and Data Mountain (Robertson et al., 1998), have focused on supporting efficient management of bookmarks. Other tools like TopicShop (Amento, Terveen, Hill, & Hix, 2000) help users organize and evaluate collections of Web sites. The Hunter-Gatherer interface (schraefel, Zhu, Modjeska, Wigdor, & Zhao, 2002) helps organization of smaller-than-page-sized information components extracted from Web pages. Some tools have been designed to help users summarize personal Web browsing sessions. Dontcheva, Drucker, Wade, Salesin, and Cohen (2006) designed a system to help users select Web page elements and label them with pre-defined keywords. SearchBar (Morris, Morris, & Venolia, 2008) helps users manage information across multiple Web sessions by storing query histories, browsing histories, and users' notes and ratings in an inter-related fashion.

Though these tools were not explicitly designed to support sensemaking in Web search tasks, their ability to help users select, organize, evaluate, and re-visit information found during Web search makes them important examples for consideration when designing sensemaking support for Web search. However, these tools have all been designed for individuals.

Supporting sensemaking in Collaborative Web Search

Recently researchers have developed collaborative search tools which provide either UI-level (Morris & Horvitz, 2007) or algorithm-level mediation (Freyne & Smyth, 2006) of search results. Tools that mediate at the UI level (e.g. SearchTogether (Morris & Horvitz, 2007), CoSearch (Amershi & Morris, 2008)) provide features such as division of labor and increased awareness to group members so they can coordinate their searches. Tools that mediate at the algorithmic level (e.g. Cerchiamo (Pickens, Golovchinsky, Shah, Qvarfordt, & Bach, 2008)) record and re-use search histories of like-minded users. However, these tools currently have little support for helping users make sense of the information generated during a collaborative Web search task.

Some Web-based tools and websites have been designed to support collaboration around shared information. Many Eyes (Viegas, Wattenberg, Ham, Kriss, & McKeon, 2007) is a website that allows users to upload data, create visualizations of that data, and leave comments on both the visualizations and data sets. While the comments, annotations, and discussions on visualizations helps people make sense of the data together, they do not collaborate on generating the data itself. Other Web 2.0 sites like del.icio.us (www.del.icio.us.com), Mag.nolia

(www.mag.nolia.com), and CiteULike (www.citeulike.com), augment solo search and browsing by facilitating link sharing with friends.

In summary, most sensemaking-support tools have been designed for individuals searching over document collections and the Web. Recently there has been emergence of tools that allow social augmentation of Web search results on search engine sites and some tools are being designed to allow UI-level or algorithmic mediation of search results for collaborative search. However, these tools are still new and we have very little understanding of how they support sensemaking in Web search tasks. We conducted a study of sensemaking in SearchTogether. In the next section we briefly describe SearchTogether, a formative study of sensemaking in SearchTogether and the design of a new tool, CoSense which enhances sensemaking in SearchTogether.

3. METHODS

We began by conducting a formative study of sensemaking within SearchTogether. We wanted to examine how sensemaking is currently supported in SearchTogether and what additional features could enhance the current level of sensemaking support. We believe findings about sensemaking in SearchTogether are generalizable since descriptions of other collaborative search tools in the literature suggest that the level of sensemaking support in SearchTogether is representative of the status quo for such collaborative search systems. Based on the findings of our formative study, we built a new tool, CoSense. Here we provide a short overview of SearchTogether, the design and findings from our formative study, and the design of the tool CoSense to enable readers to contextualize our results and discussion; a more detailed discussion of the formative study and the design of CoSense can be found in (Paul & Morris, 2009).

3.1. SearchTogether

SearchTogether¹ is a publicly available, free plug-in for the Internet Explorer 7 Web browser, whose feature set is based on the system described in (Morris & Horvitz, 2007). There are currently 1,312 registered users². SearchTogether is meant to facilitate synchronous and asynchronous remote collaboration on Web search, among small, task-oriented groups.

Figures 1(a) and 1(b) show the SearchTogether plug-in. In the example depicted, three family members are conducting a joint search to plan a vacation to Disney World. SearchTogether's collaboration features include shared Web browsing support (through the "peek" and "follow" actions), shared awareness of group members' query terms, the ability to "split" a search results page by distributing the results among group members, the ability to associate a rating or comment with a page (which is then visible to the group through the "summary" view, see Figure 1(b)), and integration of chat with the browsing application. All data from a SearchTogether session is automatically saved and stored on a central server, in order to facilitate asynchronous collaboration and re-use of search results over extended periods of time.

¹ For more information about SearchTogether see <http://research.microsoft.com/searchtogether/>

² At the time of writing this article

(Figure 1(a) about here)

(Figure 1(b) about here).

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

3.2. Formative Study of Sensemaking in SearchTogether

We conducted a formative study to understand how well SearchTogether currently supports sensemaking and what additional features might enhance sensemaking in SearchTogether. We recruited six three-member groups to participate in a vacation planning task using SearchTogether. The task was to find fun activities for a weekend in Seattle given the constraints that each group member could spend only \$50, and that the activities chosen should include one each of cultural, outdoor, and dining activities. The task was conducted in two phases – in phase 1, two members from each group were online synchronously (but in different locations) and searched together, knowing that their third group member would log in later to complete the task at a later time. The information they found was automatically stored in SearchTogether. In phase 2, which occurred at a later time, the third group member logged into the group's SearchTogether session alone and continued the task in order to come up with the final vacation itinerary. This study design helped us observe sensemaking during both synchronous and asynchronous collaborative search, and also enabled us to observe the “handoff” between group members searching asynchronously. We observed participants as they conducted the task and also asked them to “think aloud” and tell us about their experience using SearchTogether. We audio and video recorded the sessions and conducted semi-structured interviews with participants after they had completed the task to understand what sensemaking challenges they had faced while using SearchTogether.

Sensemaking Challenges in SearchTogether Use

Participants felt that collaborative Web search necessitated support for sensemaking beyond what was offered by SearchTogether. We found three important challenges participants faced in making sense of information found during collaborative search.

First, the temporality of the search process was important for group members' sensemaking. Many participants said that they wanted to see chronological orderings of content (such as comments and ratings associated with web pages, query terms, links followed, etc.). Persistence of the process of collaborators' sensemaking was important. Group members wanted to be able to view the path that others had followed during the search and felt that currently they “*didn't have an idea of what route they [group members] were taking.*” Persistence of the products of sensemaking was also important. SearchTogether allows group members to comment on Web pages, but participants said that they wanted to be able to note meta-comments and decisions that were not associated with particular Web pages, but rather with the task itself. They also wanted to be able to edit these meta-comments as the group's sense evolved over time.

Second, awareness played a key role in group members' sensemaking. Participants wanted awareness of others' actions. For example, they wanted notifications when another group member looked at a web page that they had added to the summary, or when a collaborator had typed a chat message. They also wanted more awareness of the context surrounding the various kinds of content generated, such as Web pages, queries, and chat messages.

Third, we found that sensemaking was particularly difficult for phase 2 participants to whom the search task had been "handed off". These participants were overwhelmed with all the information in the search session and felt that there was no quick way to get an overview of "what others were thinking." They found it difficult to correlate the different kinds of information (web pages, comments, ratings, chat) and determine what decisions had been made by others. They also found it hard to distinguish "old information" from "new information."

Thus, our formative study showed that there was a need to enhance sensemaking in SearchTogether. Based on our findings, we designed a new tool, CoSense.

3.3. CoSense

CoSense is an extension of SearchTogether that enables users to make sense of the information found during a collaborative Web search task as well as the process group members used to find that information. CoSense uses data from a group's SearchTogether session and provides alternate views of this data to enhance sensemaking. Users log into CoSense along with SearchTogether. When a user logs into CoSense, the tool reads the user's SearchTogether search session data from a database and displays this data in four views – the search strategies view, the timeline view, the workspace view, and the chat-centric view. Data added via CoSense are reflected in SearchTogether and vice versa. CoSense updates its views in real-time in response to new data from any other group member's instances of SearchTogether and CoSense (that is, changes made by any group member are reflected in all group members' copies of CoSense in real-time). As suggested by the findings of our formative study, the views of information in CoSense were designed to make explicit the temporal nature of the search, to provide action and context awareness, and to support sensemaking during handoffs.

Search Strategies View

The search strategies view (Figures 2(a) and 2(b)) visualizes the query and browsing activity of individual group members and of the group as a whole. This view is designed to help group members make sense of the search process and of the roles and skills of each group member during the search task. The view shows three kinds of information about users – query history, browsing history, and search skills and strategies.

(Figure 2(a) about here)

(Figure 2(b) about here)

Query history is depicted by graphs showing the total number of queries issued by each group member, by tag clouds of the keywords used in group members' queries, and by a timeline that shows group members' queries side-by-side in a chronological view. The query tag clouds

are interactive in that hovering over a keyword will show all queries which contained that keyword and clicking on the keyword will re-issue all queries containing that keyword and display the results of those queries in separate tabs of the current browser window.

Browsing history is made explicit via graphs that show the total number of URLs visited by each group member, and tag clouds of the websites visited by each group member and the group as a whole. The website tag clouds are interactive too; hovering over a website name in the website tag cloud shows all the URLs associated with that website. Clicking on the website name in the tag cloud opens up all the URLs in tabs of the current browser window. The query and website tag clouds provide at-a-glance information about each group member's search strategy and help users make sense of the similarities and differences between the roles and search strategies of different group members.

The skills and strategies of group members are made explicit through graphs for each group member that show the advanced operators used in their queries, the average number of keywords in their queries, and the time between queries. These graphs are inspired by research (White, Dumais, & Teevan, 2009; White & Morris, 2007) on what makes someone an expert searcher since understanding levels of expertise seems necessary for making sense of group members' search process and roles.

Timeline View

This view (Figure 3) makes explicit the browsing and search history of the group and allows users to inter-relate different kinds of content (such as Web pages viewed, chat messages, comments and ratings). It shows chronologically all the actions performed by group members during a search session in the form of an integrated timeline. The timeline contains queries issued, web pages visited, comments and ratings associated with web pages, and chat messages. Content is color-coded by user. This timeline is interactive — clicking on a website in the timeline opens it in the browser window. Also, a “preview” of the webpage appears in the right side of the timeline tab. This preview shows a thumbnail of the web page, group members who visited that page, chat messages exchanged when that page was being viewed, and any comments and ratings associated with that web page. The timeline can be interactively filtered by group member or action type.

(Figure 3 about here)

Workspace View

The workspace (Figure 4) is designed to support categorization of search results and storing of the products of sensemaking, such as meta-comments associated with the search session and files or other electronic artifacts group members might create. The left side of the workspace contains summaries of web pages group members have commented on. The summary for each web page contains a link to the webpage, comments and ratings associated with that web page, and a list of group members who visited that web page. Group members can tag summary items and then filter the workspace by tags. The right side of the workspace contains areas for free-form note-taking (allowing group members to note to-do items or decisions reached). It also allows uploading of digital artifacts like text files, spreadsheets, photos, or email that group

members might have created during their search. The notes and artifacts in the workspace are accessible to all group members.

(Figure 4 about here)

Chat-centric View

The chat-centric view (Figure 5) shows a transcript of the chat conducted during the search session, color-coded by user. Clicking on a chat message in this transcript shows the web page that was open in the browser of the person who authored that chat message, at the time that chat message was typed.

(Figure 5 about here)

3.4. Evaluation of CoSense

We evaluated CoSense to investigate whether it helped participants overcome the sensemaking challenges found in the formative study. To evaluate CoSense, we recruited 18 participants from within Microsoft to perform a collaborative Web search task using SearchTogether and CoSense. The task was similar to the task used in our formative study. It required four-member groups to plan a vacation in a European city given the constraints that participants could spend only 100 Euros per person and they had to plan at least four different vacation activities – sightseeing, outdoor, cultural, and dining. We designed two versions of the task (task 1 and task 2) which were identical except for the vacation location.

Similar to the formative study, the evaluation study was conducted in two phases. Phase 1 consisted of two three-member groups completing one of two versions of the task. Phase 1 participants worked on the task for 25 minutes and were told that a fourth group member would log in later to complete the task. In phase 2, each of the remaining 12 participants played the role of the fourth group member and continued either version of the task. Each phase 2 participant logged into the search session of a given phase 1 group and continued the task for 25 minutes. Figure 6 below shows the set-up for the evaluation task:

(Figure 6 about here)

All participants' actions in SearchTogether and CoSense were logged automatically. After completing the task, both phase 1 and phase 2 participants answered an online questionnaire (Appendix A); in addition to logging participants' answers, we also recorded which features of CoSense were accessed when answering each question. We also conducted semi-structured interviews with phase 2 participants (Appendix B). We analyzed data from both SearchTogether and CoSense logs to examine how search and sensemaking took place both during the task and when answering the questionnaire. We were interested in observing how participants switched between search and sensemaking and how these patterns of search and sensemaking varied across individuals and between synchronous and asynchronous search.

For further details about the evaluation task, please refer to (Paul & Morris, 2009) where we focused on how findings of the formative task were used to design CoSense and the design of

CoSense, along with some preliminary quantitative results from the evaluation of CoSense. In this article, we expand upon that prior work by providing a detailed qualitative analysis of the results of our evaluation of CoSense, in order to provide additional insight into users' sensemaking behavior during collaborative Web search.

4. RESULTS

In order to understand how sensemaking takes place in collaborative search, we analyzed participants' patterns of search and sensemaking. For our analysis, we categorized participants' actions as follows:

- | | |
|-------------|--|
| search | ▪ Opening Web pages and submitting queries in SearchTogether |
| sensemaking | ▪ Commenting on Web pages and exchanging chat messages in SearchTogether. |
| | ▪ All actions in CoSense (such as clicking on tabs, viewing tag clouds, viewing Web pages associated with chat messages, etc.) |

In addition to analyzing how participants switched between search and sensemaking, we were interested in qualitatively examining how sensemaking took place and the role that CoSense played in supporting sensemaking. For this, we examined when and why participants switched from SearchTogether to CoSense and how the different views in CoSense were used. The following sections present these findings for both synchronous and asynchronous search.

4.1. Sensemaking During Synchronous Search

Sensemaking-lead Strategy

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

(Figure 7(a) about here)

(Figure 7(b) about here)

Figure 7(b) shows a breakdown of the search and sensemaking actions for this group across time. The group started by using SearchTogether's chat feature to discuss their strategy for searching. They decided that they would all work simultaneously on each of the four activities (sightseeing, dining, outdoor, and cultural) one by one, instead of splitting up the activities between group members, and that they would start with the sightseeing activity. They also discussed that since 100 Euros was not much, they were "going on the cheap". Thus, during the

first 5 minutes of the task, sensemaking took place only through the chat in SearchTogether. After discussing their strategies and constraints, group members switched to searching and submitted their queries to SearchTogether. Depending on the search results returned, each group member then diverged in a different direction and looked at different websites.

As the group members searched, sensemaking took place in the form of chatting and adding comments to interesting Web pages in SearchTogether, such as “possible sightseeing destination”. CoSense wasn’t used at all during the first five minutes of the task, but as search progressed, group members started using CoSense to understand what aspects of the task others were working on. However, they continued to use the chat in SearchTogether to express their opinion on things they found. In the last 7 minutes of the task, group members spent more time on making sense of the information found than on searching for new information and most of their sensemaking during this time was using CoSense.

Search-lead Strategy

The other group (performing task 2) used a different strategy for approaching the search task. They did not start by discussing or making sense of the task, instead they started by searching for information. We call this the *search-lead* strategy. Figure 8(a) shows the proportion of search and sensemaking activities for the group with the search-lead strategy. This group started with searching and consistently performed more search than sensemaking; during the entire duration of the task more than 75% of the group’s actions were search. Figure 8(b) shows the breakup of the search and sensemaking actions of the group. Here again we found that during the first 5 minutes of the task, sensemaking took place only via SearchTogether’s chat. Group members did not comment on Web pages, but instead used the chat to leave comment-like messages such as “found a day long hike” or “this amusement park is around 38 euros per person”. Later, they commented on Web pages in SearchTogether but used this feature only in the middle part of the task. CoSense wasn’t used until 13 minutes into the task and overall was used much less than it was by the task 1 group.

(Figure 8(a) here)

(Figure 8(b) here)

CoSense Usage During Synchronous Search

We analyzed the CoSense log files to understand which features of CoSense were used (and how) during synchronous search. We found that the most-used views in phase 1 were the **search strategies view** (accessed by 83% of participants and viewed 17 times across both tasks) and the **chat-centric view** (accessed by 67% of participants and viewed 16 times across both tasks). Participants used the search strategies view primarily to look at tag clouds and tooltips. They periodically switched to the search strategies view to keep track of what others were searching for and which Web sites were being used the most. This helped them update their own search strategies in real time. Group members said that viewing the individual tag clouds of others helped them sometimes to make sure that their searches were not overlapping and at other times to follow up on what others were searching for.

The importance of the chat-centric view was linked to the importance of chat during synchronous search. We noted that chat in SearchTogether played an important role during synchronous search. In initial stages of the search, the chat helped groups discuss their strategy for conducting the task, such as having different group members focus on different components (such as sightseeing activity, dining activity, etc.) of the task or having the whole group focus on one component at a time. The chat was also useful in helping group members share information they had found and their preferences for how they wanted to spend their vacation. However, making sense of the chat messages in SearchTogether was difficult since group members were simultaneously searching and could easily lose context of what others were saying in the chat. The chat-centric view in CoSense was often used by participants to contextualize the chat with respect to the Web pages found. For instance, in task 2, group members started the task by entering queries into SearchTogether such as “Helsinki Finland” and “Helsinki”. As they started exploring the results returned by the search engines, they shared what they found by typing in the chat “here’s an amusement park in Helsinki” and “found a day long hike”. But since the chat messages were devoid of context, other group members found it hard to understand which amusement park or hike the person was talking about. This is where the chat-centric view in CoSense was used by group members to make sense of chat messages. Group members clicked on these chat messages in the chat-centric view in CoSense to directly see the Web page that the person was looking at when that message was typed.

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

Both groups of phase 1 participants used the workspace view the least (accessed by 50% of participants and viewed 7 times across both tasks). They primarily used the summary in SearchTogether rather than the one in CoSense, suggesting that these groups’ strategies were to read and comment on pages during the search process itself, rather than quickly building up a set of candidate pages and then reading and reflecting on them as a separate stage in the process. Also, only one group used the to-do and scratchpad areas to record a rough itinerary of the options they were considering (Figure 9). We think that this might be because (due to time constraints) they were still in too preliminary a stage to start recording their decisions.

(Figure 9 about here)

Handoff in Synchronous Search

We told phase 1 participants that a fourth group member would log in later to continue the planning of their vacation. We also told them that all the information they found during the task,

as well as their chat, comments, and ratings would, be automatically stored for the fourth group member to see. After working on the search task for 25 minutes, phase 1 groups had generated a lot of content as shown in Figure 10 below:

(Figure 10 about here)

Thus, it would be a daunting task for the fourth group member to make sense of all this information in order to successfully complete the handoff and continue the task.

We were interested in observing if phase 1 participants made any special efforts to ensure an effective handoff to the fourth group member such that he or she would be able to easily make sense of the information found in phase 1. We found that phase 1 participants did not make explicit preparations for handoff. They recorded the sense they had made about specific Web pages in the form of comments added to those Web pages, and one of the groups listed four activities that they were considering for their vacation (Figure 9), but neither phase 1 group left any notes or instructions specifically for the fourth group member. It would be valuable to repeat this study with a larger number of phase 1 groups, in order to verify this trend of leaving minimal information for future group members during asynchronous task handoff. However, this trend does make sense when considered in light of studies of individual information seeking that suggest that many users take a “do nothing” approach toward organizing found information for their own future use (Jones, Bruce, & Dumais, 2001; Morris, Morris, & Venolia, 2008).

4.2. Sensemaking During Asynchronous Search

Handling Handoff: Search-lead vs. Sensemaking-lead Strategies

We were interested in understanding how the twelve phase 2 participants resumed the search task that was handed off to them, and whether CoSense helped with this. We found that, like phase 1 participants, phase 2 participants used one of two strategies when resuming the search task. Four out of twelve (33%) phase 2 participants used a *search-lead* strategy, and started by searching for and making sense of task-related information (such as information about the vacation location, costs, currency conversion rates etc.) before looking at and making sense of the information already found by their group members. These participants wanted to first get their own sense of the information space and took between 30 seconds and 5 minutes for making sense of task-related information at the beginning of the task. Figure 11 depicts the search and sensemaking actions of a participant who used the search-lead strategy.

(Figure 11(a) about here)

(Figure 11(b) about here)

The remaining 8 participants (66%) used a *sensemaking-lead* strategy, and started by making sense of the information already found by phase 1 participants (such as which activities had been covered, which landmarks had been considered for each activity, what decisions had been made etc.) before starting their own search. Figure 12 shows the activities of a participant who used the sensemaking-lead strategy.

(Figure 12(a) about here)

(Figure 12(b) about here)

Those who used the search-lead strategy used generic queries for their search, such as “Gothenburg Sweden” and “helsinki tourism”, indicating that they wanted to start by finding the most basic information about the location. However, we found that usually these participants read the top few Web pages in their search results and then switched into sensemaking mode and started exploring the information found by phase 1 group members (as in Figure 11). The participants who used a sensemaking-lead strategy had two approaches to make sense of the information found by other group members. They either re-issued the queries of other group members by clicking on them in the SearchTogether query history and exploring the search results returned by those queries or they used CoSense views to understand the information already found. When sensemaking-lead strategists resumed search, their queries were more specific than those of search-lead strategists, such as “Ehrensvar museum” or “Brudaremossen masts”. Their search was also more focused; for instance they searched for directions to and from landmarks that had been discussed by group members in phase 1 or for the cost of tickets or meals at locations discussed by phase 1 group members.

In general, phase 2 participants performed more sensemaking than search as compared to phase 1 participants. Most of this sensemaking took place in CoSense, rather than through the chat and comments in SearchTogether. Participants used the various views of CoSense to understand what other group members had done. They moved the search task forward by summarizing the options considered, decisions reached, and things left to do before the vacation itinerary could be finalized. In order to do this, they spent a lot of time making sense of the information handed off to them.

These findings are interesting in light of Sharma’s (2008) study of sensemaking during handoffs at a computer helpdesk. Sharma suggested that external representations handed off from one sensemaker to another should indicate how much work had been done and how mature the representation was. Less mature external representations show that not much progress has been made on the task; the recipient of the representation can skim the information present and start working on the task herself (i.e., adopt a search-lead strategy). With a more mature representation, on the other hand, the recipient is better off spending time to make sense of the material handed-off before starting work on the problem (i.e., adopt a sensemaking-lead strategy). In our study, since phase 1 groups had made little preparations for handoff, the external representations passed on were not mature and hence, phase 2 participants should have mostly adopted a search-lead strategy. But we found that a majority (66%) of phase 2 participants adopted a sensemaking-lead strategy.

CoSense Usage During Asynchronous Search

We compared CoSense view usage in asynchronous search to that observed in synchronous search to see whether different views were useful during these two kinds of collaborative search. While in phase 1 the search strategies and chat-centric views were accessed the most, in phase 2 the **workspace view** (accessed by 92% of participants and viewed 67 times across both tasks) and the **timeline view** (accessed by 83% of participants and viewed 58 times across both tasks)

were accessed most frequently. The workspace view was very important for phase 2 participants since this allowed them to store the “sense” that they had made in the form of comments and ratings on Web pages, to-do lists, and decisions reached. This view also allowed them to associate external files created during the search task. We found that the summary in SearchTogether and the summary in the workspace view of CoSense served different purposes. While in phase 1 participants mostly added items to the summary through SearchTogether, in phase 2, participants used the summary in CoSense since CoSense enabled modification of the organization of the summary as they made sense of the information. For instance, participants tagged, sorted, and deleted summary items in the workspace.

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

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

4.3. Measuring Sensemaking: Questionnaire Results

In order to understand how participants made sense during our tasks, we designed a questionnaire and a semi-structured interview, both administered to participants after the task. The questionnaire (Appendix A) was built to measure participants’ sensemaking in two ways – through the quality of their answers and the time taken to answer each question. We also designed the questionnaire to help us understand which features of CoSense were useful in helping participants understand different kinds of information during a search task. Thus, our software logged participants’ answers to each question, which CoSense views participants were using to answer each question, and how much time they took to answer each question.

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

CoSense Views Used to Answer Questions

We found that different views of CoSense were useful in answering different types of questions (for detailed analysis of this see (Paul & Morris, 2009)). Figure 13 below summarizes what questions each view of CoSense was used in answering, thus providing insight into how the different views supported sensemaking of different kinds of information during the search.

(Figure 13 about here)

Time Taken to Answer Questions

We also examined the average amount of time participants took to answer each question and the number of times they switched CoSense views to answer each question. More time and more view switches indicated that participants found it difficult to answer the question. Figure 14 below lists which two questions took the longest time to answer and which question took the least time to answer, for both synchronous and asynchronous search. During synchronous search, participants took the longest times to answer questions related to group members' contributions (Q1) and skills (Q2). The shortest time was taken to answer the question about what steps remained before the itinerary was complete (Q9). During asynchronous search, participants again found it difficult to answer questions about contributions (Q1) and roles of group members (Q3) and the least amount of time was again taken to answer Q9.

(Figure 14 about here)

Time taken to answer questions was indicative of how hard or easy it had been for group members to make sense of certain information; longer times indicated greater uncertainty and lack of sensemaking regarding a question while shorter times indicated better sensemaking. This was validated by the quality of the answers (see 'Quality of answers' below); it was seen that the questions that participants took longer to answer were also those which they couldn't answer or where the replies were inconsistent across participants.

View Switches in Answering Questions

More view switches in answering a question indicated difficulty in making sense of that information. In synchronous search, the most view switches occurred in answering questions about who the most skilled searcher was (Q2) and which websites the group found most useful (Q4). On the other hand, participants did not switch views at all to answer Q9. This suggests that

sensemaking regarding group dynamics (skills and contributions of group members) was less important to participants than sensemaking regarding task progress and state. Interestingly, during asynchronous search, the most view switches occurred in answering the question about which queries were the most successful (Q7) and group members contributions (Q1). Once again, participants did not switch CoSense views to answer Q9. Figure 14 summarizes this.

Quality of Answers

Judging from the quality of their answers, participants in both phases found it hard to answer the questions about group dynamics, such as contributions (Q1), skills (Q2), and roles (Q3) of group members. For Q1, two phase 1 participants said that it was hard to tell who contributed most, all others said that all group members had contributed equally to the search task. However, phase 2 members all had different answers to this question. For Q2, 50% of phase 1 participants said they couldn't tell who the most skilled searcher was and phase 2 participants were inconsistent in answering this question.

Participants also found it hard to answer questions regarding task-related information. Phase 2 participants often answered the question about the most important website incorrectly. This was because they were judging the importance of websites by the size of that websites name in the tag clouds in the search strategies view. However, the tag clouds reflected *frequency of use* and not *usefulness* of websites or query keywords; most participants in phase 2 did not realize this. Both phase 1 and phase 2 participants found it hard to understanding which websites generated a lot of discussion (Q6). Similarly, both phase 1 and phase 2 participants found it hard to tell which queries were the most successful (Q7). One phase 2 participant said “*No way to figure out as there is no way for someone to mark useful results from a query*”.

In the next section, we discuss why participants might have had difficulty in answering these questions (see section 5.4 on success in sensemaking) and how interfaces can be designed to enhance their understanding of such information.

5. DISCUSSION

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

5.1. Comparison of Individual and Collaborative Sensemaking

We found that sensemaking in collaborative information seeking is far more complex than individual sensemaking as described by extant models and theories (Dervin, 2003; Russell, Stefik, Pirolli, & Card, 1993). In individual information seeking, sensemakers need to only make sense of task-related information. In collaborative information seeking, sensemakers also need to understand information about group dynamics, information found by other group members, and

the sense other group members have made. This is specifically challenging during synchronous Web search since other group members are constantly interacting with the search space, adding to it not only new information like Web pages they found, but also their sense of the information (in the form of comments and ratings). Additional challenges arise from the need to constantly interact with others (via chat or comments) and contextualize these interactions with respect to the content being found. This is also troublesome in the case of asynchronous search where users need to connect and contextualize different kinds of information. For such contextualization, collaborative Web search tools need to provide features that help users connect different kinds of information; the chat-centric and timeline views in CoSense are examples of how to accomplish this.

We found three important requirements of collaborative sensemaking that make it different from individual sensemaking and hence make it difficult to design tools to support collaborative sensemaking:

Understanding Sensemaking Trajectories

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

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

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

Prioritizing Information

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

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

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

Managing Group Representations

While group sensemaking was different and more complex than individual sensemaking, we found that there were some similarities, too. The use of representations (Russell, Stefik, Pirolli, & Card, 1993) was equally important to the group scenario. Three phase 2 participants created external documents (using OneNote, Word, and Excel) to map the information they found to the structure of the task, which was that there were four activities to be planned for the vacation – sightseeing, outdoor, dining, and cultural – and task constraints, such as budget. Other participants (7) used the scratchpad and to-do for creating mappings of the information found to this task structure. These mappings were akin to Russell et al.’s (1993) notion of representations used to ‘encode’ task-related information; in this case task-related information was the locations, prices, links etc. associated with each activity.

While participants used the free-form text entry areas to create representations to map task categories to information found in each task category, some participants expressed the need to have the tool automatically provide the structure and make it easier to create representations of information. One of the participants said,

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

Several other participants echoed this sentiment. Another participant said,

“...since all this is so activity-based, there could be something where we create a tab just for activities. The moment you have an activity you list it as an activity, and you have the ability to

multiply that with the number of people, associate that with cost, and once you are done with the activity it [the tool] can mail out directions to all the people.”

Thus, while the users in our formative study found the lack of support for free-form note-taking in SearchTogether disadvantageous, when supplied with such functionality users of CoSense wanted the tool to support representations that mapped to the task structure. So a challenge for designers is to provide the right level of structure for noting the intermediate and final products of sensemaking. We discuss some ways of doing this in section 5.2.

5.2. Differences in Sensemaking Strategies

We found that participants had two strategies when approaching a collaborative search task – search-lead and sensemaking-lead. This was true for both phase 1 participants (when they started the task) and phase 2 participants (when they resumed the task that was handed off to them). In post-test interviews with phase 2 participants we found that there were some differences between participants who used these two strategies with respect to 1) features of SearchTogether and CoSense they preferred, and 2) ability to answer questions in the questionnaire (discussed in Section. 5.4). Here we discuss how these strategies differed for participants who searched asynchronously and the implications supporting both strategies have for the design of collaborative search tools.

Search-lead Strategy

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

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

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

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

Thus, since the timeline showed *all content* instead of the “useful” content, participants found it overwhelming and wanted the tool to make explicit the useful content in the timeline. Only one search-lead strategist found the timeline useful and he filtered content out by user. Thus, in addition to providing filtering of content, another important design feature for presenting

chronological information in a collaborative search tool should be visual indicators of useful content. An important question here is how to decide which content is ‘useful’ and who it is useful to (e.g. useful to the group vs. useful to the individual). One approach is to allow users to mark content as useful while another is for the tool to algorithmically determine which content is useful (i.e., by employing heuristics based on factors such as length of time spent on a page, number of times a page was revisited, and/or the number of group members visiting a particular page).

Finally, all search-lead strategists found the chat-centric view useful; one of them said,

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

Only 50% of search-lead strategists used the workspace view in CoSense. One participant used it to create a checklist of activities which he checked off as he worked on each, the other created an emerging itinerary.

Sensemaking-lead Strategy

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

62.5% of sensemaking-lead strategists mentioned that they liked the search strategies view; they particularly like the query history timeline which shows how group members’ queries have evolved over time. One participant said about the query history timeline,

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

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

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

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

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

Procedural Knowledge of Sensemaking

Researchers (Bhavnani, 2002; Bhavnani et al., 2003) have found that users who have search expertise in a particular domain also have *procedural search knowledge* which consists of 1) the sub-goals to organize a search in a particular domain, 2) the order in which to satisfy those sub-goals, and 3) the selection knowledge to determine which information sources (websites) will satisfy those sub-goals. We were interested in observing whether searchers exhibit similar procedural knowledge of sensemaking. Since the participants in our study were not experts in planning vacation tasks, we found that they did not exhibit procedural search knowledge by breaking up the task into sub-goals, though some participants did structure their search according to the four vacation activities. However, from analyzing the log files, we found that for asynchronous search, participants exhibited procedural sensemaking knowledge that consisted of satisfying sensemaking sub-goals. The order of satisfying sub-goals differed depending on whether a participant used a search-lead or a sensemaking-lead strategy.

Figure 15 shows the sensemaking procedural knowledge corresponding to both types of strategies. The numbered points are sub-goals while the lettered points are steps to satisfy the sub-goals. Both search-lead and sensemaking-lead strategists had the same high level goals, which were to (1) understand task-related information, (2) understand task state and progress on goals, and (3) understand group dynamics information. Executing goals (2) and (3) did not differ with strategy, rather it was in how they understood task-related information that search-lead and sensemaking-lead strategists differed. So we focus on the procedure followed for satisfying goal (1). For a given high level goal (1, 2 or 3) there were smaller sub-goals that were executed (e.g. 1.1, 1.2 etc.). It is to be noted that for these sub-goals, the specific order of steps to satisfying that sub-goals (lettered points) varied across participants; for instance in sub-goal (1.3) for the search strategy, participants could view others Web pages (b) before viewing other's queries (a). Also, steps indicated within [] were optional steps, not all participants performed these.

(Figure 15 about here)

As can be seen, search-lead strategists first focused on finding new information and then making sense of the information found by others while it was the other way around by sensemaking-lead participants. We found that it is important for a collaborative search tool to support both these strategies, since both were common among our participants, with 50% using search-lead strategies and 50% using sensemaking-lead during synchronous search and 33% using search-lead strategies and 66% using sensemaking-lead strategies during asynchronous search. SearchTogether query history and the CoSense timeline view supported search-lead strategists while the search strategies and workspace view supported sensemaking-lead

strategists. The chat-transcript view supported both types of strategies. One implication of this could be that the different views of CoSense could be sequenced so as to encourage one strategy over the other if the designed felt that one or the other strategy was more effective. However, our findings did not indicate any clear advantage of one strategy over another for this kind of collaborative task.

5.3. Products of Collaborative Sensemaking

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

Chat Messages

An important theme in our findings was the importance of chat messages for communicating “sense” to other group members. During synchronous search, other than using chat to discuss their search strategies for the task (as discussed in Section 4.1), participants used the chat to pass on various kinds of “sense” such as how landmarks they found fit task constraints, how tool features could be used to share information, and whether certain information they found would be of interest to the group or of personal interest. Accordingly, participants’ chat messages during synchronous search could be categorized as shown in Figure 16. Chat messages in each category not only contained information, but also some “sense” about that piece of information that the author of the chat message wanted to pass on to other group members.

(Figure 16 about here)

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

During asynchronous search it was difficult for participants to decide whether they should note the sense that they made about an information source as a comment or pass on the sense they made through the chat. We did not expect participants to use the chat during asynchronous search since they were working on the task alone. However, we found that 2 participants used the chat, along with the comments, to record their sensemaking. These chat messages were important meta-comments that participants wanted to let other group members know. For instance, in one example (in Section. 4.2) a participant left a message that the average cost of meals in Helsinki would be 25 Euros per person. When asked why he had used the chat to leave the message he said,

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

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

CoSense recognizes the centrality of the chat in collaborative search by allowing participants to connect the Web pages to chat in various ways. Participant can get to the chat through the Web pages (as in the timeline view which not only shows the chat inter-leaved with the rest of the information, but also shows the chat conversation that occurred 2 minutes before and after every Web page viewing) and can get to the Web pages from the chat (as in the chat-centric view which shows the web page associated with each chat message).

As discussed in Section 4.2, the chat-centric view played an important role in both synchronous and asynchronous search. We found the chat-centric view was useful to participants irrespective of whether they used the search-lead or the sensemaking-lead strategy. Thus, an important design implication is that it is important for collaborative search tools to store persistent chat along with the task-related information. However, the challenge with providing persistent chat is to prioritize information in the chat transcript. Participants in phase 2 found the chat overwhelming since they couldn't prioritize information and tell the recommendations and suggestions from the rest of the conversation. Thus, designers must consider how to help participants make better sense of such persistent chat. One way of doing this would be to categorize the chat messages in the chat transcript (for instance by highlighting them with different colors) according to the categories in Figure 16. One of the phase 2 participants who rated the chat transcript as the feature he found most useful, suggested another way to prioritize information in it; he said,

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

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

Comments

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

During asynchronous search, participants used comments which again fell in the same categories as noted in Figure 16. However, we found that some comments were directed toward specific group members and were used to delegate responsibilities to them or simply to bring things to their attention. For instance, one phase 2 participant left a comment on a Swedish website, “Hey Justin, this site looks like it could have some good info, but it's in Swedish. Can you take a look?” Later this participant said,

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

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

Notes

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

5.4. Success in Collaborative Sensemaking

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

Understanding Group Dynamics

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

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

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

Understanding Search Skills and Strategies of Others

Though previous research (White & Morris, 2007) has suggested the importance of search skills and expertise in individual Web search, it seemed understanding other's search skills was not an important aspect of sensemaking during collaborative search. When asked which group member was the most skilled searcher, one participant said he didn't pay attention to what people were searching for and how successful their searches were. However, while understanding other's search skills were not important, participants said that their searches were influenced by one another during synchronous search. One participant said,

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

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

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

Understanding Relative Importance of Information/Information Sources

For those engaged in asynchronous search, it was difficult to understand the *relative importance* of queries and websites to the search task (Q4, Q6 and Q7). Questions about the "most" useful query or website were hard to answer because participants didn't evaluate the *relative* value of information sources (i.e., Web pages and queries) in a collaborative search task. Since this was not a part of their sensemaking, participants used the search strategies and timeline views to answer questions about relative importance of information sources. However, since these views make explicit the *frequency of use* and not *usefulness* of different queries and websites, phase 2 participants answered this question incorrectly (i.e., their answer did not correspond with that of phase 1 participants). Thus, phase 2 participants ended up judging those websites and queries as important to the search task which were visited/used more frequently since they were more prominent in the tag clouds of the search strategies view (as discussed in Section 4.2). This leads to an important implication for design; our interface used frequency as a proxy for importance of information, but this may not always be true. Other proxies for importance could be time spent viewing a website or useful content generated from a query. These could be made visually explicit in the search strategies view.

Instead of evaluating the relative importance of information sources, participants were interested in evaluating the relative importance of the information itself (i.e., Web pages of landmarks or restaurants that group members wanted to visit during the vacation). Several

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

Understanding Task State and Progress on Goals

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

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

Success in Search-lead vs. Sensemaking-lead Strategies

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

On the other hand, sensemaking-lead strategists took longer to answer which websites had generated lots of discussion (Q6, 41 seconds longer), and which queries which had been the most successful (Q7, 13 seconds longer). Some of these findings were contrary to our expectations. For instance, we expected sensemaking-lead strategists to take less time than search-lead strategists in answering questions about task-related information like importance of websites and queries to the search task since they spent more time on making sense of information and less time searching. But we found search-lead participants to be quicker in answering these questions.

When asked if they felt they had been successful in completing the task given the time they were given, search-lead strategists were more positive about their success in the task; all search-lead strategists said they thought they had been successful. In contrast, only 50% of sensemaking-lead strategists said that they felt they had been partly or completely successful in developing a vacation itinerary. Most felt they had only been successful in refining the group's efforts rather than reaching the final decisions. Our findings indicate that in terms of understanding group dynamics information, both strategies were equally unsuccessful while in terms of understanding task-related information, search-lead strategists performed better.

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

6. CONCLUSION

Research in sensemaking has mostly been conducted in the context of individual information seeking tasks. We conducted a study of sensemaking in collaborative Web search tasks using SearchTogether and found that collaborative sensemaking extends beyond making sense of task-related information. We built and evaluated a new tool, CoSense, which enhanced sensemaking in collaborative search tasks. The evaluation of CoSense showed how collaborative sensemaking differed from individual sensemaking in terms of the different kinds of information that collaborators need to make sense of. We also discussed how sensemaking occurs in synchronous and asynchronous collaboration, specifically throwing light on the challenges participants face in handling handoffs. We found that participants had two different strategies of handling handoffs – search-lead and sensemaking-lead, and that participants with these two strategies exhibited different procedural knowledge of sensemaking though they didn't show marked difference in terms of success. We also highlighted how complex and varied the products of sensemaking are and discussed design implications for storing the products of sensemaking. Through our evaluation of CoSense we provided insights into the design of tools that can enhance sensemaking in collaborative search tasks.

In future work we intend to study the differences between search-lead and sensemaking-lead strategists in more detail and also explore why search-lead strategists were better at making sense of task-related information and perceived themselves as more successful. We are also interested in studying subsequent rounds of handoff, i.e., if phase 1 group members resumed the task after phase 2, how they would interpret the information found/decisions made by phase 2 participants. Finally, we are also be interested in studying different kinds of tasks and different group structures, such as hierarchical group with assigned roles.

NOTES

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FIGURE CAPTIONS

- Figure 1(a)** The SearchTogether browser plug-in’s “contacts” view fills the left-hand portion of the Web browser, and the “integrated chat” runs across the browser’s bottom. These features provide some basic support for collaborative sensemaking around the *process* of searching by providing shared awareness of query terms and associating context (conversation from the integrated chat) with the search topic
- Figure 1(b)** The “summary” view of the SearchTogether plug-in can be switched to in place of the “contacts” view, and provides some basic support for collaborative sensemaking around the *products* of a search, such as creating a collection of links and associating comments with them.
- Figure 2(a)** The search strategies view shows individual and group tag clouds of the query keywords and the websites used in the search. It also shows graphs for the number of URLs visited and queries issued by group members. The cursor is placed over the keyword “Gothenburg” which shows a list of all queries which contained the word ‘Gothenburg’.
- Figure 2(b)** The search strategies view also shows the ‘query history timeline’ which shows a chronological side-by-side view of group members queries and “advanced” graphs which make explicit the search skills of group members.
- Figure 3** The left side of the timeline view shows a chronological, color-coded listing of Web pages viewed, chat messages exchanged, and comments and ratings on Web pages. Clicking on a Web page in the timeline shows a “preview” of the Web page on the right side.
- Figure 4** The workspace provides a place to store the products of the sensemaking process. It shows web pages that have been commented on, “to do” and “scratchpad” areas, as well as links to external documents associated with the task
- Figure 5** Figure 5: The chat-centric view shows the group’s color-coded chat conversation (on the left). Clicking any chat message shows the webpage associated with that message (on the right).
- Figure 6** Set-up for CoSense evaluation study.
- Figure 7(a)** Proportion of search and sensemaking activities during synchronous search (for task 1). This group had a sensemaking-lead strategy
- Figure 7(b)** Categories of search and sensemaking actions during synchronous search (task 1) for the sensemaking-lead group.
- Figure 8(a)** Proportion of search and sensemaking activities during synchronous search (for task 2). This group had a search-lead strategy.

- Figure 8(b)** Categories of search and sensemaking actions during synchronous search (task 2) for the search-lead group.
- Figure 9** Workspace view of phase 1 group conducting task 2 shows that they recorded four activities in the scatch-pad. The other group did not note anything in either the to-do or scratchpad areas.
- Figure 10** Content generated by phase 1 groups for both tasks
- Figure 11(a)** Proportion of search and sensemaking during asynchronous search for a phase 2 participant (task 1). This participant had a sensemaking-lead strategy.
- Figure 11(b)** Categories of search and sensemaking during asynchronous search for a phase 2 participant (task 1) with a sensemaking-lead strategy
- Figure 12(a)** Proportion of search and sensemaking of during asynchronous search for a phase 2 participant (task 2). This participant had a search-lead strategy
- Figure 12(b)** Categories of search and sensemaking during asynchronous search for phase 2 participant (task 2) with a search-lead strategy.
- Figure 13** CoSense views used to answer questions in the questionnaire.
- Figure 14** Time taken and view switches to answer questions in the questionnaire
- Figure 15** Procedure followed for sensemaking in asynchronous search by participants with search-lead and sensemaking-lead strategies.
- Figure 16** Classification of chat messages during synchronous search

FIGURES

Figure 1(a). The SearchTogether browser plug-in's "contacts" view fills the left-hand portion of the Web browser, and the "integrated chat" runs across the browser's bottom. These features provide some basic support for collaborative sensemaking around the *process* of searching by providing shared awareness of query terms and associating context (conversation from the integrated chat) with the search topic

The screenshot shows a Windows Internet Explorer browser window displaying the website <http://www.tickets2you.net/>. The browser's address bar and search bar are visible at the top. The main content area features a large banner for "TICKETS 2 YOU" with a photo of a child and the text "Lowest Orlando Ticket Prices on the Planet!". Below the banner, there are sections for "Orlando Theme Park Tickets", "Orlando Dinner Show Tickets", "Orlando Entertainment Tickets", and "Theme Park Information". A prominent section titled "Discount Disney World Tickets and More" includes logos for Disney Tickets, SeaWorld Adventure Park, and Universal Studios Islands of Adventure, each with a "View Tickets" button. Below this, there are "Tickets Specials" such as "Get 2 Days at Disney FREE!", "Get 1 Day at Sea World FREE!", "Get 5 Days at Universal and Islands of Adventure Free!", and "Half Off Arabian Nights Dinner Show!".

The left sidebar contains a "SearchTogether" plug-in interface. It has a "Contacts" tab selected, showing a list of three contacts: Merrie (Online), Dan, and Gloria. Merrie's contact list includes "disney discount tickets", "disneyland best deals", "disney tour packages", and "disneyland discounts". Dan's contact list includes "disney resort hotels". Gloria's contact list includes "best disney rides", "california adventure", "california adventure rides", "site disney.com ride details", and "space mountain".

At the bottom of the browser window, there is an integrated chat window titled "Messages:". The chat history shows the following messages:

- (03/06/08 02:05 PM) Merrie: Hi Mom, can you pick what rides we should visit?
- (03/06/08 02:05 PM) Gloria: OK, are you still looking for discount passes?
- (03/06/08 02:48 PM) Merrie: Yep!
- (03/06/08 02:48 PM) Dan: I'll find hotels

The chat window has a "Send" button and a text input field.

Figure 1(b): The “summary” view of the SearchTogether plug-in can be switched to in place of the “contacts” view, and provides some basic support for collaborative sensemaking around the *products* of a search, such as creating a collection of links and associating comments with them

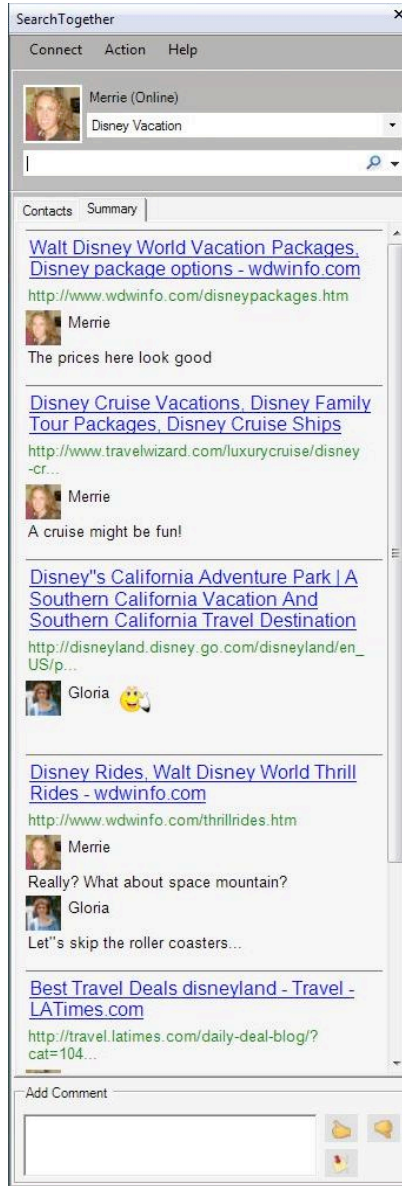


Figure 2(a). The search strategies view shows individual and group tag clouds of the query keywords and the websites used in the search. It also shows graphs for the number of URLs visited and queries issued by group members. The cursor is placed over the keyword “Gothenburg” which shows a list of all queries which contained the word ‘Gothenburg’.

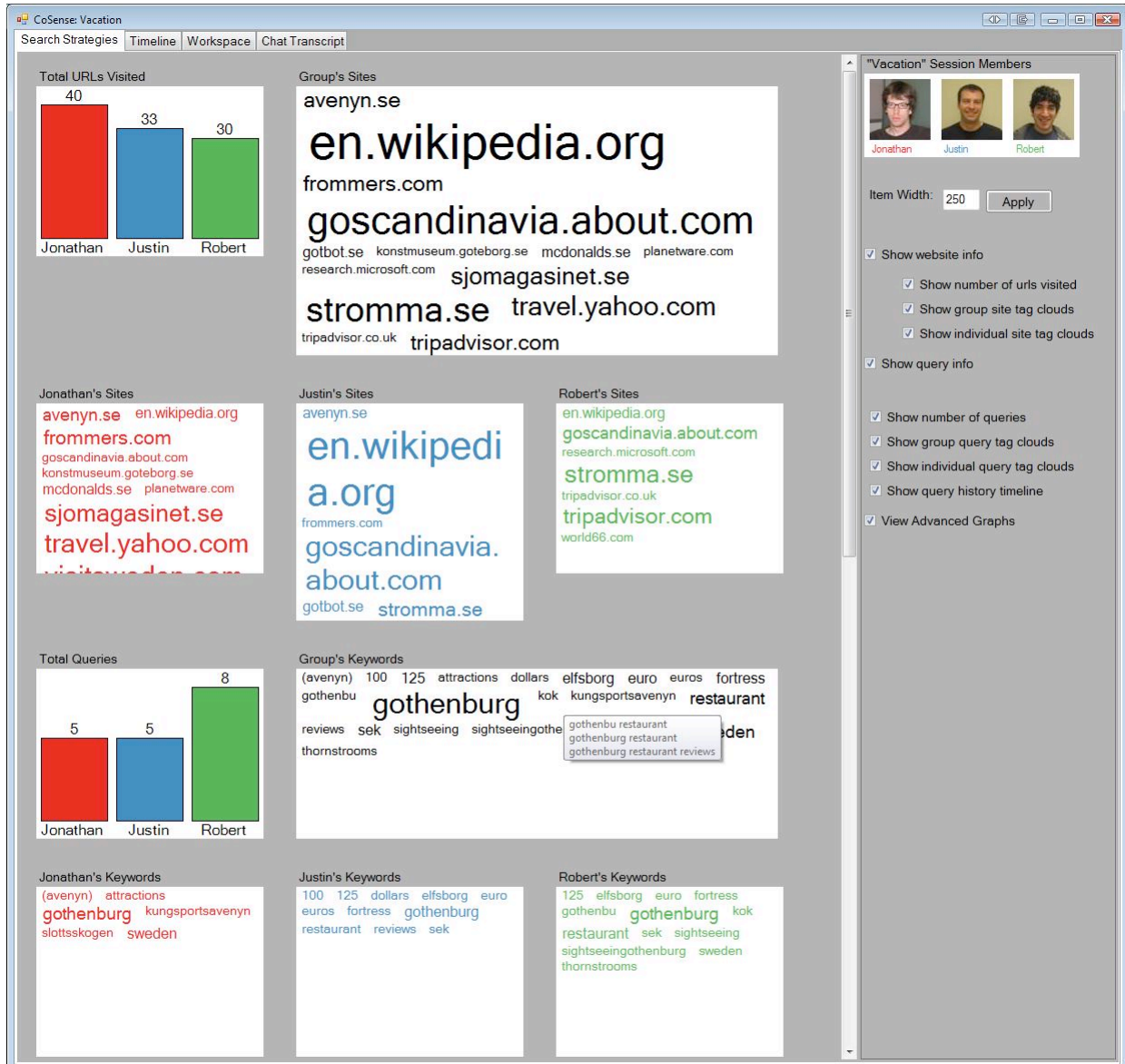


Figure 2(b). The search strategies view also shows the ‘query history timeline’ which shows a chronological side-by-side view of group members queries and “advanced” graphs which make explicit the search skills of group members.



Figure 3. The left side of the timeline view shows a chronological, color-coded listing of Web pages viewed, chat messages exchanged, and comments and ratings on Web pages. Clicking on a Web page in the timeline shows a “preview” of the Web page on the right side.

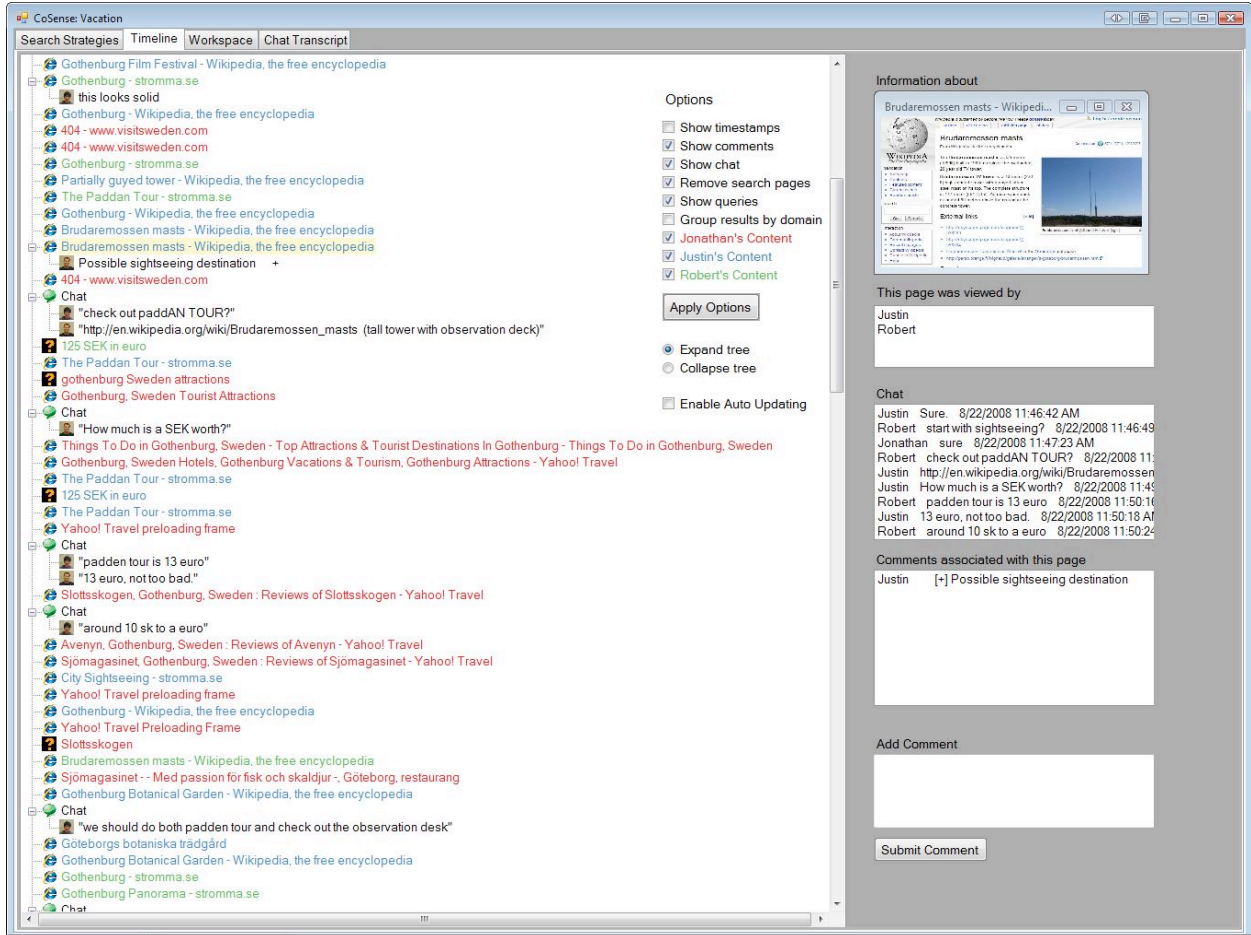


Figure 4. The workspace provides a place to store the products of the sensemaking process. It shows web pages that have been commented on, “to do” and “scratchpad” areas, as well as links to external documents associated with the task

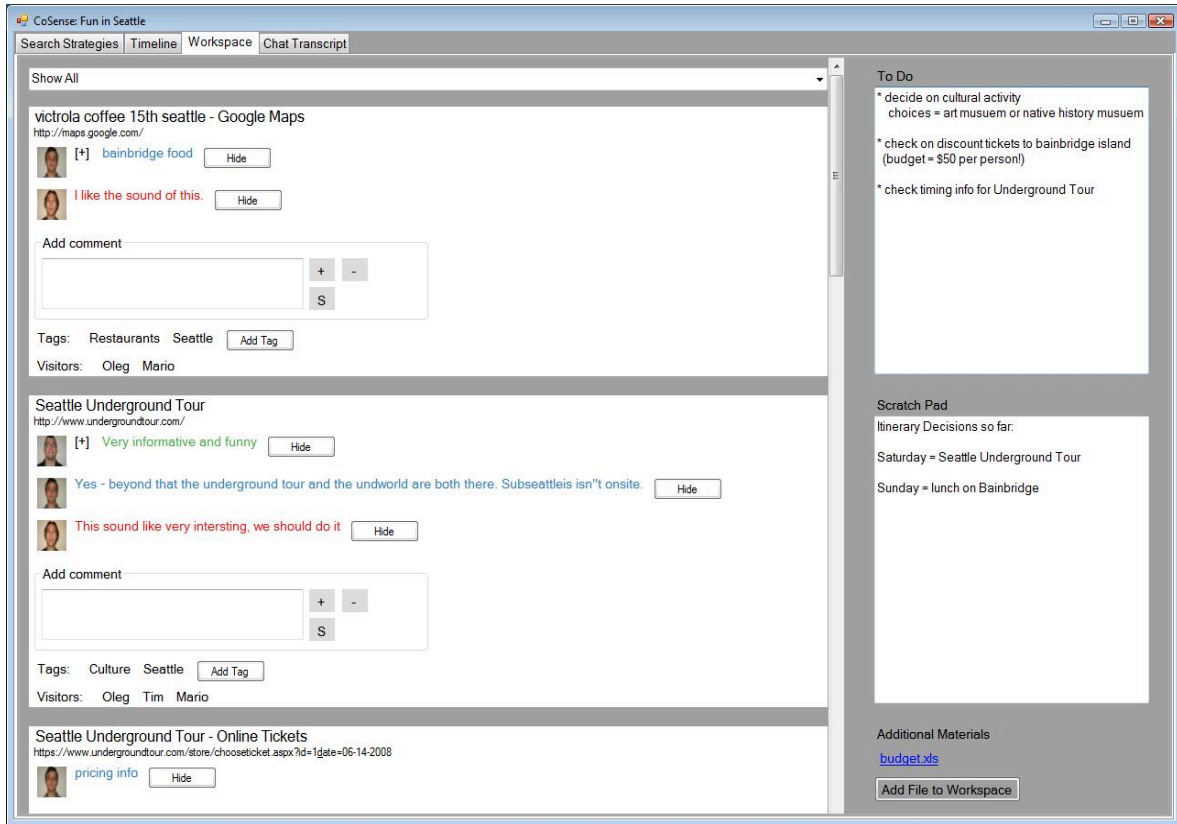


Figure 5. Figure 5: The chat-centric view shows the group's color-coded chat conversation (on the left). Clicking any chat message shows the webpage associated with that message (on the right)

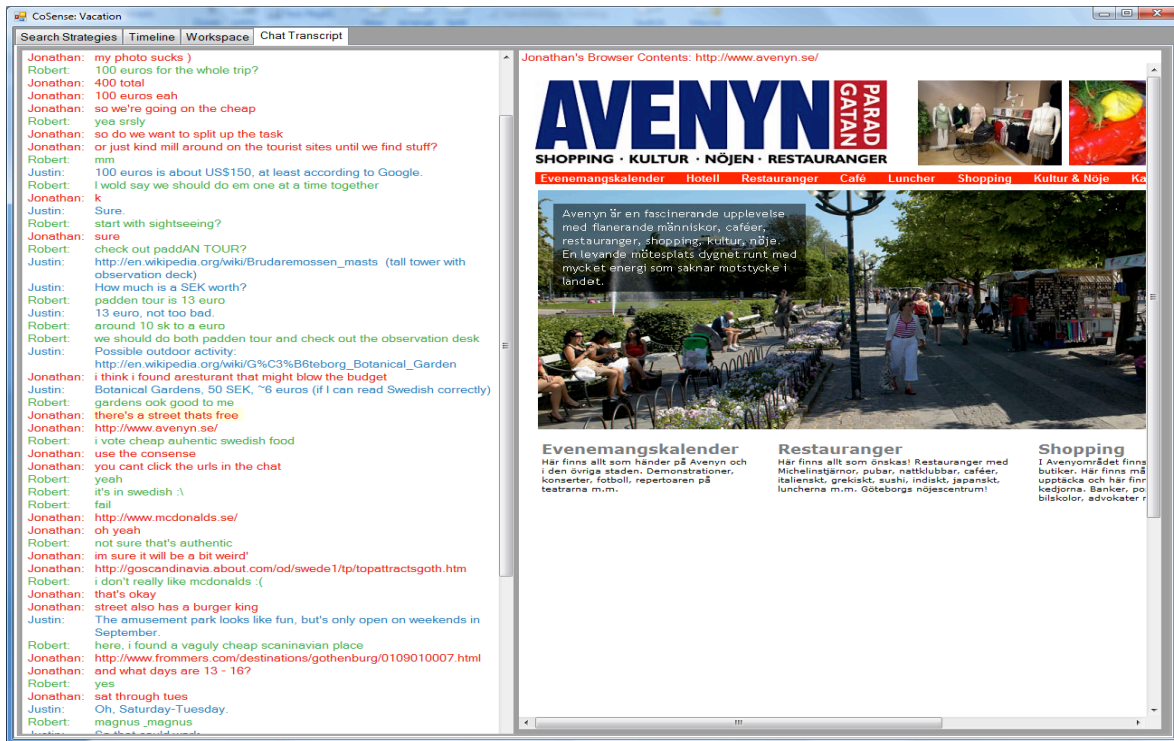


Figure 6. Set-up for CoSense evaluation study

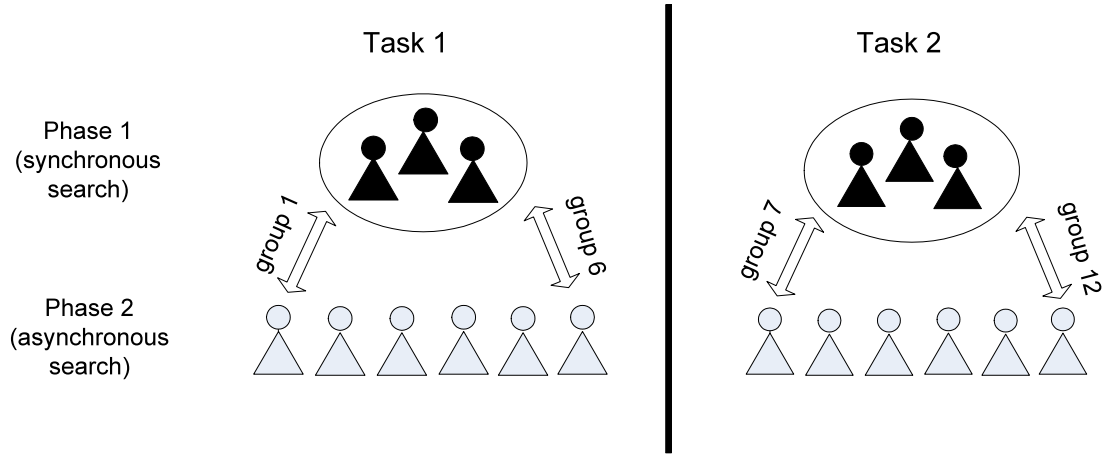


Figure 7(a). Proportion of search and sensemaking activities during synchronous search (for task 1). This group had a sensemaking-lead strategy

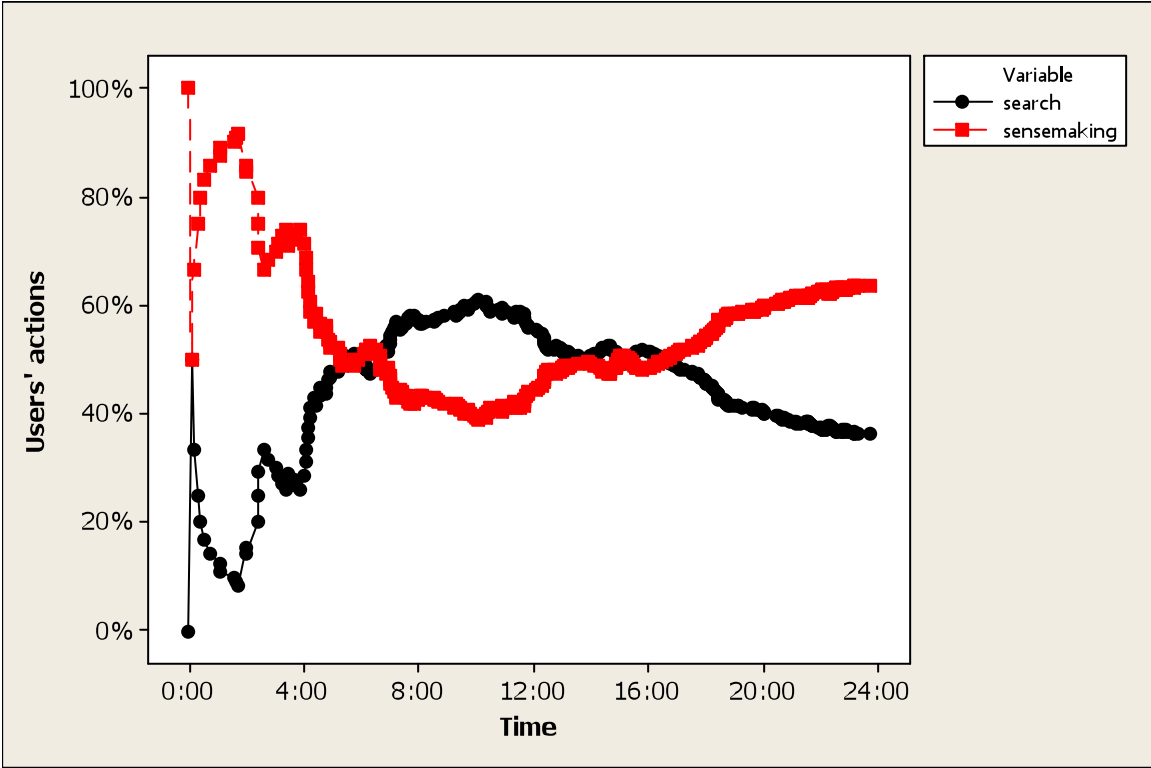


Figure 7(b). Categories of search and sensemaking actions during synchronous search (task 1) for the sensemaking-lead group

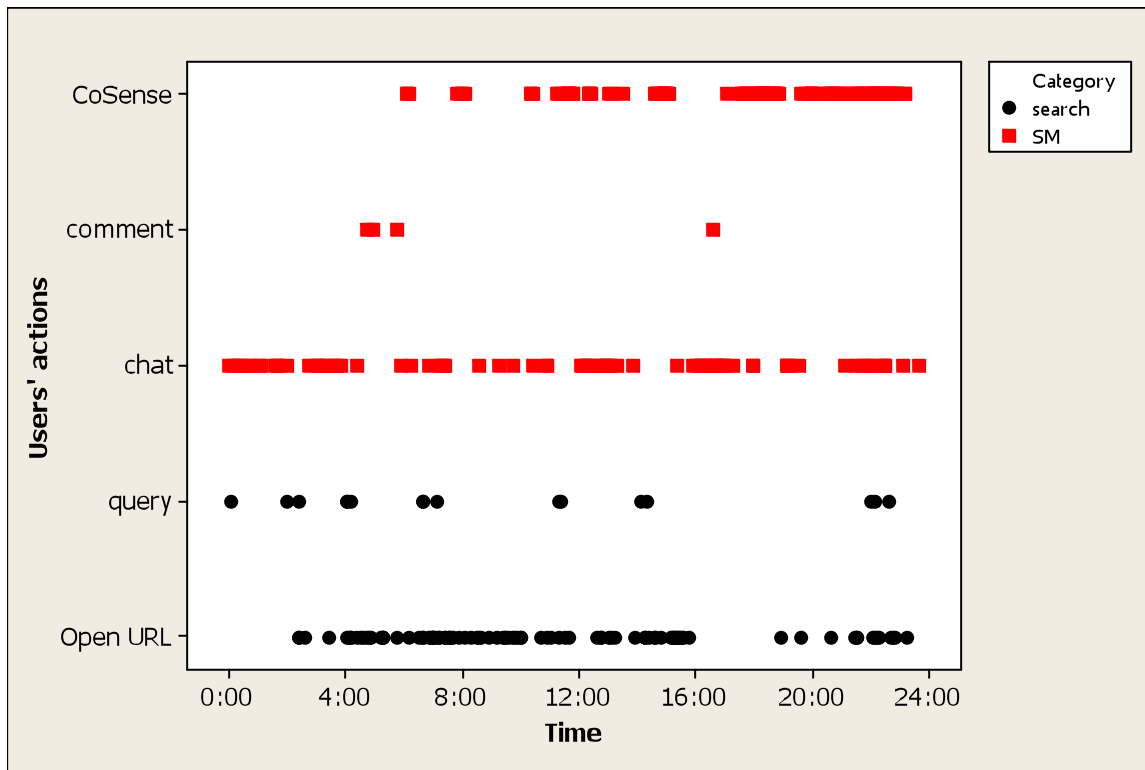


Figure 8(a). Proportion of search and sensemaking activities during synchronous search (for task 2). This group had a search-lead strategy.

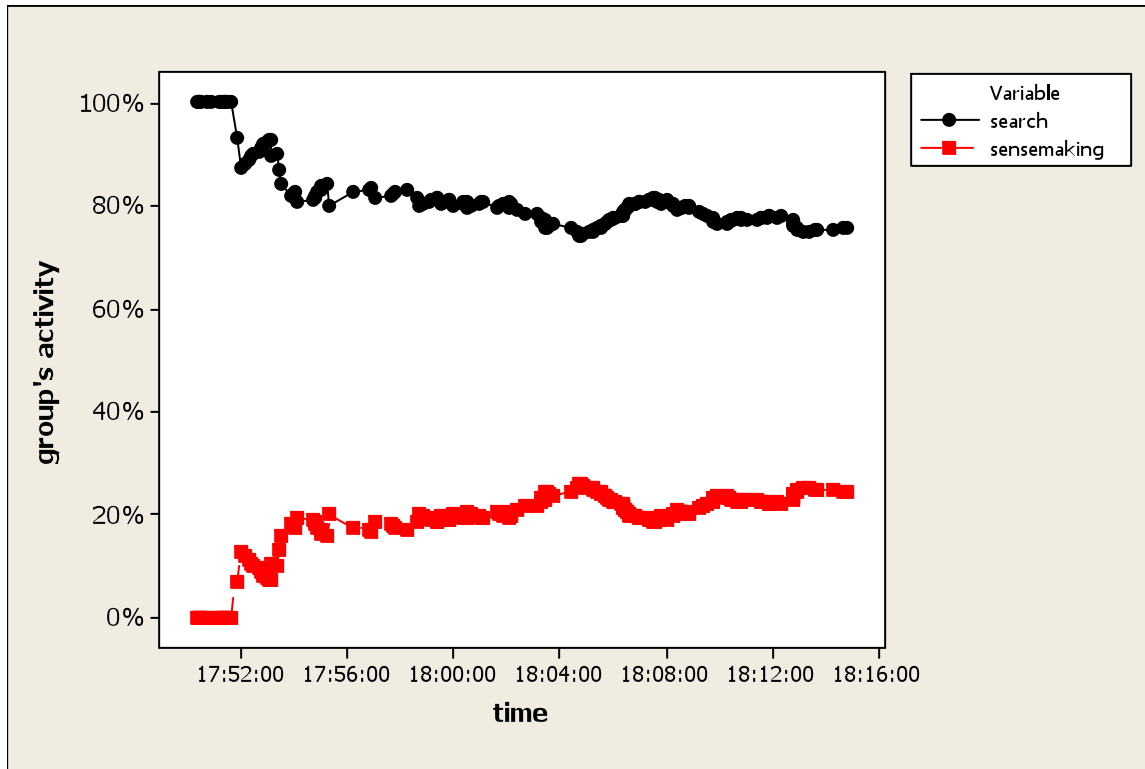


Figure 8(b). Categories of search and sensemaking actions during synchronous search (task 2) for the search-lead group

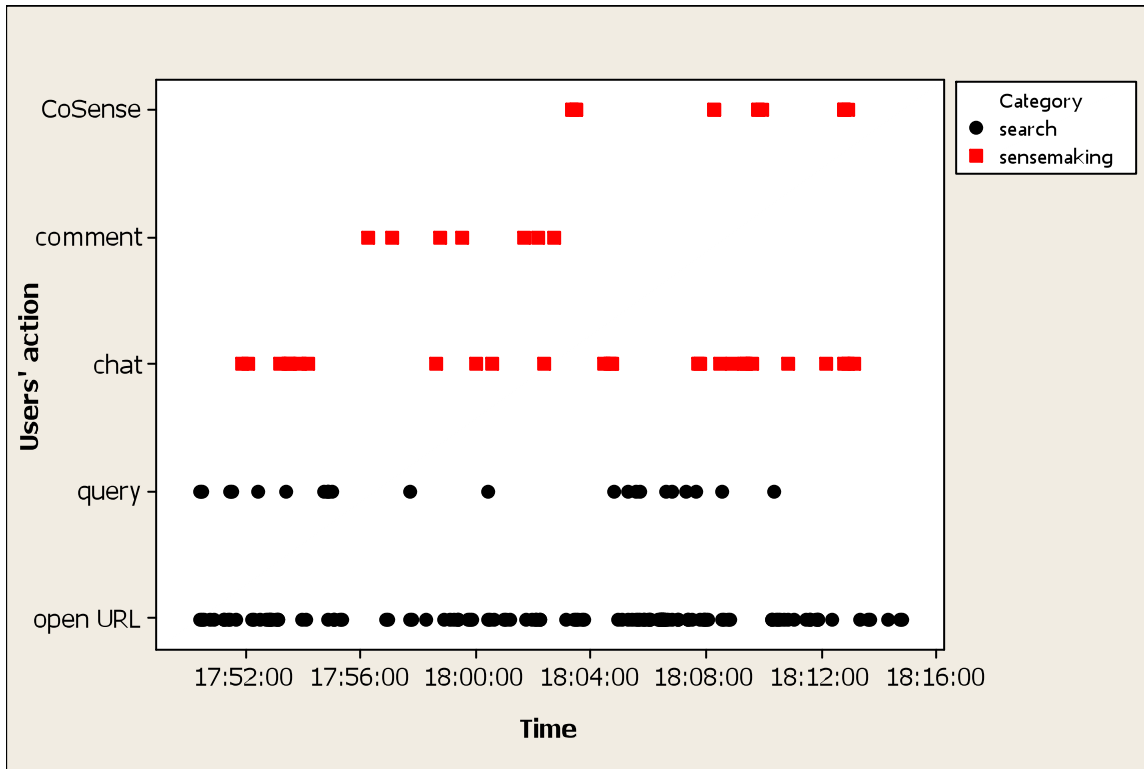


Figure 9. Workspace view of phase 1 group conducting task 2 shows that they recorded four activities in the scratch-pad. The other group did not note anything in either the to-do or scratchpad areas.

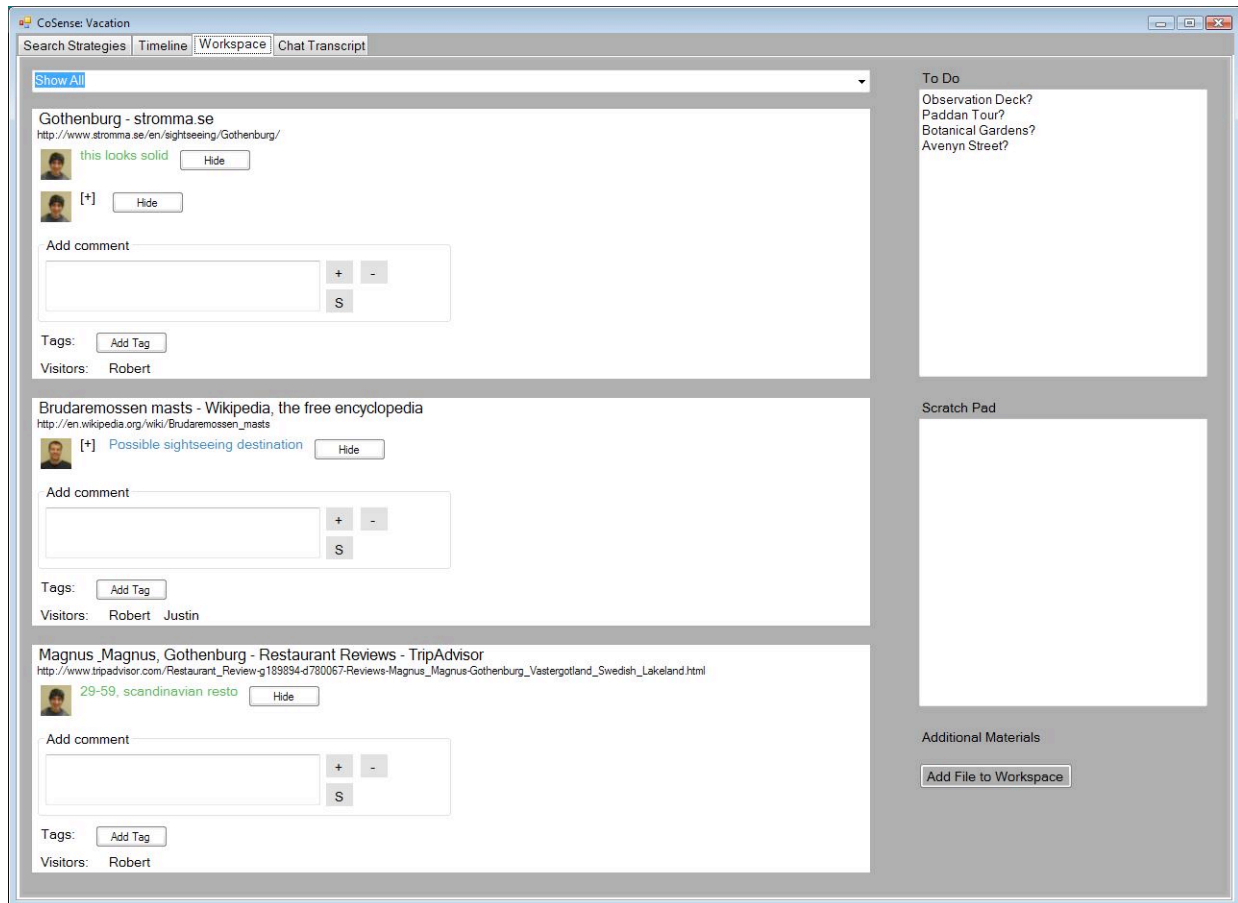


Figure 10. Content generated by phase 1 groups for both tasks

	URL visits	Queries	Chat messages	Comments
Task 1 group	98	16	75	4
Task 2 group	120	22	26	7

Figure 11(a). Proportion of search and sensemaking of during asynchronous search for a phase 2 participant (task 2). This participant had a search-lead strategy

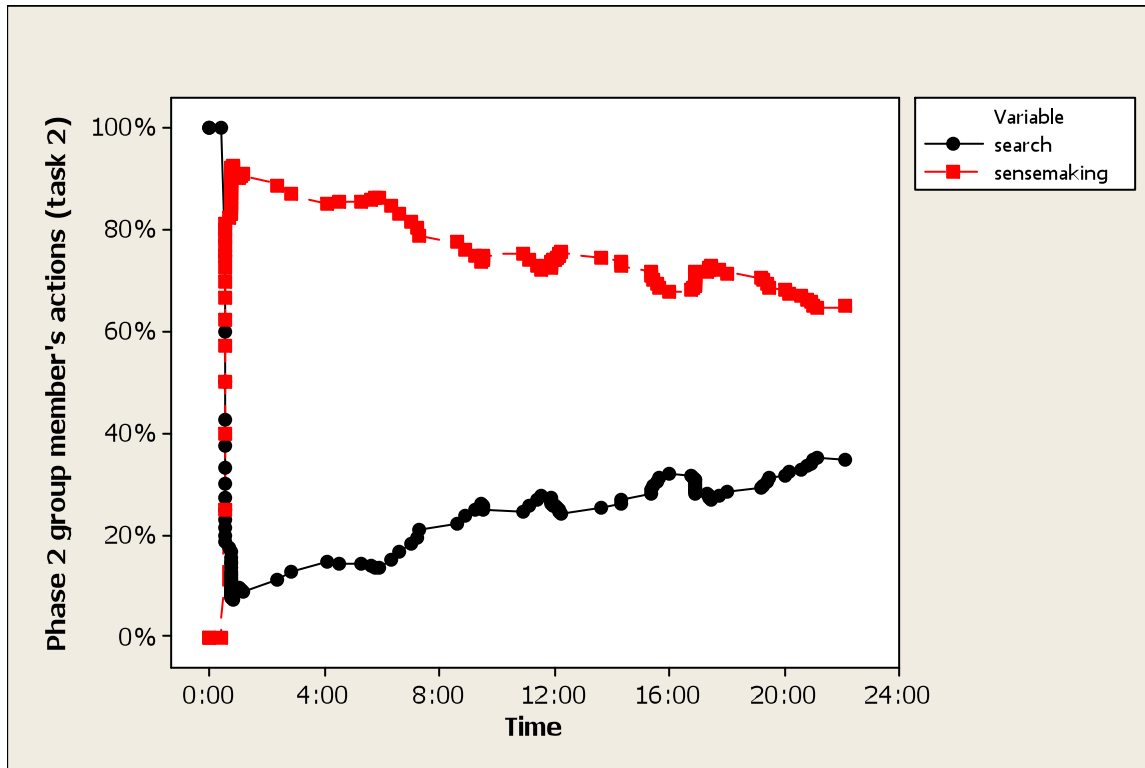


Figure 11(b). Categories of search and sensemaking during asynchronous search for phase 2 participant (task 2) with a search-lead strategy.

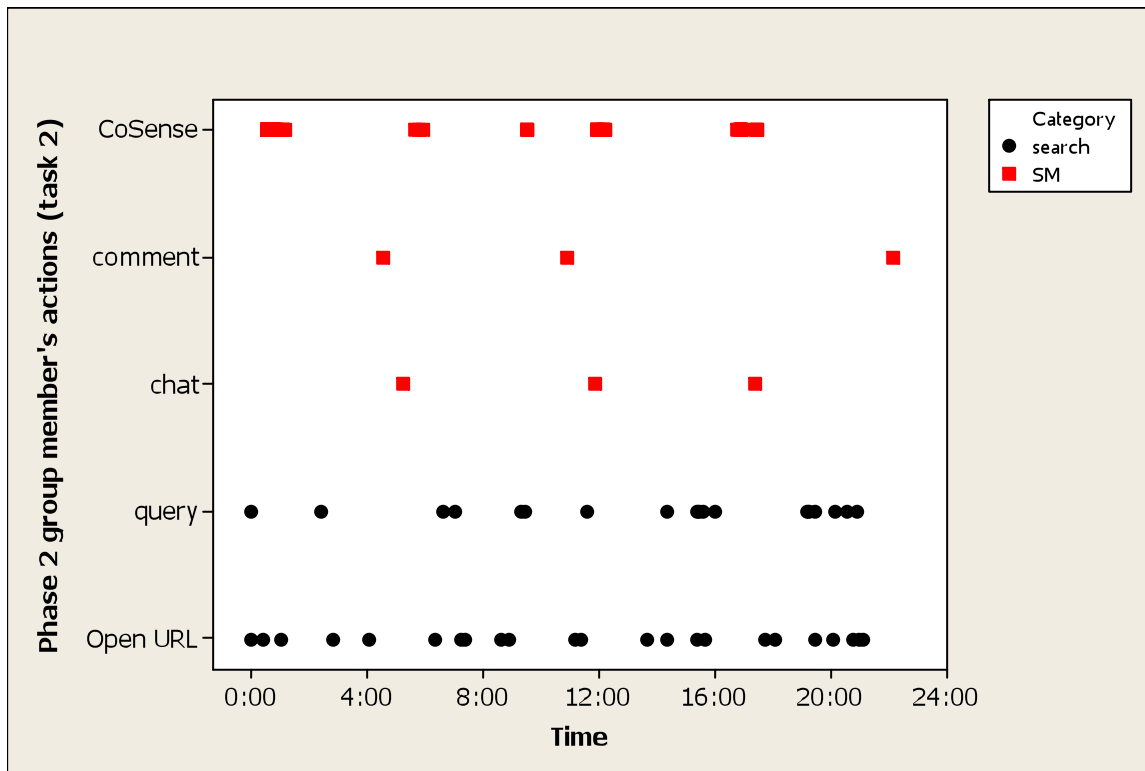


Figure 12(a). Proportion of search and sensemaking during asynchronous search for a phase 2 participant (task 1). This participant had a sensemaking-lead strategy.

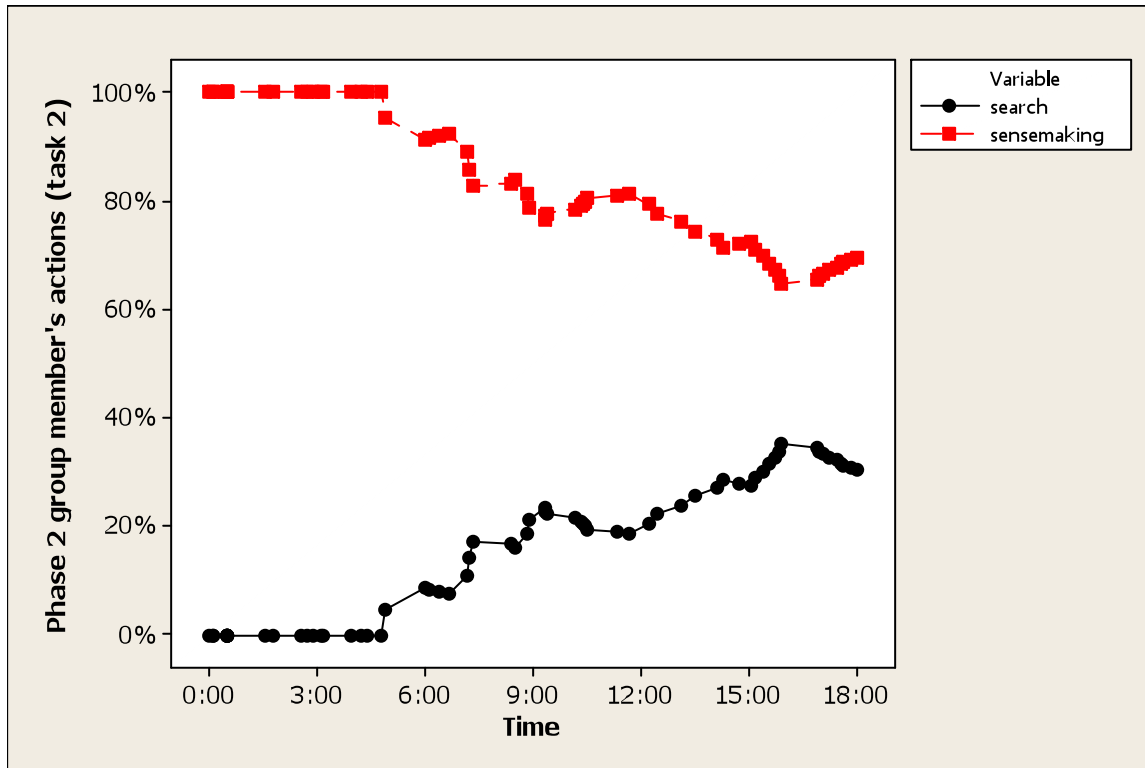


Figure 12(b). Categories of search and sensemaking during asynchronous search for a phase 2 participant (task 1) with a sensemaking-lead strategy

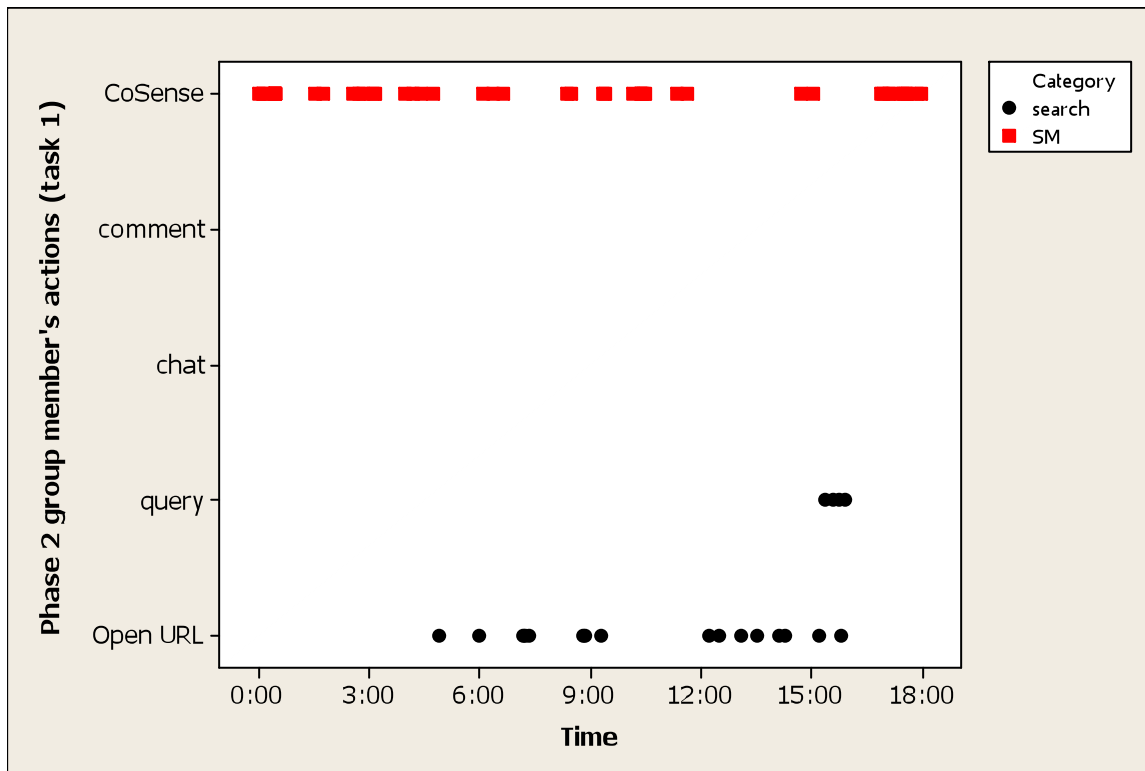


Figure 13. CoSense views used to answer questions in the questionnaire

View	Questions answered using the view
Search strategies	group members' search skills (Q2) relative importance of websites (Q4)
Timeline	how group members' search strategies influenced each other (Q5) which pages generated more discussion (Q6) which queries were most successful (Q7)
Workspace	Contributions of group members (Q1) Roles of group members (Q3)
Chat-centric	Contributions of group members (Q1) Decisions reached (Q8)

Figure 14. Time taken and view switches to answer questions in the questionnaire

Time to answer question		View switches to answer question	
Phase 1: Synchronous search			
Question	Time	Question	View switches
Longest times		Most view switches	
Q1	2.08	Q2	21
Q2	2.03	Q4	14
Shortest time		Least view switches	
Q9	0.6	Q9	0
Phase 2: Asynchronous search			
Question	Time	Question	View switches
Longest times		Most view switches	
Q1	1.51	Q7	28
Q3	1.38	Q1	26
Shortest time		Least view switches	
Q9	0.49	Q9	0

Figure 15. Procedure followed for sensemaking in asynchronous search by participants with search-lead and sensemaking-lead strategies.

Search-lead strategy	Sensemaking-strategy
<p>1. Understand task-related information</p> <p>1.1. Find and understand new information</p> <p>a. Issue generic queries e.g. “Gothenburg”, “Helsinki attractions”</p> <p>b. Visit generic websites e.g. Wikipedia.com, traveladvisor.com OR</p> <p>a. Issue queries specific to task categories e.g. “cultural activity Gothenburg”</p> <p>b. Visit Web pages specific to task categories e.g. Wikipedia article about Gothenburg book fair</p> <p>[1.2 Record understanding of new information</p> <p>a. Comment on Web pages e.g. “I like it, we should do it”</p> <p>b. Leave chat messages or to do items for others e.g. “25 Euros for a meal per person”</p> <p>c. Create representations to map task categories to information found Use the workspace in CoSense or create external documents]</p> <p>1.3. Understand information found by others</p> <p>a. View queries used by others Use search strategies view in CoSense or query history in SearchTogether</p> <p>b. Visit Web pages found by others Use the summary in SearchTogether or the timeline and workspace in CoSense</p> <p>c. View chat messages of others Use the timeline or chat-centric view in CoSense</p> <p>[1.4. Record understanding of information found by others</p> <p>a. Comment on Web pages e.g. “I like it, we should do this”</p> <p>b. Leave chat messages or to-do items for others e.g. “25 Euros for a meal per person”</p> <p>c. Create representation to map task</p>	<p>1. Understand task-related information</p> <p>1.1. Understand information found by others</p> <p>a. View queries used by others Use search strategies view in CoSense or query history in SearchTogether</p> <p>b. Visit Web pages found by others Use the summary in SearchTogether or the timeline and workspace in CoSense</p> <p>c. View chat messages of others Use the timeline or chat-centric view in CoSense</p> <p>[1.2. Record understanding of information found by others</p> <p>a. Comment on Web pages e.g. “It’s just a radio tower, why would you want to see that?”</p> <p>b. Create representation to map task categories to information found] Use the workspace in CoSense or create an external document]</p> <p>1.3. Find and understand new information</p> <p>a. Issue queries specific to others preferences, suggestions, and recommendations e.g. “Helsinki restaurant reindeer”, “Helsinki attractions”</p> <p>b. Visit websites returned by above queries e.g. hotels-helsinki.com/restaurants/ OR</p> <p>a. Issue queries specific to task categories not covered by others e.g. “Helsinki museums”</p> <p>b. Visit websites returned by above queries e.g. Helsinki.fi article on various museums in Helsinki</p> <p>[1.4. Record understanding of new information</p> <p>a. Comment on Web pages e.g. “nice restaurants here”</p> <p>b. Leave chat messages or to-do items for others e.g. “Suomenlina – two random pick? Ask for preference”</p>

<p>categories to information found Use the workspace in CoSense or create an external document]</p> <p>2. Understand task state and progress on goals </p> <p>3. Understand group dynamics information </p>	<p>c. Create representation to map task categories to information found Use the workspace in CoSense or create an external document]</p> <p>2. Understand task state and progress on goals </p> <p>3. Understand group dynamics information </p>
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Figure 16. Classification of chat messages during synchronous search

Chat message categories	“sense” contained in the message
Pointers to information sources “http://en.wikipedia.org/wiki/Brudarremosen_masts (tall tower with observation deck) “there’s a street that’s free: http://www.avenyn.se”	Description of landmark Matching cost constraints
Constraint satisfaction “paddan tour is 13 euros”	Matching cost constraints
Tool usage tips “use the CoSense”	Tool feature to use for sharing information
Suggestions On an activity “We should do both paddan tour and check out the observation deck” On an information source “There is an itinerary at frommers.com”	Activities to consider for the task Information source to consider for the task
Recommendations On an activity “The amusement park looks like fun, but only open on weekends in September” (thumbs up) On an information source “The itinerary [at frommers.com] is nice”	Activity might be of interest to the group Information source might be of interest to the group
Preferences “They serve reindeer at this restaurant “Aino”. I’d like to go there.” ‘I don’t like amusements parks”	Activity might be of personal interest Activity might not be of personal interest

Appendix A. CoSense Evaluation Study: Post-task Questionnaire

1. Which group members do you think contributed most to the task? Why?
2. Which group member was the most skilled searcher? Why?
3. What aspect of the task did each group member work on?
4. Which websites did the group find most helpful for this task?
5. Were any group members' search strategies influenced by others? If so, how and why?
6. Which websites generated a lot of discussion?
7. Which queries were the most successful?
8. What decision, if any, did the group reach regarding the trip's itinerary?
9. What steps, if any, remain before the itinerary is complete?
10. What is your name?
11. What is your age?
12. What is your gender?

Appendix B. CoSense Evaluation Study: Interview Questions for Phase 2 Participants

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

1. Rate your expertise (with respect to the general population) in searching for information online

1	2	3	4	5
Novice	below average	Average	above average	expert

2. What was the 'status' of the search task when you resumed it?
3. How did you continue the task?
 - a. Did you follow the links to websites found by other group members?
 - b. How did you know which links or information sources to visit?
4. Are there any advantages you found in using SearchTogether and CoSense to collaborate with your group? If so, what were they?
5. Are there any features you would like to improve about SearchTogether and CoSense? If so, what were they?
6. How did you understand what your other group members had already done?
 - c. What features of SearchTogether and CoSense helped you understand this?
 - d. Were there aspects of what your group had done before that you found confusing or that you didn't understand?
7. Do you think CoSense helped you better understand what other group members had done online? If so, how?
8. Did you feel the need to communicate with other group members while you were performing the task? If so, for what?
9. Did you create any artifacts (notes, diagrams) outside of SearchTogether to help you accomplish the task?
 - e. Did you use any non-electronic artifacts created by the group (such as maps, diagrams etc.)? If so, how?
10. Do you think you were successful in finding things to do in Finland/Sweden given the time you were allotted? If no, why not?
11. Any general comments for us?