Understanding and Supporting Collaborative Sensemaking in Collaborative Information Seeking

Yihan Tao

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Declaration of Originality

I, Yihan Tao, hereby declare that the work presented in this thesis is my own, and that this thesis has not been submitted, either in the same or different form, to this or any other university for a degree.

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Abstract

With the ubiquity of current information retrieval systems, users move beyond individual searching to performing complex and exploratory information seeking tasks together with collaborators for social, leisure or professional purposes. As a consequence, collaborative information seeking (CIS) systems become popular to support users for CIS tasks. These CIS systems aimed at enhancing the awareness of each others activities between collaborators but provide little support for collaborative sensemaking of the CIS task and related information together. To design tools for collaborative sensemaking, we lack an understanding of how users perform collaborative sensemaking and what support they need for collaborative sensemaking in CIS. Therefore, the aim of this thesis is to understand user strategies for collaborative sensemaking and the challenges they face in collaborative sensemaking, and to design tools to support collaborative sensemaking in CIS.

In this thesis, we first present an exploratory study that investigates how users perform collaborative sensemaking, and the challenges they encountered in CIS. A follow-up study then compared the collaborative sensemaking behaviour and challenges users encountered between different CIS tasks. Through a comparative analysis, we acquired an understanding of the difference of collaborative sensemaking behaviour according to task as well as the general patterns in collaborative sensemaking behaviour and the challenges that users face. Based on the findings from our user studies, we proposed and designed a tool MakeSenseTogether, with novel topic-related features, to support collaborative sensemaking behaviour. An evaluation study of MakeSenseTogether shows that the topic-related features improved user experience of collaborative sensemaking in CIS.

This thesis contributes to our understanding of collaborative sensemaking in CIS in two ways. Firstly, we gain a comprehensive understanding of the general process of collaborative sensemaking and the challenges users face. Secondly, we proposed novel topic-related features which can improve users experience in collaborative sensemaking.

List of Publications

Tao, Y.,and Tombros, A. (201X). How collaborators make sense of the task together: a comparative analysis of collaborative sensemaking behaviour in different tasks. *In Submission to Journal of the Association for Information Science and Technology.*

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Tao, Y., and Tombros, A. (2013). An exploratory study of sensemaking in collaborative information seeking. In *Proceedings of the 35th European conference on Information Retrieval (ECIR'13),* pages 26-37, Moscow, Russia.

Contents

List of Tables

List of Figures

Chapter 1

Introduction

Searching the web with friends, family or colleagues to solve an information seeking task together is very common these days (Morris, 2008, 2013). For example, people search for tourist information online with friends to plan for a holiday together and search the web with colleagues to solve a technical problem together. Alternative to individual information seeking, two or more persons collaboratively resolving a shared information need is known as *collaborative information seeking* (CIS) (Poltrock et al., 2003).

Usually, people rely on the web browser and the search engine to perform information seeking tasks. Search engines enable users to locate the most relevant information on the Web in response to search queries in seconds. However, they do not support multiple users in performing information seeking tasks collaboratively. Working together on a information seeking task, people employ additional communication tools, such as emails, conference calls and instant messaging to exchange information with collaborators (Morris, 2008; Capra et al., 2010).

CIS systems (Morris and Horvitz, 2007; Shah, 2010; Diriye and Golovchinsky, 2012) have been designed to address the lack of an integrated and shared workspace for people to conduct information seeking tasks collaboratively. These CIS systems enable users to coordinate their search activities and thus to find information more efficiently, but provide little support for understanding and using the information found to solve the shared information need. For example, SearchTogether (Morris and Horvitz, 2007) supports CIS tasks from three aspects: firstly, it enhances the awareness of collaborators' search activities, such as queries and visited webpages; secondly, it provide mechanisms for both manually and automatically dividing labour between

collaborators; and finally, it facilitate the persistence of task state by providing a chronological representation of the webpages which are rated as useful. All of the three aspects focus on enabling users to search for information together. However, as people usually collaborate to resolve a complex information need rather than simple fact finding tasks (Spence et al., 2005; Reddy and Jansen, 2008), an important and challenging aspect of CIS is *collaborative sensemaking*, which refers to collaboratively making sense of information collected and creating a shared understanding of the task problem (Paul and Reddy, 2010; Umapathy, 2010). Recognising the importance and challenges of collaborative sensemaking, some researchers (Paul and Morris, 2009a; Umapathy, 2010) have pointed out that collaborative sensemaking is not sufficiently supported in current CIS systems.

Therefore, in this thesis we focus on understanding and supporting collaborative sensemaking behaviour in CIS.

1.1 Motivation

In general, sensemaking is the process of understanding a problem or topic through iteratively building a mental structure to incorporate the data collected, synthesising the data into the structure and constantly adjusting the structure and data to create a knowledge product (Russell et al., 1993; Pirolli and Card, 2005; Klein et al., 2006). In individual sensemaking, the structure is usually formed during the process of searching for data, and can exist only in a person's mind. However, in collaborative sensemaking, multiple individuals work towards a shared understanding. Their individual findings and understanding need to be externalised and shared with collaborators during the sensemaking process (Qu and Hansen, 2008). Therefore, collaborative sensemaking can be more complex than, and is not simply an aggregation of, individual sensemaking.

Several CIS systems (Morris and Horvitz, 2007; Diriye and Golovchinsky, 2012) take into account the sensemaking aspect in their design. These systems mainly focus on supporting for the awareness of collaborators' search results. For example, SearchTogether (Morris and Horvitz, 2007) allows users to append ratings and comments to webpages and provides a summary view of the webpages which are rated as useful by group members. Querium (Diriye and Golovchinsky, 2012) also provides a summary view of information including queries, shared documents and viewed documents in a search session. These CIS systems, however, do not support for the sharing of the mental models about the task problem which are established through indi-

vidual searching, and for the creation of a shared understanding based on the information found. CoSense (Paul and Morris, 2009a), a tool designed to enhance the support for collaborative sense-making in CIS systems, focus on helping user understand the sensemaking process. It provides four different views (search strategies, timeline, chat-centric and workspace) to visualise information related to different aspects of the task process, but provides little support for users to collaboratively understand and synthesise information related to the task problem.

To develop effective tools to support collaborative sensemaking in CIS tasks, we also lack a theoretical understanding of the collaborative sensemaking process. Collaborative sensemaking behaviour has been studied mostly in specific domains, such as healthcare in the emergency department (Paul and Reddy, 2010), patent searches (Bhavnani et al., 2008) and crisis management (Muhren and de Walle, 2010). In these areas, users usually carry out professional information seeking tasks using specialised information systems. As far as we know from literature, no studies investigate the collaborative sensemaking behaviour in everyday CIS tasks, such as travel planning and literature search Morris (2008, 2013), which are carried out on the Web.

Therefore, this thesis aims at filling the gap in the state of the art in CIS by looking at support collaborative sensemaking for common CIS tasks. To do so, we first investigate how users perform collaborative sensemaking and the challenges they face in common CIS tasks. Based on a thorough understanding of the collaborative sensemaking challenges, we then develop a tool, MakeSenseTogether, with novel topic-related features to address the lack of support for collaborative sensemaking in CIS. We evaluate this tool with users and provide insights into how the novel topic-related features influence collaborative sensemaking behaviour.

1.2 Research Contributions

The work presented in this thesis contains two part: firstly understanding collaborative sensemaking behaviour in CIS tasks through user studies, and then supporting collaborative sensemaking in CIS using a user-centred approach. In this section, we briefly describe each part of the work and contributions made to the research of CIS.

For understanding collaborative sensemaking, we present two user studies in chapter 4 and 5 with travel planning and topic research tasks respectively. These studies address the gap in literature that no studies have looked at collaborative sensemaking behaviour in everyday CIS tasks (e.g. travel planning, university group work) performed on the Web, and made the following

contributions to our theoretical understanding of collaborative sensemaking in CIS:

- **Contribution 1**: Based on an analysis of user behaviour in both travel planing and topic research task, we identify the main activities involved in collaborative sensemaking for CIS tasks and derive a model of the general process of collaborative sensemaking. This model provides a framework for researchers to study the collaborative sensemaking behaviour in CIS tasks.

- **Contribution 2**: We present a comparative analysis of collaborative sensemaking behaviour between the travel planning and topic research tasks in chapter 5. This comparison address the gap in literature that no studies have looked into how task influence collaborative sensemaking behaviour. Results of the comparative analysis suggest that the collaborative sensemaking strategies users employed can be different depending on the task. This finding has implications for supporting collaborative sensemaking for different CIS tasks.

- **Contribution 3**: In the user studies, we also investigate the collaborative sensemaking challenges users face in the travel planning and topic research tasks. The thorough understanding of collaborative sensemaking challenges in CIS provide insights into aspects of collaborative sensemaking which require support.

For supporting collaborative sensemaking, we develop and evaluate a tool to support collaborative sensemaking, focusing on the common challenges found in our user studies. In chapter 6, we proposed the tool, MakeSenseTogether, with novel topic-related features to support collaborative sensemaking in CIS tasks. We evaluate MakeSenseTogether with users in a lab study presented in chapter 7. This part of work has the following contribution:

- **Contribution 4**: The tool, MakeSenseTogether, proposes a new way to support collaborative sensemaking, addressing the user requirements that we gathered through user studies. The evaluation study shows that the topic-related features of our tool significantly and consistently improve user experience of collaborative sensemaking. In the evaluation study, we also compared collaborative sensemaking behaviour using our proposed tool with that in previous user studies that are presented in chapter 4 and 5. This comparison provides insights into the influences of our proposed tool on collaborative sensemaking behaviour.

1.3   Thesis Outline

In this section, we outline the structure of the rest of this thesis and introduce the contents of each chapter.

Chapter 2 provides a comprehensive review of the literature on collaborative information seeking and sensemaking, mainly from the field of information seeking and retrieval, human computer interaction (HCI), and computer supported collaborative work (CSCW). This review covers both theoretical and practical research on collaborative information seeking and sensemaking.

Chapter 3 outlines the research questions of this thesis based on the research gaps that are identified in chapter 2, and introduce the methodology we employ for addressing the research questions of this thesis, including user studies, interaction design, qualitative data analysis and statistical testing. We also describe the research flow of the thesis.

Chapter 4 presents an exploratory study to investigate how users collaboratively make sense of the task and what sensemaking challenges users face. We discuss the findings from this study to reflect on design implications for supporting collaborative sensemaking in CIS.

Chapter 5 reports a comparative study to investigate the general patterns and differences in collaborative sensemaking behaviour between two CIS tasks, namely travel planning and topic research. We also identify the common challenges of collaborative sensemaking.

Chapter 6 describes MakeSenseTogether, a tool we designed to support collaborative sensemaking, focusing on the common challenges we identified from user studies. We first introduce the design concepts which are derived from the user studies described in chapters 4 and 5. We then describe the design process and features of MakeSenseTogether.

Chapter 7 presents an evaluation study of MakeSenseTogether with users, focusing on how users interact with MakeSenseTogether to perform collaborative sensemaking activities in CIS tasks. Furthermore, we investigate the influence of the novel topic-related features on collaborative sensemaking behaviour

Chapter 8 provides a conclusion of our work according to the research questions proposed in chapter 3 and an overview of the main contributions of this thesis. In addition, we outline the limitations of this thesis and research directions that are worth further investigation.

Chapter 2

Literature Review

This thesis involves two interdisciplinary research areas: collaborative information seeking and sensemaking. In this chapter, we present a review of the related work from various domains including information seeking and retrieval, cognitive science, human computer interaction (HCI) and computer supported cooperative work (CSCW). This review aims to provide a context for the thesis and to identify the research gaps in the literature.

We first provide an overview of CIS in section 2.1, with respect to the definitions, tasks, models and supporting systems, and in section 2.2, we review the influence of search task on information seeking behaviour. In section 2.3, we discuss the sensemaking theories and tools for information seeking at individual level. In section 2.4, we introduce the concept of collaborative sensemaking in the context of CIS, and summarise existing knowledge on collaborative sensemaking, including the challenges and supporting tools. Finally in section 2.5, we summarise the research gaps that are identified from the review of the literature.

2.1 Collaborative Information Seeking (CIS)

The work of this thesis is set in the context of CIS. As CIS is an interdisciplinary research field related to the domain of information seeking and retrieval, HCI and CSCW. Researchers have applied theories and models of information seeking at individual level to CIS, carried out empirical studies to explore user behaviour in CIS and designed systems to support the CIS process. In the following, we summarise and discuss the literature related to CIS in terms of its definitions, tasks, models, and supporting systems.

2.1.1   Definitions and Dimensions of Collaborative Information Seeking

While there is not an universally accepted definition, CIS is broadly recognised as "*the activities that a group or team of people undertakes to identify and resolve a shared information need*" (Poltrock et al., 2003, p.239) and "*the study of the systems and practices that enable individuals to collaborate during the seeking, searching, and retrieval of information*" (Foster, 2006, p.330). Some researchers also referred to this research area as collaborative information retrieval (CIR) (Hansen and Järvelin, 2005; Foley et al., 2010; Pickens et al., 2008a), collaborative exploratory search (Pickens and Golovchinsky, 2007; Shelby and Capra, 2011) and collaborative web search (Morris and Teevan, 2009; Paul and Morris, 2011; Kelly and Payne, 2014).

In general, CIS practices can be categorised according to the dimensions of *intent, depth of mediation, concurrency* and *location* (Golovchinsky et al., 2009). More specifically, peoples' intent of collaboration can be explicit and implicit. In explicit collaboration, people know the existence of their collaborators and they carry out an information seeking task together towards a shared information need. For example, family members search for related information to plan for a holiday together. On the contrary, people do not interact with each other directly in implicit collaboration. Instead, the system suggest information to a user based on the historical data of other users. A typical application of implicit collaboration is collaborative filtering recommender systems (Schafer et al., 2007) which recommend items to a user based on the preference of similar users. In literature, CIS usually refers to explicit collaboration on information seeking in which "*groups of people actively participating as a team to gather information on a shared goal*" (Wilson and m. c. schraefel, 2009).

In terms of depth of mediation, most CIS systems (Amershi and Morris, 2008; Morris and Horvitz, 2007; Shah, 2010) support the CIS process at user interface level by facilitating sharing of information and shared awareness between users. However a few systems (Golovchinsky et al., 2008; Pickens et al., 2008b; Diriye and Golovchinsky, 2012) also mediate the CIS process at retrieval algorithm level, for example, suggesting queries and re-ranking search results according to collaborators search activities.

As for concurrency and locations, CIS can be carried out synchronously or asynchronously, and co-located or distributed. Co-located collaboration is usually also synchronous, in which collaborators work at the same place and can communicate face to face. Distributed collaboration could be more difficult compared to the co-located situation because collaborators need further

support, such as chat channels and a shared workspace to store information found, to coordinate their work. Synchronous but distributed collaborations are even more difficult as collaborators actively work on an information seeking task at the same time. They need a better coordination for the task, but the distributed setting could impose challenges for them to interact with each other in real time.

In this thesis, we define CIS as the process in which two or more individuals who share the same information need explicitly collaborate to solve an information seeking task. We especially focus on synchronous and distributed CIS practices that are the most challenging yet also the most common situation of CIS.

2.1.2 Collaborative Information Seeking Tasks

Despite search engines' focus on individual users, there are many cases in which people collaboratively search on the web to perform a search task. Investigating collaborative web search practices in everyday life, Morris (2008, 2013) reported the information seeking tasks that people usually perform collaboratively. Topics of these tasks are ranging from casual, such as travel planning and online shopping, to professional, such as literature search and finding technical information.

Several studies (Capra et al., 2011; Yue et al., 2014) suggest that CIS behaviour can be vary depending on the search tasks. Capra et al. (2011) investigated how task type impact user engagement in CIS. They studied one self-generated tasks and four assigned tasks. The four imposed task including a transactional task, a fact finding task and two exploratory tasks (collecting task and decision/planning task). Results demonstrate that user engagement are significantly different between self-generated and assigned task and also between different types of assigned tasks.

Yue et al. (2014) examined the differences in the search patterns in CIS between an academic task and a travel task. They thought the academic task represents an information gathering task while the travel task represents a decision making task. As they found, significant differences exist between the two tasks. For example, participants mostly focus on the detail of shared information in the decision making (travel) task while they focus more on the overview of workspace in the information gathering (academic) task.

While these studies suggest the influences of task on CIS behaviour, no studies have looked into the collaborative sensemaking behaviour in CIS. In section 2.2, we also present a detailed review of research on task types, task characteristics and their influence on individual information

seeking behaviour.

2.1.3   Models of Collaborative Information Seeking

In general, information seeking behaviour has been studied and modelled from different perspectives. Several standard models and theories of the information seeking process have been developed and can be summarised in the following three main streams:

- **Activity models**: One stream of the information seeking models depicts the information seeking process as a sequence of stages or activities (Kuhlthau, 1991; Sutcliffe and Ennis, 1998; Marchionini and White, 2007). For example, a widely recognised model proposed by Kuhlthau (1991) depicts the information seeking process in 6 stages: firstly a initiation stage in which the information need is recognised; followed by a selection stage in which a general topic related to the information is identified and the approach to seek information is chosen; then a exploration stage to search for information and gain a basic understanding of the chosen topic; and a formulation stage to decide the focus of the general topic; after that a collection stage to gather information on the focus topic; and finally a presentation stage in which the information seeker summarise and present the collected information.

- **Cognitive models**: The second stream focuses on the cognitive process of information seeking (Bates, 1989; Pirolli and Card, 2005). Typical examples include a berry-picking model (Bates, 1989), which point out that searchers' information need evolve as they search and learn the topic, and a sensemaking model by Pirolli and Card (2005), which considers the information seeking process consists of two loops: a foraging loop to collect information, and a sensemaking loop to analyse and synthesis information into a mental structure.

- **Strategic models**: The third stream describes information seeking as a strategic process which contains a number of search tactics (Bates, 1979), such as term tactics (e.g. rephrase query terms using the query suggestions mechanism search engine provided), information structure tactics (e.g. follow the hyperlinks on a webpage to find information) and monitoring tactics (e.g. comparing the current state with the original goal).

Some researchers applied and extended individual information seeking models to the context of CIS. Shah and González-Ibáñez (2010) re-examined the six-stage model of information

seeking process (Kuhlthau, 1991) in the CIS context. They found that the stages of formulating, exploring and collecting information can not be apparently differentiated in CIS, because of the interactions between collaborators. Yue et al. (2012) examined the CIS process from the view of search tactics and strategies, such as querying and browsing. Their findings also show that differences exist in the search tactics that users employed between collaborative and individual information seeking.

Field studies have also been carried out to model user behaviour in CIS in various domains. For example, Reddy and Spence (2008) conducted a study in the emergency department of a hospital to investigate CIS behaviour in a healthcare context. They found that the collaborative information needs of the patient care team focus on not only medical information but also on organisational information which is related to some coordination issues. In addition, they identified three triggers of CIS activities, namely, lack of expertise, lack of immediately accessible information and complexity of information need.
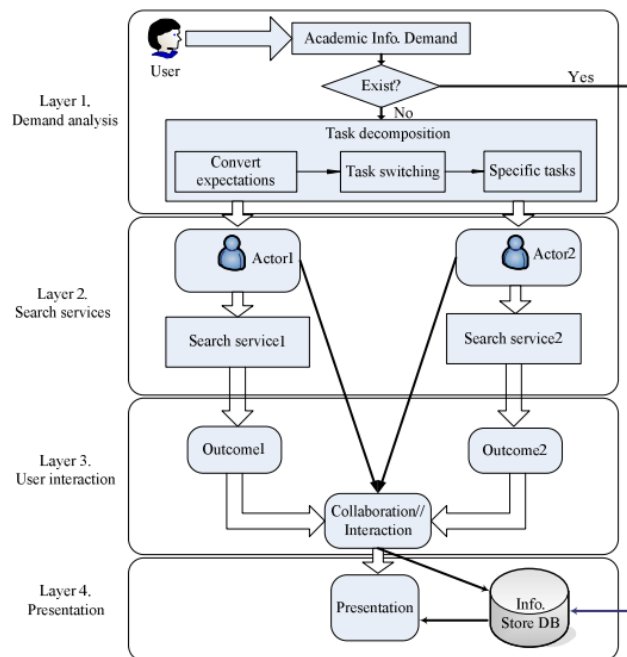
Figure 2.1: A 4-layer model of CIS behaviour for academic information (Shen, 2010)

Shen (2010) studied the CIS behaviour of researchers seeking academic information and proposed a four-layer model of the CIS process. As shown in Figure 2.1, the CIS process begins with a demand analysis layer in which researchers decompose the task into search topics, search service, user interaction and presentation. The second layer is the search services layer. In this

layer, researchers work on different search topics separately at the same time. The third layer of the model is user interaction in which researchers already have the outcome of their search topic and can interact and collaborate with each other. Collaborative information seeking ends with a presentation layer in which the outcome of the user interaction layer is stored for later use by other researchers who have the same academic information demand.

Karunakaran et al. (2013) proposed a model of collaborative information behaviour in an organisational context. As shown in Figure 2.2, this model depicts collaborative information behaviour in three phases, namely problem identification, collaborative information seeking and information use. Collaborative information seeking contains iterative activities of seeking, retrieving and sharing of information. Collaborative sensemaking and information sharing and evaluation are occurred in all three phases.
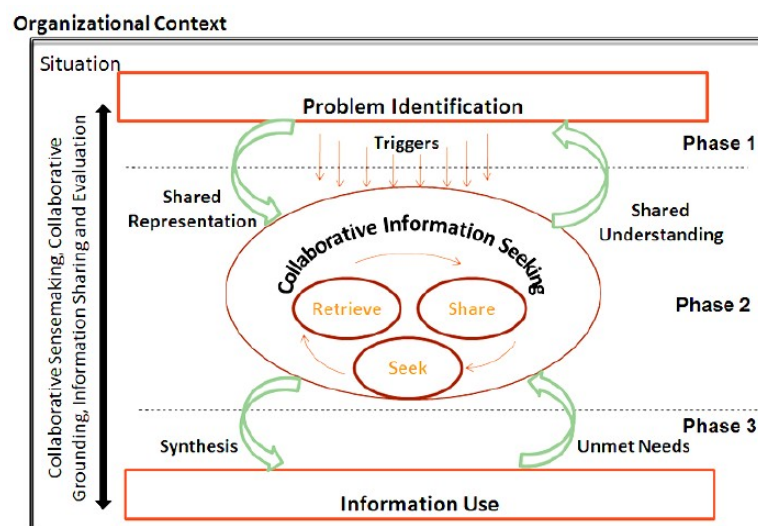
Figure 2.2: A 3-phase model of collaborative information behaviour in organisations (Karunakaran et al., 2013)

Despite that models of CIS behaviour have been derived from different contexts and provide some insights into the activities involved in CIS, there is not a universal model of CIS as those for individual information seeking. Studies on CIS behaviour suggest that the CIS process involves both information seeking activities and collaborative sensemaking activities to create a shared representation and a shared understanding. However, a comprehensive understanding of the CIS process, especially the sensemaking aspect, is lacking behind.

2.1.4 The Design Focus of Collaborative Information Seeking Systems

CIS systems have been designed to provide an integrated environment for collaborators to search, share and discuss search results together in a shared workspace. By looking into the design goals of several representative CIS systems (Morris and Horvitz, 2007; Shah, 2010; Diriye and Golovchinsky, 2012; Paul and Morris, 2009a), we found three common aspects that researchers focus on in the design of CIS systems: awareness, coordination and sensemaking.

Awareness

Supporting awareness is a well-discussed issue in the CSCW literature (Dourish and Bellotti, 1992; Schmidt, 2002). Awareness refers to "an understanding of the activities of others, which provides a context for your own activity" (Dourish and Bellotti, 1992, p.107). According to Liechti (2000), awareness can be categorised into four types:

- **Group awareness**: This type of awareness is aimed at providing information about the status and activities of group members.

- **Workspace awareness**: This refers to a higher level of awareness which allows users to work together in a shared space both synchronously and asynchronously.

- **Contextual awareness**: This kind of awareness is for the system to adjust the service according to what information is interesting to users in the current context.

- **Peripheral awareness**: This is related to the information which is presented in a way that does not actively attract the attention of users.

Most CIS systems (Morris and Horvitz, 2007; Shah, 2010; Diriye and Golovchinsky, 2012; Paul and Morris, 2009a) facilitate *group awareness* by providing information about collaborators' search activities such as queries, visited webpages and ratings or comments for webpages. Some of the systems (Shah, 2010; Paul and Morris, 2009a) provide *workspace awareness* by enabling collaborators to collect and synthesise information in a shared space. For example, Coagmento (Shah, 2010) provides a shared editor similar to Google Docs which enables collaborators to compose a report together. In terms of *contextual awareness*, Coagmento (Shah, 2010) presents the name of current task and the task topic description in the toolbar. CoSense (Paul and Morris, 2009a) presents a chat-centric view which shows the webpage which the user was viewing at the time a chat message is sent. For *peripheral awareness*, Coagmento (Shah, 2010) presents the group activity histories (documents and snippets saved, queries used, etc.) in the sidebar.

CIS systems usually provide as much information as they can to collaborators. However, Paul and Morris (2009a) found that users are sometimes confused and overwhelmed when confronting large amount of information provided by systems to support awareness. Shah and Marchionini (2010) also pointed out that awareness should be presented in a way that does not add extra cognitive load to collaborators.

Coordination: Communication and Division of labour

Supporting coordination is another important aspect in collaborative systems (Dourish and Bellotti, 1992). In CIS, two important issues related to coordination are communication of ideas and division of labour (Foley et al., 2010; Kelly and Payne, 2013). A communication channel is the basis for users to coordinate their activities. Most CIS systems provide text-based chat tools for collaborators to coordinate the process, including explicitly dividing labour between them. Some CIS systems also provide algorithmic mediation for division of labour. For example, SearchTogether (Morris and Horvitz, 2007) provides a recommendation mechanism and split search for users to distribute search results between them. Cerchiamo (Golovchinsky et al., 2008) facilitates division of labour by assigning explicit roles to group members. While the prospector is responsible of finding useful information sources and give it to the miner, the miner examines the search results and judges their relevance.

Sensemaking

Information seeking can be seen as a process which consists of finding information through searching and browsing, and synthesising and using information found to solve a information need (Pirolli and Card, 2005). Searching is only part of the information seeking task. In CIS, people need to make sense of the information found together. However, most CIS systems focus on supporting collaborative searching rather than supporting collaborative sensemaking.

Several CIS systems (Morris and Horvitz, 2007; Diriye and Golovchinsky, 2012; Paul and Morris, 2009a) support sensemaking through facilitating the awareness of the group search process and enabling the persistence of information in asynchronous collaboration. SearchTogether (Morris and Horvitz, 2007) support persistence through storing the shared search session. Querium (Diriye and Golovchinsky, 2012) support session-based sensemaking by presenting summary view of activities and allowing users to filter activities to show incremental results. CoSense (Paul and Morris, 2009a), a tool aimed at support sensemaking for collaborative web search, mainly focus on enhance activity and contextual awareness in different stages of CIS task

but provide little support for users to create a shared understanding from the collected information. It enhance different type of awareness by providing four views: search strategies view, timeline view, chat-centric view and workspace view. The detail of each view is discussed in section 2.4.2.

Paul and Morris (2009a) argues that in CIS, people need to make sense of the search products as well as the search process together with collaborators (Paul and Morris, 2009a). However, CIS systems only support sensemaking of the search process but not support understanding and use of search products to produce a knowledge product collaboratively.

2.2 The Influence of Task on Information Seeking Behaviour

Task is an important factor that influences information seeking behaviour. In literature, information seeking tasks were categorised from different facets and their influence on information seeking behaviour was extensively studied (Marchionini, 1989; Qiu, 1993; Kim, 2001; Kellar et al., 2007). In this section, we summarise the common categories used to characterise different types of task and the studies on how task type affects information seeking behaviour.

2.2.1 Closed Task vs. Open-ended Task

Marchionini (1989) studied the information seeking strategies and search patterns of elementary school students in closed and open-ended tasks. They used two different tasks in the study: (1) identify the year in which speed skating was introduced into the modern Olympic; and (2) finding information about women who have travelled in space. The first task is called a closed task which has only one correct answer, while the second task is referred to as an open-ended task which could have many possible answers and the answer could be multi-faceted. They found that participants spent longer time and takes more moves in the open-ended task than in the closed task.

More recently, Lee and Yoon (2014) carried out a study to examine the differences between users cognitive search strategies in open/purpose-driven task and in closed/target-specified task. They found that re-planing and goal reformulation were more frequent in the open task than in the closed task.

2.2.2 General Task vs. Specific Task

Qiu (1993) compared the search state patterns in hypertext information retrieval system between

two types of search tasks: general and specific tasks. The general task is finding information about hypertext systems and write a page of encyclopaedia entry for it. The specific task is finding answer to a specific question about hypertext system, e.g. what size should a node be. According to the description of the two type of tasks, general task and specific task can be mapped to open-ended task and closed task respectively as described in the work of Marchionini (1989). This study shows that in the specific task, users followed a structure search pattern while in the general task users were browsing randomly with no structured path.

2.2.3 Known-item Task vs. Subject Task

Kim (2001) investigated the impact of user and task factors on information seeking behaviour on the Web. Two types of tasks were used in their study, namely known-item task and subject task. The known-item task is defined as "finding a piece of information known to exist", while the subject task is defined as "task requiring the searcher to retrieve information that is related to the given subject or topic regarded as useful to the searcher". They pointed out that the known-item task can be mapped to the closed task and the specific task while subject task is comparable to the open-ended and the general task. They found in the study that task type and user experience interactively influence the search and navigational behaviour of users.

2.2.4 Factual, Interpretive and Exploratory Task

Kim (2007) adopted three types of task to study how task type influence users information seeking strategies. Factual task is the search task which has specific question and specific answer. Interpretive task is the task which has specific question but general answer. Exploratory task is the task with both general question and answer. The results of this study revealed that the frequency and pattern of information seeking strategies are vary among the three type of tasks.

2.2.5 Informational vs. Transactional Task

Saito et al. (2009) carried out a study investigating the influence of task type and user experience on search behaviour. They compared a report-writing task with a trip planning task. According to the categories proposed by Broder (2002), they refers to the former as an informational task and the latter as a transactional task . They found that the task impact users examination of results and the judgement of relevance. However, in both task, users followed a similar search process.

2.2.6   Fact Finding, Information Gathering, Browsing and Transactions

Kellar et al. (2007) examined user interaction with web browser in four different types of task, i.e. fact finding, information gathering, browsing and transactions. They found that each type of task are different in respect to characteristics such as task duration, number of pages viewed and the use of browser functions.

2.2.7   Characteristics of Work Tasks that Affect Information Seeking

Despite the different categories of search task used in studies, Kim (2007) pointed out that these categories are generated according to some common task attributes, including task structure, topic, goal, expected info and expected source. Except for task type, task actor (e.g. domain knowledge, perceived difficulty) and task situation (e.g. time, place) will also affect information seeking strategies. Li and Belkin (2008) proposed a comprehensive classification from the work task level which incorporate two categories of task facets. One of the categories is the common attributes of task, which includes both task characteristics, e.g. objective complexity and degree of structure, and user's perception of task such as subjective complexity and knowledge of task topic. Another category is the generic facets of task, such as source of task, product, and goal.

Studies (Bystrom and Järvelin, 1995; Li and Belkin, 2010; Liu et al., 2010) have explored the impact of various characteristics of task on information seeking behaviour. Bystrom and Järvelin (1995) carried out a study to examine the influence of task complexity on information seeking and use with respect to information types, channels and sources. They generated five types of task with different levels of complexity according to the certainty of information needs, process and target product. Results of the study indicate that as the task are more complex, multiple types of information, channels and sources are involved and problem reformulation and sensemaking are crucial.

Vakkari (1999) reviewed the related theory and empirical studies in literature and suggest that information seeking and retrieval behaviour are highly link to problem structure in addition to task complexity. He stated that the search strategies users employed for ill-structured and structured tasks are revealed to be different. As the focus of search is identified clearly in a structured task problem, users use querying as the main strategy, while browsing is employed to seeking structure in a unstructured task problem since the focus of search is vague and unknown.

Li and Belkin (2010) categorised work task according to product and objective task com-

plexity and probed the influence of work task on interactive information search behaviour. They found that both the two factors impact various aspects of search behaviour, such as the results pages viewed and the query length.

Liu et al. (2010) specified four task varied in four facets, namely product (mixed vs. factual), task level (document vs. segment), goal (specific vs. amorphous vs. combined) and objective complexity (high vs. low). They examined the task performance and eye movement between different type of task and found that users search behaviour are significantly associated with these task facets.

As described above, most of these studies focused on the influence of task on individual search behaviour, for example, the examination of search results, querying and browsing behaviour. No studies have explored the relationship between task and information seeking and sensemaking behaviour in the context of CIS.

2.3 Sensemaking

As an interdisciplinary concept, sensemaking has been extensively studied in information science (Dervin, 1983; Russell et al., 1993), organisational studies (Weick, 1995), human computer interaction (Pirolli and Card, 2005) and decision science (Hasan and Gould, 2001). As a result, models of sensemaking have been drawn from different perspectives. In the following, we review sensemaking theories in different fields and in particular discuss sensemaking related to information seeking.

2.3.1 Sensemaking Theories

One of the most important sensemaking theories in information science is Dervin's Sense-Making approach (Dervin, 1983) to study information seeking and use. In this approach, sensemaking is defined as the behaviour of people "*constructing information needs and uses for information*" to "*make sense of their worlds*" (Dervin, 1983). She argues that each action people make in the information seeking process is based on their understanding of the current information need. Sensemaking can be depicted as a gap bridging process which involves three elements: situations, gaps and uses. Sensemaking occurs when a person recognises a "gap" that impedes the person moving through time-space. The time-space context of the moment is called "situation". "Uses" refers to the way how information is assessed and put to work, either helpful or not. This

gap bridging metaphor of sensemaking depicts the role of sensemaking in information seeking and use. However, as the model is generic, it does not provide detailed information on how sense is constructed in the sensemaking process.
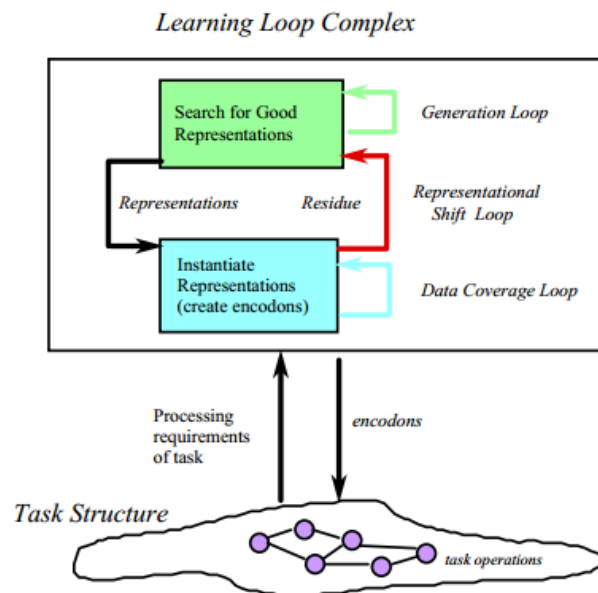
Figure 2.3: Russell et al.'s (1993) sensemaking model

Russell et al. (1993) proposed an cyclic model of sensemaking from the HCI perspective. They argue that in information-rich tasks, sensemaking is usually involved in the process of understanding and solving the problem. Sensemaking is an iterative process of searching for a representation (i.e. task structure) and incorporating information in it. As shown in Figure 2.3 the process of sensemaking contains three loops, a generation loop to find a good representation for the task; a data coverage loop to encode information into the representation; and a representational shift loop in which the representation is adjusted to fit data. This model addresses the iterative nature of sensemaking process. It highlights the two-way interaction between representation and information in individual sensemaking process at a strategic level.

Similarly, Klein et al.'s (2006) sensemaking model describes the cyclic process involved with "data" and "frame". Frame, which is the same as representation in Russell et al.'s model, is the "starting framework" that regulates the type of data and changes along the sensemaking process. As shown in Figure 2.4, the overall process of sensemaking is depicted as an elaboration cycle and a reframing cycle. The elaboration cycle is to elaborate the frame with data. When

the sensemaker finds the data do not fit well in the frame, the frame will be questioned and the sensemaker decides to either preserve the frame or conduct a reframing cycle to replace the frame. This model points out the important role frame plays in sensemaking and reveals the evolution of frame throughout the sensemaking process.
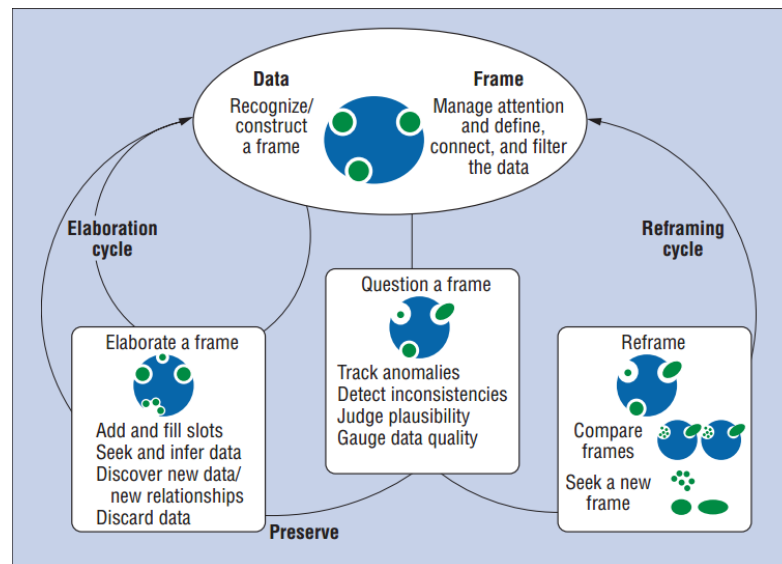
Figure 2.4: A data/frame model of sensemaking (Klein et al., 2006)

Beyond these conceptual models of sensemaking, some descriptive models elaborate the activities involved in the sensemaking process in more detail. Pirolli and Card (2005), for example, describe the overall process of a sensemaking task as two loops of activities: a foraging loop in which information is collected and a sensemaking loop in which collected information is understood and used. They also identified two directions in the information processing process: a bottom-up process from data to theory and a top-down process from theory to data. As shown in Figure 2.5, the bottom-up process consists of a series of activities from searching and filtering information, reading and extracting evidence, schematising information, building case to telling story. The top-down process starts from re-evaluating the presentation, to searching for support, evidence, relations and information.

Zhang et al. (2008) propose a comprehensive model of individual sensemaking in a professional setting which combines elements from cognitive science and learning theories. This model identifies four major activities which are envolved in the sensemaking process of intelligence analysis: identification of gaps (including data and structure gaps), building structures, instantiating structures and updating knowledge. As shown in Figure 2.6, these activities are
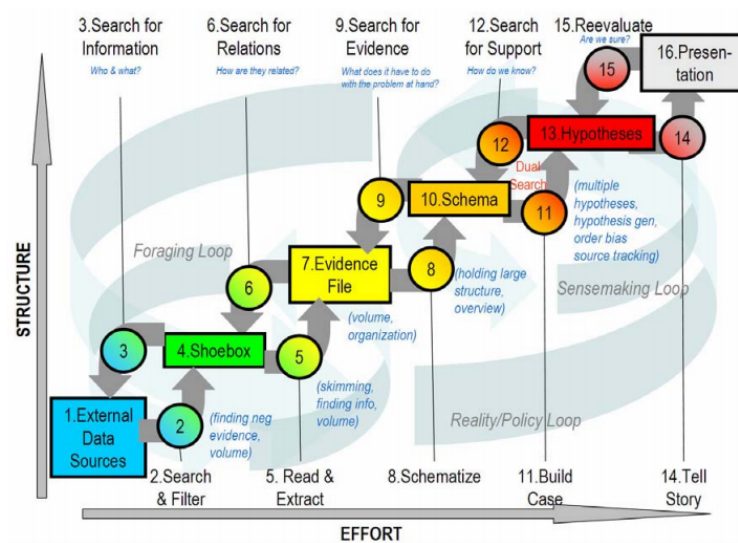
Figure 2.5: Pirolli and Card's (2005) sensemaking model

embedded in four stages of the general sensemaking process:

- *Task analysis stage*: Building an initial structure of the task situation from existing knowledge and deciding the strategy to accomplish the task.

- *Exploratory stage*: Identifying data or structure gaps and searching for background information of the task to establish an initial representation.

- *Focused stage*: Identifying specific questions about the task and searching for specific information. Sometimes also amending or restructuring the structure to create a more detailed or better representation.

- *Updates of knowledge representation*: This is usually embedded in the whole sensemaking processes, but sometimes participants also make the updates of representation explicitly.

In this model, Zhang et al. also identified two approaches for sensemaking, data-driven and structure-driven, which are similar to the bottom-up and top-down processes in Pirolli and Card's (2005) sensemaking model.

- The **data-driven (bottom-up)** approach is establishing focuses of the task from data, e.g. extracting key item from information found and summarising the collected information.

- The **structure-driven (top-down)** approach is discovering a new focus of the task from conceptual analysis, e.g. identifying different structural aspects of a concepts and specifying the structure of a concepts with detail.

The iterations typically proceed from task analysis to **exploratory** and then to **focused** search and sense-making.
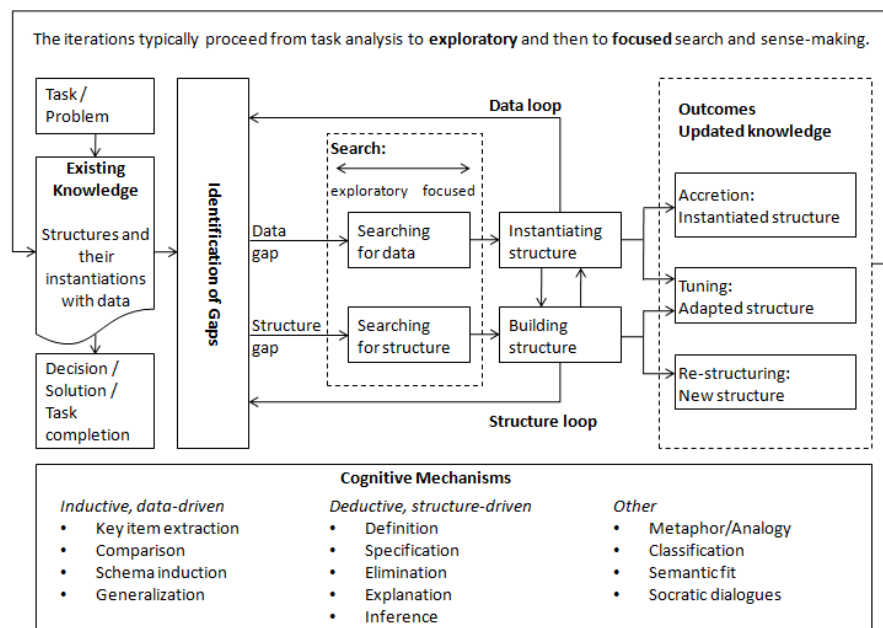
Figure 2.6: A comprehensive model of sensemaking (Zhang et al., 2008)

To the best of our knowledge, models of sensemaking process are only developed for individual cases. We lack an understanding of how these models can be extended to a collaborative context in which multiple individuals work towards a shared understanding.

2.3.2 Sensemaking Tools for Information Seeking Tasks

Sensemaking tools (Qu, 2003; Ryder and Anderson, 2009; Gotz, 2007) has been designed to support the sensemaking process for information seeking task. The sensemaking-supporting information gathering system (SSIGS) (Qu, 2003) provides an integrated workspace for both information gathering and representation building from the gathered information. SSIGS is designed based on Russell et al.'s (1993) sensemaking theory and is focused on the creation of an external representation. As can be seen in Figure 2.7, the system enables users to collect information and organise information using folders arranged in a hierarchical structure.

Coalesce (Ryder and Anderson, 2009) is a web-based tool supporting sensemaking through facilitating representation construction. As shown in Figure 2.8, Coalesce has a "SenseMap" feature with tagging mechanism which helps users construct structural representation from information.

The ScratchPad (Gotz, 2007) is also a web browser based tool helping users capture, organise and use information during a sensemaking task. The interface of the system is shown in Figure
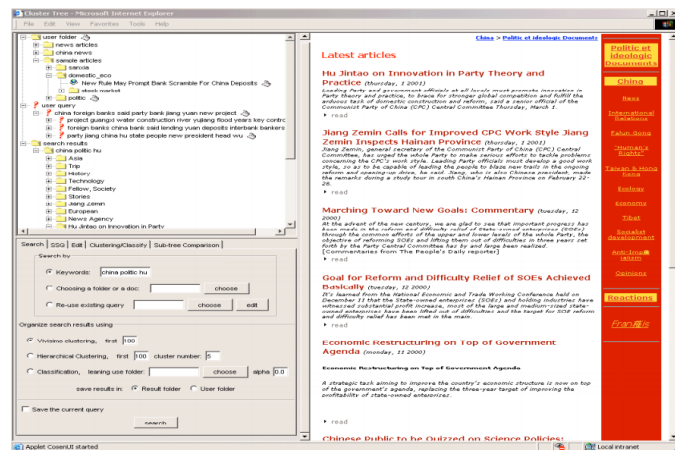
Figure 2.7: The user interface of SSIGS (Qu, 2003)
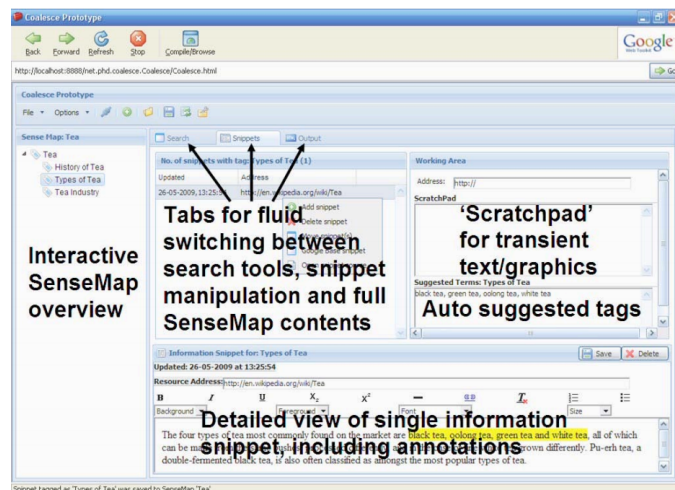
Figure 2.8: The user interface of Coalesce (Ryder and Anderson, 2009)

2.9. The tool allows users to collect information through dragging the elements such as URL, images and text segments from webpages to workspace. It also supports manipulation of the collected information, including modifying and relating information. Algorithms are developed to automatically detect the relevance between the current web page and saved information and inform users the relevance level by different colours.

Most sensemaking tools are designed to help individuals make sense of information collected in the information seeking process and especially to help users construct representation from information. However, the existing sensemaking support might not be sufficient for collaborative sensemaking in CIS which several individuals working on a information seeking task together.
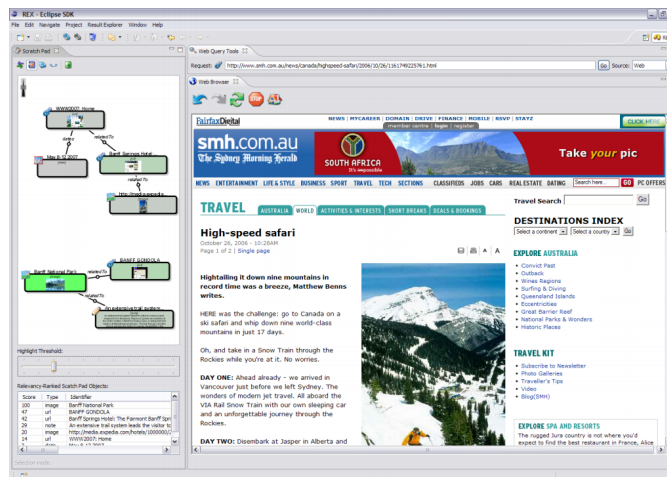
Figure 2.9: The user interface of ScratchPad (Gotz, 2007)

2.4 Collaborative Sensemaking in CIS

Collaborative sensemaking has been investigated in various domains, for example, emergency management (Wu et al., 2013; Landgren, 2005) and learning analytic (Knight et al., 2013). To the best of our knowledge, there is not a framework of collaborative sensemaking behaviour that are applicable to all contexts. While most of the theories and support for sensemaking in information seeking task were built at the individual level, collaborative sensemaking behaviour is rarely explored in the context of CIS. However, some researchers (Paul and Morris, 2009b; Umapathy, 2010) have pointed out the lack of understanding and support for collaborative sensemaking in CIS. In this section, we discuss prior work on the challenges of collaborative sensemaking, and tools to support collaborative sensemaking in CIS.

2.4.1 The Challenges of Collaborative Sensemaking in CIS

In CIS, collaborative sensemaking refers to making sense of the information found together (Paul and Morris, 2011). Unlike individual sensemaking, which is a cognitive activity in one's mind, collaborative sensemaking has a social aspect, i.e. interaction between collaborators to build shared understanding (Paul and Morris, 2009b).

As we stated in section 2.3.1, most sensemaking theories are at the individual level. The key challenge for individual sensemaking is to organise information found in a structural representation and to create new knowledge. Collaborative sensemaking involves individuals who find, share, understand and use information together. It is not simply an aggregation of individual sensemaking. The existing literature has addressed some challenges that are exclusive to collab-

orative sensemaking, including creating a shared representation, keeping aware of collaborators'
work, prioritising information and handing off sensemaking products (Umapathy, 2010; Paul and
Morris, 2009a; Morris and Amershi, 2008).

Creation of a Shared Representation

The purpose of collaborative sensemaking is to generate a shared understanding of the informa-
tion found and of the task problem. In order to achieve a shared understanding, collaborators
usually create a explicit shared representation (Qu and Hansen, 2008). It is difficult for col-
laborators to construct their own representation separately and then combine them together. Re-
searchers suggest that a proper level of structure or template for collaborators to map the informa-
tion found and keep record of products of sensemaking is helpful for group representation (Paul
and Reddy, 2010; Umapathy, 2010). Faisal et al. (2009) categorise the representation according
to formats into six categories: spatial, argumentational, faceted, hierarchical, sequential and net-
worked, which are suitable for different collaborative sensemaking scenarios. For instance, when
comparing or choosing a product, faceted representations are appropriate. When categorizing a
research area and making clear of the relations between them, a hierarchical representation is a
better choice. A question raised here is whether there can be a uniform framework for all sense-
making tasks, or whether users need various frameworks for different kinds of tasks. In reality,
collaborative sensemaking tasks are usually more complex than these example scenarios. Col-
laborators may need to use several combinations of these representations. The challenge is how
to support co-existence of different representations and combine them in a shared representation.

Awareness of Collaborators Work

Unlike when searching individually, in collaborative search, individuals needs to remain aware
of the sense that has been made by collaborators. One challenge of collaborative sensemaking
is to understand other collaborators' sensemaking trajectories (Paul and Morris, 2011), i.e. the
sensemaking steps which lead to the current understanding of information, rather than only the
search histories which describe how information is found. Visualising sensemaking trajectories
makes both the process and products of sensemaking persistent. Sensemaking products refers
to representations of information in a meaningful form and sensemaking process is related to
search strategies (Twidale and Nichols, 1998). In synchronous CIS, awareness of the process is
important for collaborators, while in asynchronous CIS, users pay more attention to the products
(Morris and Teevan, 2009). Research has indicated that visualising the query history is helpful

for users to keep aware of search and sensemaking strategies (Marchionini and White, 2007). Some researchers (Ryder and Anderson, 2009; Haraty et al., 2010) also find that an automatically generated map of webpages gives an overview of the information seeking paths and interlinks between information. Using timelines, like in CoSense (Paul and Morris, 2009a), is another effective way to visualise the sensemaking path of all collaborators in sequence. In CoSense, the timeline view lists all the activities, including query history, websites visited, comments and chats, of collaborators and can be filtered to see each category. Users find it useful when they want to filter the content of a specific user or a certain part of search history but overwhelmed when they want to examine the whole process. So the key problems of visualising collaborative sensemaking trajectories are how much information and in what way it should be presented. First, we need to figure out what components of the sensemaking process are of significant help and therefore should be included in visualised trajectories, and we can then investigate well-organised ways of visualising information.

Prioritisation of Information

Prioritising information between group members is another challenge for collaborative sense-making (Paul and Reddy, 2010). In individual sensemaking, prioritising information usually happens at the early stages of sensemaking to gain an overview and identify areas for further exploration (Yi et al., 2008). In collaborative sensemaking, collaborators may find it overwhelming when all the search results and sensemaking products from each individual are made visible but it is hard to tell which ones are more useful. Prioritising the most relevant information might greatly assist collaborators to make sense of the topic. In collaborative sensemaking, each collaborator may prioritise different pieces of information and they need to reach a consensus. A common way to support the prioritisation of information is re-ranking information according to users' annotations and comments. Several search tools (Morris and Horvitz, 2007; Diriye and Golovchinsky, 2012) enable users to rate and comment the shared webpages.

Prioritising can also be done according to the roles and expertise of group members. Information commented by people who have expertise in some area may aid other people make sense of information. Algorithms to prioritize information need to be developed based on criteria for the most important or useful content.

Sensemaking Handoffs

Sensemaking handoffs refers to the transfer of the sensemaking task in asynchronous collaboration (Sharma, 2008). It usually happens in a special situation which collaborators work in turn in a multi-session task. In that situation, sensemaking products need to be handed over from one person to another between task sessions. Morris and Amershi (2008) give a broad definition of sensemaking handoffs. They consider sensemaking as a collective process for the community of web users. The final products of individual and group sensemaking task can be stored in some formats of representations and will benefit other web users later on.

Sharma and Furnas (2009) indicate that not all sensemaking handoffs are successful since there are no supporting procedures and structures for sensemaking handoffs. Sensemakers may have different level of skills and knowledge bases. If there are no uniform frameworks for sensemaking handoffs, the external representation generated by one sensemaker may not be comprehensible to another. In addition, a supporting framework may diminish the effort sensemakers make on producing handoffs. To build a framework aiding collaborators in sensemaking handoffs, we need to examine what are the key factors contributing to successful sensemaking. As Sharma and Furnas (2009) suggest, we need to gain a better understanding of when handoffs are needed, how the form and timing of handoffs affect the quality of sensemaking handoffs.

The challenges identified by researchers shed a light on the possible directions to support collaborative sensemaking in CIS but provide little guidance on what kind of support users need in collaborative sensemaking activities. Some of the challenges are identified through evaluating existing CIS systems. However, the CIS system used in such studies might influence user behaviour and strategies for collaborative sensemaking.

2.4.2 Supporting Collaborative Sensemaking in CIS

Most collaborative sensemaking tools Pioch and Everett (2006); Keel (2007); Chung et al. (2014) are developed for specialised task, such as visual analytics and intelligence analysis. POLESTAR (Pioch and Everett, 2006) is a set of tools for collaborative knowledge management and sensemaking, which is designed to fit analysts workflow. It enables intelligence analysts to carry out collaborative evidence analysis and argument evolution through real-time collaborative information sharing and editing. EWall (Keel, 2007) is a visual analytics interface for collaborative sensemaking. Visual analytics refers to making sense of data through analytical reasoning using interactive visual interfaces (Thomas et al., 2006). This tool allow users to organise and compre-

hend collected information through identifying the relationship between pieces of information. VisPorter (Chung et al., 2014), a tool also designed for visual analytics, enable users to share and organise information across multiple displays for collaborative sensemaking.

In CIS, systems have been developed to provide various kinds of supports for users to perform information seeking tasks together. Some early CIS systems such as SearchTogether (Morris and Horvitz, 2007) and Coagmento (Shah, 2010), focus on helping people find information together but overlook the phase of understanding information together i.e. collaborative sensemaking. Other systems (Diriye and Golovchinsky, 2012) provide some basic sensemaking support including enabling users to add comments and ratings to webpages, as well as by providing overviews of shared content, including user queries and page-view histories.

To the best of our knowledge, CoSense (Paul and Morris, 2009b) is the only system designed to support sensemaking in CIS. CoSense (Paul and Morris, 2009b), which is implemented based on SearchTogether, to enhance sensemaking in collaborative web search. As shown in Figure 2.10, CoSense presents four different views (search strategies, timeline, chat-centric and workspace) of user activities in SearchTogether. The *search strategies view*, gives a summary of the number of queries each group member issued and the number of websites each group member visited. The query history and browsing history of group members and of the whole group are also visualised as tag clouds. The activities of all group members, including chat messages, queries, viewed webpages and page comments are incorporated in a *timeline view*. This timeline view can be filtered by activities or users. The *chat-centric view* associates each chat message with the webpage that the message sender is viewing while the message was sent. To facilitate preservation of sensemaking products and sensemaking handoffs, CoSense also has a *Workspace view* that presents webpages with comments and tags and allows users to create a to-do list and take free notes.

An Evaluation study of CoSense (Paul and Morris, 2009a) found that the four views of user activities assist users to understand the collaborative sensemaking process, and they are especially useful in sensemaking handoffs. However, as the views in CoSense were designed to enhance awareness of the sensemaking process, little support were provided for users to understand the task problem and information found together and to construct a shared representation. The researchers also found that users wanted the tool to provide representations that mapped to the search task structure.
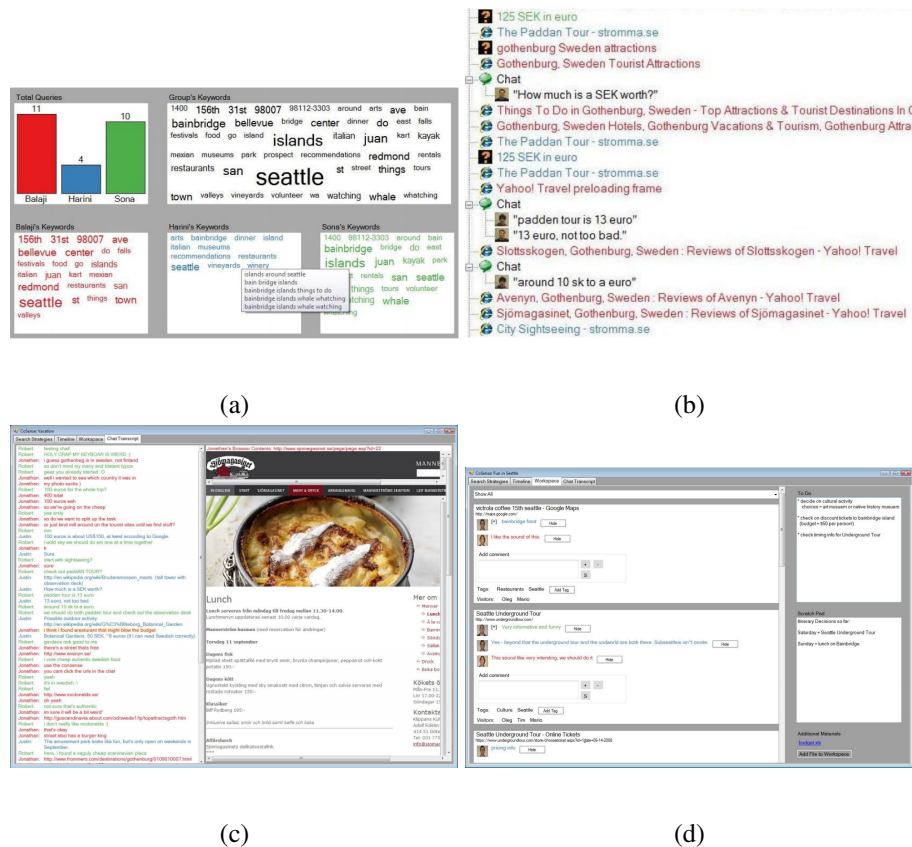
Figure 2.10: Four views of CoSense: (a) Search strategies view (b) Timeline view (c) Chat-centric view (d) Workspace view (Paul and Morris, 2009a)

Existing systems and tools for collaborative sensemaking in various context provide some guidance for supporting collaborative sensemaking in CIS. For example, visualisation of information is a important and useful way to support sensemaking. In addition, systems should take into account the workflow of sensemaking process according to the context of work task. However, we lack of knowledge about user behaviour of collaborative sensemaking and what kind of visualization is useful in the context of CIS.

2.5 Summary

In this chapter, we reviewed existing literature on collaborative information seeking and sensemaking. We found four research gaps from the review of the literature:

- Firstly, while CIS practices are found common in daily life, there is a lack of a thorough understanding of how people collaboratively make sense of the task and information found when performing CIS tasks on the Web. In particular, we have little knowledge on the collaborative sensemaking process and strategies for CIS tasks.

- Secondly, research on task-based information seeking suggests that search task is an important factor which influences CIS behaviour. Therefore, the collaborative sensemaking behaviour and challenges in CIS might also be vary according to task. However, no studies have examined how collaborative sensemaking behaviour relates to the types of CIS tasks.

- Thirdly, research has pointed out that specific support needs to be built for collaborative sensemaking as it has some distinctive characteristics compared to individual sensemaking. However, collaborative sensemaking behaviour is rarely explored in the CIS context. We have limited understanding on the challenges of collaborative sensemaking in common CIS tasks.

- Finally, CIS systems need to be improved for collaborative sensemaking. Most of the collaborative sensemaking tools were developed for users to analyse and synthesise information in specialised tasks , while CIS systems mainly focus on facilitate awareness through visualising related information. Though providing awareness is essential, supporting collaborative sensemaking is much more beyond that. There is a lack of a system which support collaborative sensemaking for CIS tasks. Research has proposed several directions for supporting collaborative sensemaking in CIS, but the kind of support users need requires further investigation.

Chapter 3

Research Questions and Methodology

In this chapter, we present the research questions of this thesis based on the gaps that are identified from literature, and also introduce the methodology for addressing the proposed research questions.

3.1 Research Questions

As stated in chapter 2, researchers have realised the importance of supporting collaborative sensemaking in CIS (Umapathy, 2010; Paul and Morris, 2009a). In order to build effective tools to support collaborative sensemaking in CIS, we need a thorough understanding of the sensemaking activities that are involved in the CIS process and the challenges users face when making sense of the task together. From a close examination of the research literature, we found there is not a model of CIS depicting the collaborative sensemaking behaviour of users. Therefore, in this thesis we aim to explore the activities and strategies collaborators perform for making sense of the task together. In addition, we are interested in identifying challenges and challenges of collaborative sensemaking that collaborators face in the CIS process. Understanding the challenges and user strategies for collaborative sensemaking, we then investigate ways of supporting collaborative sensemaking to inform the design of CIS systems.

Specifically, we address three research questions in the thesis:

RQ1: How do users collaboratively make sense of the search task in CIS?

Firstly, we would like to address the gap in literature that no model has been established for collaborative sensemaking in CIS. In our research, we are interested to define the activities and

strategies of collaborative sensemaking in CIS tasks. According to a model of individual sense-making in information seeking tasks (Zhang et al., 2008), the sensemaking process consists of the activities of task analysis, identification of knowledge gaps, exploratory or focused search for data and structure, building structure, fitting data into structure, updating knowledge and preparing task output. Though this model is developed at individual level, it provides a foundation for us to identify sensemaking activities in CIS. In our research, we identify sensemaking activities in CIS and try to extend this individual activity model of sensemaking to a collaborative context.

An important question in collaborative sensemaking is which activities are conducted collaboratively and how. Paul and Reddy's (2010) framework for collaborative sensemaking during CIS activities has proposed some characteristics of collaborative sensemaking, including sharing information and sense, prioritising relevant information, contextualising awareness of information with respect to activities and creating and manipulating shared representations. These characteristics inspire us the aspects to look into in our research as they distinguish collaborative sensemaking with individual sensemaking. More specifically, we are particularly interested in how collaborators share information and make sense of shared information in CIS tasks, how collaborators manage information and create a shared representation, and how collaborators remain aware of task progress.

RQ2: What challenges do users face in the process of collaborative sensemaking?

In addition to understanding collaborative sensemaking behaviour, another aim of this thesis is to develop supporting tools for collaborative sensemaking in CIS. Therefore, we need a better understanding of the challenges and challenges users face in the process of collaborative sensemaking and the lack of support from current tools. Researchers have pointed out several requirements for supporting collaborative sensemaking through reviewing the related literature Umapathy (2010) and evaluating a CIS system (Paul and Morris, 2009a). However, to the best of our knowledge, no study has explored the collaborative sensemaking challenges of users when performing common CIS tasks that are frequently met in everyday situations. In this thesis, we investigate the challenges of collaborative sensemaking when using standard search engine and chat tools, aiming at establishing an understanding of user requirements of the support for collaborative sensemaking.

RQ3: How to support collaborative sensemaking in CIS?

As stated in chapter 2, most CIS systems do not provide sufficient support for collaborative sensemaking. Prior research also provide little knowledge on how to support collaborative sensemaking in CIS. In order to develop tools to support collaborative sensemaking for CIS task, it is necessary to know what kind of support users find helpful for their sensemaking activities in CIS. Hence, one aim of this thesis is to investigate ways to support collaborative sensemaking in collaborative information seeking process. Based on our understanding of RQ1 and RQ2, we identify the lack of support and user requirements for tools supporting collaborative sensemaking. Then we propose our design features and evaluate the features with users to examine how they support collaborative sensemaking in CIS.

3.2 Methodology

In order to answer the research questions that we proposed in section 3.1, we employ a user-centered approach to understand and support collaborative sensemaking behaviour in CIS. For RQ1 and RQ2, we carried out two user studies to understand collaborative sensemaking strategies and challenges in CIS tasks. For RQ3, we developed a supporting tool following an interaction design process and evaluate it through a user study.

3.2.1 User Studies

User studies are an empirical and scientifically sound research method that is used in information science for various purposes, such as understanding the behaviour of users and evaluating interactive system designs (Wilson, 2000). In this thesis, we present three users studies, two for understanding how users perform sensemaking collaboratively in CIS tasks and the challenges in the process, and another one for evaluating the way we proposed to support collaborative sensemaking in CIS. In these user studies, we recruit participants from our university through email lists. To carry out studies with human participants, we have completed a research ethics questionnaire and received the ethic approval (QMREC 0728) from the research ethics committee of our university. The approval confirms that our studies on electronic sensemaking behaviour in CIS do not present any ethical concerns and are of low risk.

In the following, we describe each study in terms of its research goals and methods applied to achieve the goals.

Study 1: Exploring collaborative sensemaking strategies and challenges in CIS (chapter 4)

Exploratory studies are usually carried out to investigate a behaviour or phenomenon when little is known about it (Kelly, 2009). As there is a lack of theories for collaborative sensemaking behaviour in CIS, in this thesis we first conduct an exploratory user study to gain a preliminary understanding of collaborative sensemaking behaviour and its challenges in CIS. We use a travel planning task in this study as it is one of the most common CIS practice in real life (Morris, 2008) and is frequently used in lab studies of CIS (Paul and Morris, 2009a; Yue et al., 2012). Given the exploratory nature of this study, we mainly collect qualitative data. The data collection methods we used in this study include observation, screen recordings, questionnaires and interviews. We aim to identify sensemaking activities and strategies and summarise the sensemaking challenges collaborators face in the process. Grounded theory (Glaser and Strauss, 1998) was applied to reveal patterns from these qualitative data. The findings of this study lead to the design of the second study.

Study 2: Investigating collaborative sensemaking activities and challenges in different CIS tasks (chapter 5)

From the exploratory study, we obtain a preliminary understanding of the general patterns, strategies and challenges of collaborative sensemaking. In the second study, we examine collaborative sensemaking behaviour in a different type of CIS task - topic research and to investigate the similarities and differences in collaborative sensemaking behaviour according to different tasks. The topic research task is different from travel planning in several aspects. Travel planning is typically performed in a leisure setting and has a common structure (i.e. attractions, accommodation, transportation, etc.), while topic research task is set in a professional scenario and the search goal is vague at the beginning. In topic research, we examined the collaborative sensemaking activities that we found to be important and difficult in the travel planning task, such as building structure for the shared representation and sharing sense between collaborators. To investigate the similarities and differences in collaborative sensemaking behaviour in these two different tasks, we performed a comparative analysis of collaborative sensemaking behaviour. Both qualitative and quantitative measures are used in this analysis. Apart from identifying activities and strategies like we do in study 1, we also calculate the percentage of groups that perform a certain activity or strategy and apply statistical tests to reveal significant differences between collaborative sensemaking in travel planning and topic research tasks. The comparison

analysis helps us understand the collaborative sensemaking patterns as well as the difference due to task.

Study 3: Evaluate MakeSenseTogether, a tool we proposed for collaborative sensemaking (chapter 7)

From the previous two studies, we get an understanding of collaborative sensemaking challenges in CIS and users suggestions. Based on our understanding, we then proposed a topic-based approach for collaborative sensemaking. We developed a tool, MakeSenseTogether, which enables our proposed approach. The development of MakeSenseTogether is presented in chapter 6

This study aims to evaluate our tool through examining how topics influence collaborative sensemaking behaviour. Therefore, in this study we prepare two version of our tool, one is the complete version, which has topic features that allow users to identify topics for the task and share and organize information according to topics. Another is a simplified version called ShareTogether in which topic features are not provided and shared information are presented in chronological order. The two versions of our tool allow us compare collaborative sensemaking behaviour using our tool with and without topic-related features. In this study, we evaluate our tool on both travel planning and topic research tasks. The data collection methods in this study are the same with study 1 and 2, including observation, questionnaires and interviews. Thus we have a chance to compare user behaviour in this study with that of previous studies.

3.2.2 Interaction Design

In the thesis, we introduce an interactive tool, MakeSenseTogether, which we developed to enhance user experience on collaborative sensemaking in CIS. The design process of MakeSenseTogether followed an interaction design process, which involves identifying user requirements, developing alternative designs that meet the requirements, building interactive versions of the designs and evaluating the system throughout the process (Preece et al., 2011). Studies 1 and 2 described in section 3.2.1 help us understand the challenges and lack of support in collaborative sensemaking. As a result, user requirements are established based on the findings of these two studies. We proposed our design ideas to meet user requirements (section 6.1). Then we present our design ideas through paper prototypes and scenarios to evaluate the design with potential users (section 6.2). After that, we decide on the initial design and implement the real system. We conduct formative evaluations to test the features of our system. Through an iterative process

of evaluation and re-design, we create MakeSenseTogether. We then carried out a formal study (Study 3) to evaluate the influence of our system on user experience of collaborative sensemaking in CIS tasks.

3.2.3 Qualitative Data Analysis

In this thesis, we analyse the qualitative data from screen recordings, chat logs, questionnaires and interviews using the Grounded Theory. Grounded Theory has been widely used in information seeking studies (Ellis, 1993; Reddy and Spence, 2008; Prekop, 2002) for generating theory from empirical data (e.g. observations and interviews) without prior assumptions. The process of applying grounded theory consists of a systematic coding of the data, including open, axial and selective coding (Glaser and Strauss, 1998). Open coding is the start point of the analysis of data, in which core concepts is identified from data. Axial coding is to compare and connect the identified concepts in order to generate categories. Selective coding is to put together everything to establish a theoretical framework. In table 3.1, the application of the three-phase Grounded Theory process in our user studies to model the collaborative sensemaking process of CIS tasks is described in detail.

3.2.4 Statistical Testing

In comparing the collaborative sensemaking behaviour in the travel planning and topic research task in chapter 5 and investigating the influence of our proposed features on collaborative sensemaking in chapter 7, we performed a two-tailed unpaired t-test on the quantitative data (e.g. the average number of times identifying data gaps happened in a group). All statistical tests were performed at p value less than 0.05 using SPSS [1] to reveal the significant difference exist in the two groups we compare.

3.3 Research flow

Figure 3.1 shows the overall approach of our research. It reveals the relationship between methodology and research questions as well as the flow of our research. One part of our research focuses on understanding collaborative sensemaking behaviour and challenges of users (RQ1 and RQ2), the other part of our research aims to support collaborative sensemaking (RQ3). As described in section 3.2.1, the method we employed to understanding collaborative sensemaking

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[1]a statistical analysis tool, www.ibm.com/software/uk/analytics/spss/

Stages	Open coding	Axial coding	Selective coding
Data	Raw data from screen recordings and chat logs.	Codes generated in open coding phase.	Codes generated in axial coding phase.
Process and Tool	Playing the screen recordings of a group synchronously, annotating collaborative sensemaking behaviour using ELAN, and coding the chat transcripts	Grouping the activities to form themes and mapping to existing concepts of individual sensemaking theories	Re-annotate the activities using the code generated in axial coding in screen recordings using ELAN, establish the connection between activities
Outcome	**Codes of main activities:** - Specifying information need to be searched for - Identifying the lack of structure - Dividing labour - Searching for information - Background search for topic structure - Sharing individual findings (general resources, suggested information, individual sensemaking products) - Exchanging status and progress - Writing the shared report	**General process of collaborative sensemaking:** - Structuring the task (identifying data gaps, identifying structure gaps, building structure) - Individual searching and sensemaking - Sharing individual findings - Creating a shared representation	A general model of the collaborative sensemaking process as shown in Figure 5.2 (page 79)

Table 3.1: Stages of data analysis using the Grounded Theory

is user studies. Interaction design process is applied to build a supporting tool for collaborative sensemaking. We first conduct two user studies to explore collaborative sensemaking activities and challenges. At the same time we identify users need and establish requirements in the studies, which is the first step in the interaction design process of the supporting tool. Then we go

through an iterative design process using interaction design techniques such as paper-prototyping, scenario-based interview and formative study. After all we get a final version of the supporting tool. Using the tool, we conduct another user study to learn user interaction with our tool and the influence of our supporting tool on collaborative sensemaking behaviour.
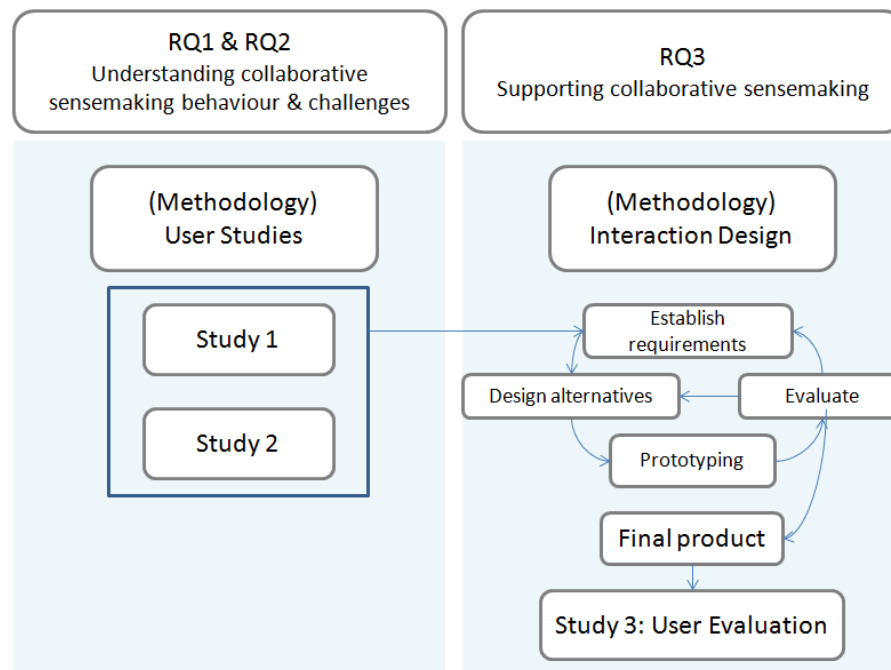
Figure 3.1: Research flow of the thesis

3.4 Summary

In this chapter, we described the three research questions of our research that are presented in the thesis (section 3.1):

- RQ1: How do users collaboratively making sense of the task and information found in CIS?

- RQ2: What are the challenges collaborators face in the process of making sense of the task together?

- RQ3: How to support collaborative sensemaking in CIS?

We then discussed the methodology that we used in our research in order to answer these research questions, including user studies (section 3.1.1) and interaction design (section 3.1.2).

The overflow of our research is summarised in section 3.2.2. The user studies and interaction design process are present in detail in chapter 4-7.

Chapter 4

Study 1: Exploring Collaborative Sensemaking Strategies and Challenges in CIS

In CIS, collaborative sensemaking is an important but also challenging aspect which requires better support from CIS systems (Umapathy, 2010; Paul and Morris, 2009a). However, existing knowledge of how users perform collaborative sensemaking and the challenges users face in the context of CIS is lagging behind. In this chapter, we present an exploratory user study to investigate collaborative sensemaking behaviour and challenges in a common CIS task, travel planning.

4.1 Motivation and Research Questions

While collaborative sensemaking behaviour has been studied in several domains, such as in emergency management (Landgren, 2005; Wu et al., 2013) and learning analytics (Knight et al., 2013), it is less explored in the context of CIS, especially in common CIS tasks (e.g. planning a holiday with friends, working on a group coursework with classmates, etc.). Therefore in this chapter, we explore collaborative sensemaking behaviour by carrying out a user study in which 8 groups, each consists of 3 participants, perform a travel planning task together. In the study, participants use standard web browser, search engines and other tools at hand (e.g. chat tools, editing tools) that they normally use for such tasks. This setting is close to their CIS practices in daily life as reported by Morris (2008).

This study aims at exploring how users collaboratively make sense of the CIS task (RQ1 of

the thesis, described in chapter 3) and what challenges users face in the process of collaborative sensemaking (RQ2 of the thesis, described in chapter 3). In terms of how users collaboratively make sense of the CIS task, we are interested in the activities involved in the collaborative sensemaking process and the strategies users employed to collaborate on sensemaking activities. More specifically, we address the following research questions in this study:

1. **What is the general process of collaborative sensemaking?**

   According to the model of individual sensemaking proposed by Zhang et al. (2008), sensemaking is an iterative process which involves the activities of identifying gaps, building structure for the task, searching for information, instantiating the structure with information and sometimes amending the structure to create a representation. In CIS, collaborative sensemaking is defined as making sense of the information found together Paul and Morris (2011). However, no studies provide a insight into the general process of collaborative sensemaking. Therefore in this study, we are interested in how collaborative sensemaking was performed and what activities are involved in collaborative sensemaking process.

2. **What strategies do collaborators employ for collaborative sensemaking?**

   Collaborative sensemaking is more complex than individual sensemaking because of some exclusive activities, for example, creating an external shared representation, sharing knowledge, etc. (Umapathy, 2010). While no studies have looked into these activities, understanding how users perform these activities is essential for supporting collaborative sensemaking in CIS. In this study, we investigate the strategies users employ for collaborative sensemaking with respect to how they collaborate and coordinate the task in general and their strategies for sharing knowledge and creating a shared representation.

3. **What challenges do users face for collaborative sensemaking?**

   As discussed in chapter 2, research suggests that collaborative sensemaking needs to be supported from several aspects, including creation of a shared representation, awareness of collaborator's work, prioritising of information and sensemaking handoffs (Umapathy, 2010; Paul and Morris, 2009a). However, an understanding of what challenges users face in the collaborative sensemaking process and what support users need is lacking. In this study, we are also interested in the collaborative sensemaking challenges users face when making sense of the CIS task together.

4.2 Study Design

To explore user behaviour of collaborative sensemaking in CIS, we carried out an observational study in which 8 groups, each consisting of 3 participants, collaboratively search information on the Web to complete a travel planning task. We choose a group size of 3 instead of 2 because in 3 member groups the complexity of interaction and collaboration are higher, thus the strategies and challenges of collaborative sensemaking in CIS process will be more thoroughly exposed.
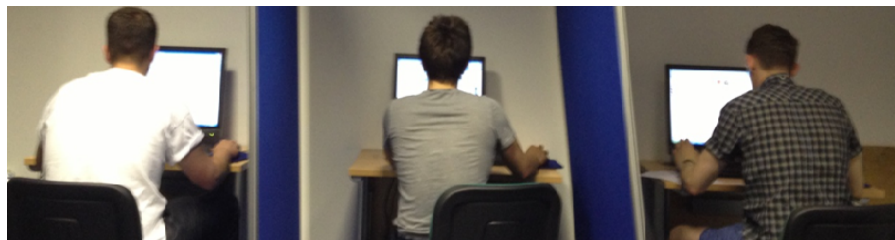
Figure 4.1: A group of participants in the study

We simulated a distributed synchronous situation in the lab setting. As shown in Figure 4.1, the study was conducted in a room with 3 separated booths, one for each group member. Since the study is anonymous, temporary Skype IDs were created for group members to allow communication within the group. Participants were free to choose the search engine and other tools (e.g. tools for taking notes, etc.) they would like to use. We encouraged participants to behave normally and express themselves fully in the group via chat tools.

In the rest of this section, we describe in detail the task, participants, study procedure, data collection and analysis of this study.

4.2.1 Task

To serve the purpose of our study, we chose a travel planning task, as it is one of the most popular collaborative information seeking tasks according to Morris (2008). We chose Wales as the destination of our task, with most participants rating themselves as having very little knowledge of this destination (See Table 4.2). The task description as seen in Table 4.1 was given to participants.

In the task scenario, each group of 3 participants have a maximum time of one hour to plan together for a weekend in Wales. Collaborators were told that they would arrive at Cardiff Central station on Friday evening and travel back to London on Monday morning. So they needed to find 2 places apart from Cardiff to stay for Saturday and Sunday and plan for activities around these places. At the end, each group should submit a document with an agreed plan for their weekend.

You are going to spend the next weekend in Wales. The train tickets are already booked. You will arrive at Cardiff Central station on Friday evening and back to London from Cardiff on Monday morning. Now you want to plan the trip together. The budget is £300 per person. You want to find 2 places (village/town/city) in Wales to stay APART FROM Cardiff, 1 for Saturday and 1 for Sunday. Find information about the 2 places to plan for the activities around these places. At the end, your group should agree upon a plan with a rough schedule for your trip.

Table 4.1: Description of the travel planning task

4.2.2 Participants

We recruited 24 students (14 male, 10 female) from different departments in our university to form 8 groups for this study. Among the 8 groups, 6 groups were formed by themselves so that group members were familiar with each other, while the other 2 groups were formed by us. However, we did not observe any significant differences between these 2 types of groups in their collaborative sensemaking behaviour.

Prior to the study, we collected demographic information about our participants using questionnaires and the statistics are shown in Table 4.2. The average age of participants is 23.5 years. Except for one participant, the rest of the participants have more than 5 year experience of computer use. 91.7% of our participants use search engines several times a day. The average score of self-rated search skill of participants is 3.78 (in a scale of 1-5). 95.8% of participants reported having experience in collaborative search either with friends (87.5%), classmates (62.5%) or family (29.2%) on travel planning (58.3%), literature/technical research (58.3%), shopping (45.8%) and social planning (41.7%).

Age	23.5 [18-29] years
Gender	Female(14), Male(10)
Self-rated search skill (Novice 1-5 Expert)	3.78 [SD = 0.60]
Collaborative search experience	1-3 times(16), 3+ times(7) , None (1)
Knowledge level about the destination	Know very little (20), Know only a few (4)

Table 4.2: Demographics of participants

4.2.3 Study Procedure

Each session of the study was conducted in the following steps:

- Before the task, participants were asked to sign a consent form and complete a pre-task questionnaire (see Appendix A.3) which is used to collect the demographic information of participants, including their collaborative search experience and prior knowledge about the destination. Then we hand out the participant instruction sheet with the travel planning task scenario (see Appendix A.2) and explained the task requirements to participants. When they were ready to begin, we set up the timer and ask them to start the screen recording software (CamStudio[1]) on their computers.

- During the task, the computer screens of the three participants was recorded. We also observed participants from the back when they were performing the task. Participants were stopped at 1 hour if they have not finished the task by then.

- After the task, we hand out a post-task questionnaire (see Appendix A.4) to each participant which collecting data about their experience in the task. Followed by the questionnaire, we carried out a semi-structured interview (see Appendix A.5) to investigate further on the strategies participants employed for collaborative sensemaking and the reasons for their choice, as well as the challenges they encountered in the collaborative sensemaking process.

4.2.4 Data Collection and Analysis

The data we collected from this study includes chat transcripts, screen recordings, pre-task and post-task questionnaires, and the notes of semi-structured interview. In the pre-task questionnaire, we collect demographic information, past experience and prior knowledge about the destination. The screen recordings captures participants' activities during the task and their interaction with the web browser, search engine, chat tools and sometime editing tools. The chat transcripts of each groups in Skype record the interaction between collaborators and their information sharing activities. The post-task questionnaire collect data on participants experience of performing the CIS task. The notes of semi-structured interview mainly records the challenges participants face in the collaborative sensemaking process of the CIS task and their suggestions for the support needed.

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[1]http://camstudio.org/

To analyse the data, we applied both qualitative and quantitative measures. There is not an existing framework of the collaborative sensemaking process for studying collaborative sensemaking behaviour in the CIS task. Hence, we applied Grounded Theory (Glaser and Strauss, 1998) to identify emerging patterns in user behaviour of collaborative sensemaking from the screen recordings. We annotate and categorise user behaviour in relation to our research questions in the screen recordings using ELAN [2]. As shown in Figure 4.2, we analyse the screening recordings of the 3 participants in each group synchronously so we can see participants' behaviour at a group level and better understand the interaction between collaborators. The notes of interviews were used to complement our findings from screen recordings and chat transcripts. In addition, we use the quantitative data from post-questionnaires to reflect on users satisfaction about group performance and how much they were aware of collaborators' work.
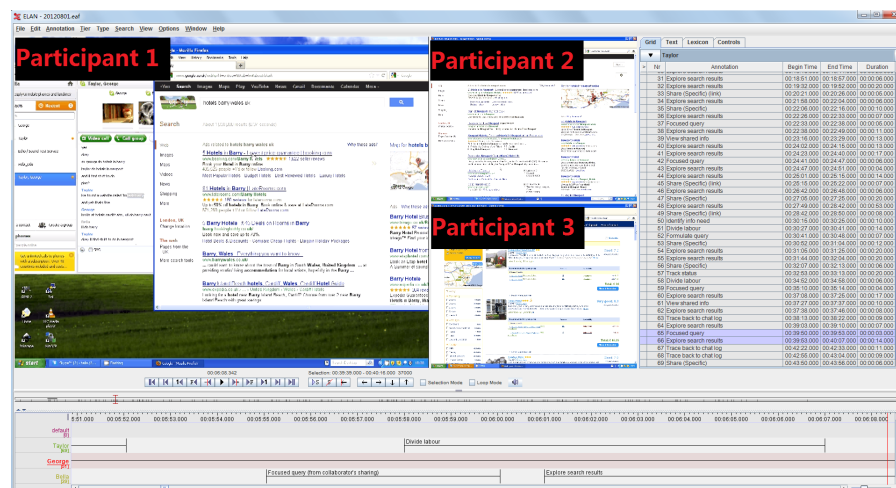
Figure 4.2: A screenshot of using ElAN to analyse screen recordings

4.2.5 Limitations

There are some limitations in the methodology of this study:

Firstly, the sample size of this study is relatively small, which might limits the generalisation of our findings. However, some common patterns have emerged in the 8 groups in this study.

Secondly, only one observer was presented at the study and the data was coded and analysed by the single observer alone. Due to the exploratory nature of the study, we focus on identify emerging patterns in collaborative sensemaking behaviour to build an initial understanding of the collaborative sensemaking process in CIS task. The findings of this study are further examined

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[2]http://www.lat-mpi.eu/tools/elan/

in another study with different CIS task which is described in chapter 5.

Thirdly, during the task we only allow users to communicate through typing on Skype. This setting might not be similar to what participants usually do in real life. Some participants said they would use the video call to communicate with collaborators because it is more efficient. However, the chat tool is also used as a place to share information, for example, the link of a useful webpage. This study is not focusing on the efficiency of communication but on how users exchange their individual findings and understanding about the task during the collaborative sensemaking process.

Finally, due to the time limit of the study, some groups did not complete the task in 1 hour and other groups might have compressed some stages compared to what they normally do. As a consequence, we did not observe a complete process of collaborative sensemaking in these groups. We complement our observation during the study with questions in the semi-structure interview such as how they would continue the task if they had more time and what is the difference of their behaviour in this study compared with in daily life.

In the following, we present the findings of this exploratory study according to the research questions that we proposed in section 4.1. Firstly, we describe the collaborative sensemaking activities that we observed during the CIS task in section 4.3. Then we summarise in section 4.4 the strategies of collaborative sensemaking in the CIS task. Finally in section 4.5, we discuss the challenges users face in terms of making sense of the task together.

4.3   The Collaborative Sensemaking Process

In this section, we report our findings about the first research question of this study, that is, the main activities of collaborative sensemaking in CIS. We investigate this question by applying Grounded Theory to the screen recordings and chat transcripts. Since in this study the chat tool is the main place where participants plan for the task together, we use the chat transcripts to especially look into the thread of collaborative sensemaking process and the collaborative sensemaking activities involved. The screen recordings were analysed to identify activities outside the chat tool, for example, writing the travel plan in a shared online document, etc.

Through an open, axial and selective coding process of the screen recordings and chat transcripts, we identified 5 main activities that are involved in the collaborative sensemaking process of the CIS task:

- **Identifying sub-tasks**: The collaborative sensemaking process usually begins with discussing the information needed to accomplish the task and divide the overall task into smaller sub-tasks. For example, in one of the groups, the participants split the task into "tourist spots, food and living place". In some groups, participants also identify sub-tasks step by step based on the current state of the task. For instance, at the beginning of the task, one participant suggests to "find 2 places for Sunday and Saturday first". When the 2 places were decided, participants continue to identify new sub-tasks throughout the task, such as "travel details", "lunch on Saturday", "a hotel in South Wales Valley", etc.

- **Dividing labour**: Once sub-tasks have been identified, participants usually explicitly tell collaborators their focus on a sub-task. For example, participants said "I can take responsibility for the plan on Sunday" or "I can do the hotel part". Division of labour usually happens when several sub-tasks have been identified at the same time. however, there are also cases where two or three participants work on the same sub-task.

- **Individual searching and sensemaking**: In this study, we found that searching is an individual activity. Whether working on the same or different sub-tasks, participants search for information separately. However, participants sometimes inform their collaborators about the progress of their focused sub-tasks. For example, one participant shared on chat tool that "I have found one [hotel] in Cardiff, now heading to do the other two". Participants also make sense of the information in order to solve their focused sub-task.

- **Sharing information**: This is the activity of sharing individual findings and understanding gained through individual searching and sensemaking. In this study, we found that participants shared different types of information with collaborators, from the raw data , e.g. links (URLs) to useful webpages, to individual sensemaking products, e.g. summary notes for their sub-tasks.

- **Creating a shared representation**: Usually by the end of the task, participants create a shared representation for the task (e.g. the travel plan in this study) which reflects participants' shared understanding on the task. Most groups in our study spared the last 10-15 minutes of the task to create the plan by combining the individual sensemaking notes for sub-tasks.

By annotating these activities in screen recordings, we found that the CIS process can be
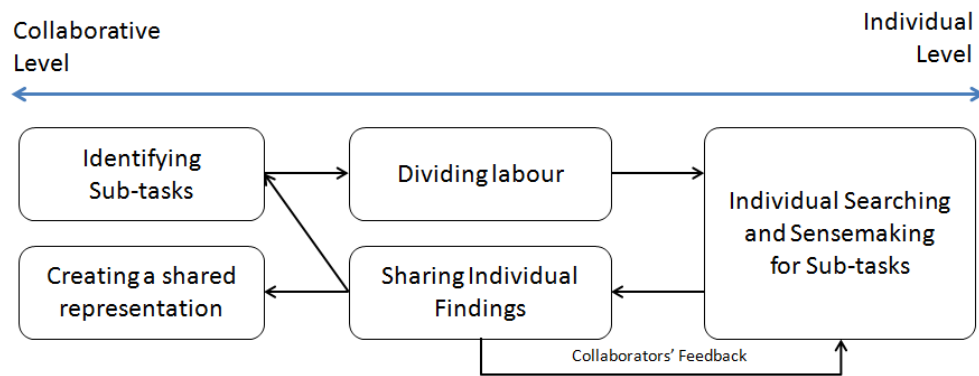
Figure 4.3: The collaborative sensemaking process in travel planning

described as an iterative loop of these activities. As shown in Figure 4.3, in CIS, sensemaking exists in both individual and collaborative level. The collaborative sensemaking process begins with identifying subtasks. Dividing labour is optional in the process as some groups decompose the task and assign sub-tasks to each group member, while other groups work on the sub-tasks together step by step. Then the task enters individual searching and sensemaking. Sharing information updates collaborators on the individual findings and understanding gained through searching as well as the task progress, thus participants know what they have achieved and identify the remaining sub-tasks from the current state of the task. Participants may also go back to search for more information according to the feedback from collaborators. At the end of the task, participants create a shared representation which summarises their findings and decisions. Division of labour and sharing of information has been identified as two key element of synchronous collaborative information seeking (Foley et al., 2010). In our study, we found that dividing labour and sharing information are the bridges that transfer the task between collaborative and individual levels. Individual sensemaking mainly happens in the searching process and is embedded in collaborative sensemaking.

4.4 Strategies for Collaborative Sensemaking in CIS

In this section, we present our findings about the strategies which participants employed for collaborative sensemaking in the CIS task. We look into both the general sensemaking strategies, the strategies users employed for collaboration, and the strategies for specific sensemaking-related activities in CIS, such as sharing information and creating a shared representation.

4.4.1 Sensemaking Strategies

As stated in section 2.3.1, two sensemaking approaches have been defined in individual sense-making, namely data-driven and structure-driven (Pirolli and Card, 2005; Zhang et al., 2008). In this study, we apply the definition of these two approaches to the context of collaborative sensemaking.

- The **structure-driven** approach refers to a sensemaking loop that starts from identifying sub-tasks in the group and then searching for related information and share items found. For example, a participant said in the group chat that " *we need to find a hotel for Sunday*", and the group then searched for related information about a hotel and added it to the plan. "A hotel for Sunday" is considered an element of the task structure, and the search and synthesis of the data about a hotel is driven by the structure.

- The **data-driven** approach refers to the sensemaking loop which starts from finding in-formation through exploratory search and then synthesising information into the structure of the task. For example, a participant searched for general tourist information using the query "Wales travel" and found an interesting museum, then the participant shared the information about the museum and the group finally decided to add the museum to their itinerary as the activity for Saturday. In this case, "an interesting museum" is data, and "the activity for Saturday" is an element in the structure of the task, the creation of which is driven by the data.

According to the adapted definition of the data-driven and structure-driven approach, we annotated the sensemaking loops of each approach in the screen recordings using ELAN. We found that each group carried out an average of 6.25 sensemaking loops, among which 70% are structure-driven and 30% are data-driven. This is different from a study of individual sense-making (Zhang et al., 2008), in which the data-driven approach is found to be four times more common than the structure-driven approach. From the post-task interviews, we found one of the reasons for this difference could be that in CIS participants want to divide labour and avoid duplication of efforts, so they first identify the sub-tasks in the group together and then search for information separately. Therefore, the structure-driven approach is preferred. For example, participants said "*lets do it from macro point of view first, e.g. 1 day nature, 1 at the beach and 1 city, each can figure out one day*". As we observed, several groups also divide labour when

writing up the travel plan. Participants thought that it is easier for them to incorporate the related information into a shared representation if they decompose the task at structure level before searching for information separately.

In addition, we notice that the difference in sensemaking strategies might also because of the search tasks. Zhang et al. (2008) were using an intelligence analysis task which is cognitively demanding and lack of structure, while we were using an everyday leisure task, travel planning, which has an inherent structure. In our study, we found that the data-driven approach was used mostly at the beginning of the task when participants explore the destination as they have little prior knowledge about the destination. However, structuring the task is not difficult for our participants as almost all of them have experience in travel planning and they are familiar with the inherent structure of it. As we observed in the study, participants can easily divide the travel planing task from different aspects, such as attractions, hotels, restaurants, and etc.

4.4.2 Strategies for Collaboration

In collaborative sensemaking, the strategy for collaboration is essential for collaborators to create a shared understanding of the task. From our observation, two group strategies were employed for collaboration, that is, dividing labour and using a shared document.

Group No.	Group strategies		Satisfaction [1-5]	Knowledge Increment [0-4]	Time spent [0- 60 mins]
	Divide labour	Shared document			
G2, G3	Y	Y	3.5 (SD = 0.17)	1.5 (SD = 0.17)	55
G1, G5, G7, G8	Y	N	2.5 (SD = 0.83)	1.34 (SD = 0.34)	60
G4, G6	N	N	4.17 (SD = 0.71)	1.5 (SD = 0.24)	60

Table 4.3: Satisfaction, knowledge increment and time spent in relation to collaboration strategies

The combination of collaboration strategies that each group used in this study is shown in Table 4.3. Six out of eight groups split up the task into sub-tasks at beginning and divided labour among them, while the other 2 groups work together step by step. Two groups used a shared document (Google Docs) to compose the shared representation (i.e. travel plan) together, while the other 6 groups combine individual representations into a shared representation.

In order to explore how the differences in strategies affect the task outcome, in Table 4.3, we compared the satisfaction, the knowledge increment and the time spent of groups. In the questionnaires, we asked participants to rate their knowledge level (in a scale of 1-5) about the tourist

attractions in Wales both before and after the task, and also to rate their satisfaction level with the performance of their group after the task. We derive the knowledge increment by calculating the difference between participants' knowledge rating before and after the task. As can be seen in Table 4.3, the most commonly used combination of strategies is dividing labour but not using a shared document. However, this combination leads to the lowest satisfaction (2.5, SD = 0.83) as well as the lowest knowledge increment (1.34, SD = 0.34) compared to other combinations. In terms of the time spent to complete the task , the groups using a shared document used less time to finish the task. Therefore, we infer that a shared document increase the efficiency of collaboration. However, the groups using no special strategies for collaborations get the highest satisfaction. This might because that collaboration strategies like dividing labour might cause more difficulties for users to understand each others' work.

4.4.3 Strategies for Sharing Information

Sharing information is an essential activity in collaborative work which helps group members to exchange individual findings and create a shared understanding. In this study, we observed two mediums where participants shared information with their collaborators, i.e. chat tool and shared documents.

The main place users shared information is the chat tool. By analysing the chat transcripts using Grounded Theory, the information shared by participants falls into three categories:

- **General resources** refer to the links of websites that might be useful to collaborators. For example, one participant shared the link of a map of Wales to collaborators and said "we can follow this map to decide the next spot".

- **Suggested information** are the information that a participant found for a sub-task. For example, participants shared details about a specific national park, castle, hotel, bar, etc. that they are interested and ask for collaborators' feedback.

- **Individual sensemaking products** are the representations of sub-tasks that are completed by a group member.

We categorised the information shared in chat logs into the 3 categories. In order to count the number of different types of information, we separated the related chat messages into pieces. A

piece of shared information is usually an entry of chat messages. However, we combined the entries that should naturally be considered as one, including those sent by one person continuously and those interrupted by collaborators. For example, in Figure 4.4, the three messages from user B are considered as one piece of shared information. In this study, each group shared an average 13.1 pieces of information, among which 19.45% are general resources, 69.45% are suggested information and 11.11% are individual sensemaking products. We also found that 77.1% of the shared information contains links (the URLs to webpages), but only 35.1% of the shared links were explored by all collaborators. 28.4% of the links were not viewed by any collaborators at all. In addition, only 32.4% of the shared links received approval or feedback from collaborators. In addition to sharing information on the chat tool, one of the groups also shared information on

[2012/7/18 14:44:35] George: I found this for Sunday night, typical Bed and Breakfast quite cheap⏎
[2012/7/18 14:44:45] George: http://securebooking.eviivo.com/MyWebsite/details.aspx?...⏎
[2012/7/18 14:45:07] George: (the price is for 3 persons)⏎

Figure 4.4: Example of a piece of shared information

a shared document (created using Google Docs). The shared document was created for group members to collaboratively edit the final representation. However, they also created a column for sharing information. Participants posted information under the column, usually the links to webpages, and waited for collaborators' comments. In the post task interviews, participants explained that they want a separate place to keep shared information other than in chat tools. In that way, they do not need to check the shared information immediately and they can easily get back to any shared information and use them later on.

4.4.4   Strategies for Creating a Shared Representation

In general, representation, which also referred to as schema (Pirolli and Card, 2005) or frame (Klein et al., 2006), is a structured way which sense-makers present information found for a task (Russell et al., 1993). In this study, the 3 participants in a group were asked to collaboratively create a travel plan that incorporate related information. During the study, each participants might create representations for their sub-tasks. This travel plan is a shared representation that created between all collaborators for the overall task.

From our observation, there are two approaches that our participants create a shared repre-

sentation. The majority of groups (6 out of 8) chose one group member to synthesise shared information into a travel plan. The rest of the group members shared information on chat tools, mostly in the form of sub-task representations. Two out of the eight groups created a shared document using Google Docs in early stage of the task and each group member write different parts of the task in the shared document.

In Table 4.4, we compared the groups that employ these two different ways in terms of satisfaction of their work, knowledge increment (i.e. the difference between how participants feel they know about the tourist places in Wales before and after the task) and time taken to finish the task. We found that there are no significant difference between the groups using a shared document and the groups not. However, either strategy has some strength and weakness. As shown in Table 4.4, using a shared document slightly decreases the satisfaction level but increases the knowledge increment. It also decreases the amount of time used to complete the task. On the contrary, groups that combine representations by one participant, are more satisfied with their work, but acquire less knowledge increment and spent more time on the task.

	Synthesis strategy	
	Together using shared document	By one participant
Satisfaction (1-5)	3.5 [SD=0.17]	3.67 [SD=0.99]
Knowledge increment (0-4)	1.5 [SD=0.16]	1.2 [SD=0.65]
Time used (mins)	55 [SD=5]	57.5 [SD=3.82]

Table 4.4: Comparison of synthesis strategy (Mean [Standard Deviation])

4.5   Challenges of Collaborative Sensemaking in CIS

In this section, we present the findings about the challenges users face for collaborative sense-making. Three main challenges were summarised from our observation and post-task interviews, namely managing shared information, creating a shared representation and keeping track of the task progress and collaborators' status.

4.5.1   Managing Shared Information

In this study, we found sharing information on chat tool makes collaborators hard to follow and managing the shared information for later use.

Firstly, we found that participants have challenges in following the shared information on

chat tool. In the study, only 35.1% of the shared links were explored by all collaborators and only 32.4% of the shared information received feedback from collaborators. 28.4% of the shared links were not viewed by collaborators at all. In post-task interviews, participants explained that checking the shared information on chat tool sometimes interrupt their own work. They need to constantly switch between the window of web browser and of chat tool.

Secondly, participants lacks a common space to keep and manage information shared. In the study, we found participants have their own ways of keeping useful information. 53.33% of the participants take notes in a document using editing tools (e.g. Microsoft Word, Notepad). However, participants only record the information related to their sub-tasks. These individual notes are in different format which makes it difficult to be combined in later stage of the task to create a shared representation. From our observation, Participants also trace back shared information in chat histories as chat tool is the only place recorded the shared information.

To solve these challenges, our participants suggested a integrated space other than chat tool to share and manage useful information. In that way, they would not need to check the shared information immediately and can easily go back to view and manage information later on.

4.5.2 Creating a Shared Representation

The most challenging activity of collaborative sensemaking is to create a shared representation. In this study, the shared representation refers to a travel plan that agreed by all group members.

Most groups create the final representation by combining individual representations. From our observation and post-task interviews, we found participants face challenges in combining representations of individual work into a shared representation if they do not share the same structure. For example, one of the groups in the study split the work into finding information restaurants, attractions and hotels. Each group member created a representation for their allocated topic. They spared the last 15 minutes to combine their information, but finally failed to combine the representations of sub-tasks into a final representation because of the mismatch of the structure in their representation.

Therefore, we believe that the consistence of representation structure is important to the successful synthesis of information. Users need to be aware of the structure of the overall task and link between sub-tasks.

4.5.3 Keeping Track of Sensemaking Progress and Collaborators' Status

From our observation, collaborators have the need to know the task progress and other collaborators' status. Participants told their collaborators the sub-tasks they were working on, and sometimes also asked what their collaborators were doing. For example, participants said "I've found one (hotel) in Cardiff. Now heading to do the other two", "I'm figuring out Saturday", and they asked "who is searching for hotel now?" "Taylor, how is your search coming along?". In post-task interviews, participants claimed that sharing and tracking status helps them to avoid overlaps and to keep aware of collaborators' work.

However, from the screen recordings and interviews we found that collaborators sometimes did not check the chat tools immediately so they missed the status and progress sharing/tracking in chat logs. Also, collaborators do not always share their status, in most cases people do not know what others are doing even though they thought they did.

From observation, we found that some groups share less status on chat tool. We counted the sharing of status in chat logs for each group. From Table 4.5, we can see that groups without a shared representation share a significantly higher number of status and progress than other groups (t(6) = 2.61, p = 0.0401). Hence we infer that a shared representation helps collaborators make sense of the task status and progress.

Group strategy		Avg. times of status sharing
Not divide labour		3 [SD=1]
Divide labour	With a shared document	3 [SD=1]
	Without a shared document	8 [SD=3.2]

Table 4.5: Sharing of status and progress in groups using different collaboration strategy (Mean [Standard Deviation])

In the post-task questionnaires, we investigate usefulness for collaborators to search activities such as queries and webpages. In the interview, we also asked participants about what activities of their collaborators do they want to know and why. Participants says they consider queries more useful because they can easily get what topic their collaborators are searching for from the queries they are using and make immediate interactions with them. For example, one participant said that if he knows his collaborator is searching for the same topic with him, he can discuss with them right away. Some participants also claim that it is not necessary to know the specific queries if there is a better way to know collaborators' search topic.

4.6 Implications for CIS systems

In this section, we discuss the implications of the study findings for the design of CIS systems that supporting collaborative sensemaking and for future work. Based on the findings that groups vary in the strategies to perform collaborative information seeking, the supporting tools must support different strategies. In this section, we discuss the lack of support for collaborators in collaborative sensemaking activities.

4.6.1 Supporting for the Creation of a Shared Representation

Our findings that a structure-driven approach is more frequently used indicate that there is a lack of support for collaborators to construct structure from data. Qu and Furnas (2008) has researched the source and strategies of structure construction in individual sensemaking and suggests using clustering to help users building structure from data. Further research should investigate effective ways of supporting structure construction from data in collaborative information seeking so that collaborators can easily apply data-driven strategy to collaborative sensemaking.

In our study, we investigated the impact of a shared document on collaborative sensemaking. Results suggest that visualising the structure in a shared place enhances the common understanding between group members. Collaborators get better idea of the progress of sensemaking and could identify remaining sub-tasks from the shared representation. However, existing tools for collaborative sensemaking provide little help for constructing structure from information. In the future, visualisation of structure should be integrated in collaborative information seeking tools to better support sensemaking.

4.6.2 Supporting for Sensemaking of Shared Information

From our findings, we recognised a need for more flexible sharing of information between collaborators. Links as the most common way of information sharing may not be efficient enough. Participants want to share not only the links, but proportions of the webpages, such as a picture or several sentences. Collaborative information seeking tools need to support sharing part of webpages and organise them in their own way.

In addition, we found that many participants checked the chat-logs to view the shared information again, especially when they were synthesising information into representations. Our participants suggest that shared information should be presented in a way that their collabora-

tors can easily edit, organise and trace back. Also, chat tools may not be a good place to share information. It is disruptive to collaborator's search process because they have to view the message immediately. Some participants also mentioned they need a common place to save and edit shared information. Thus, it is easier for collaborators to synthesise agreed information into a final representation even though they do not use a shared document which enables co-editing. Current tools like CoSense (Paul and Morris, 2009a) provide a view of shared webpages with collaborators' comments but do not allow collaborators to change the way items are presented. Therefore, a more flexible information sharing mechanism should be developed to better support the understanding and management of shared information.

4.6.3   Group Awareness of the Sensemaking Process

Our findings on status/progress sharing show that collaborators want to be aware of the task progress and status of other collaborators during the task. Participants indicate that queries and viewed webpages are a useful hint to learn about the current topic that collaborators are focusing on. Some participants further explained that the purpose to know the search topics of collaborators is not avoiding overlap but interacting with each other immediately. Existing CIS tools present all the activities of collaborators including chat messages, queries, viewed webpages in a timeline, which is found overwhelming by users (Paul and Reddy, 2010). Future research should investigate a clear but not disruptive way of presenting the status of collaborators and task progress, and also how collaborators interact with each other providing this information.

4.7   Summary

In this chapter, we described an observational user study of the sensemaking behaviour for collaborative information seeking. We presented findings about the activities, strategies and lack of support in collaborative sensemaking process and then discussed design implications for new collaborative information seeking tools. The results of our study show that current tools do not efficiently support collaborators in information sharing, representation construction and sensemaking of task progress and collaborators' status. We outlined design implication for new CIS tools in terms of supporting for structure construction and visualisation, supporting sharing and organising information, and supporting group awareness of sensemaking process.

This study is the first step to understand sensemaking in collaborative information seeking

from the user perspective. In the next chapter, we investigate sensemaking behaviour in a different type of task to better understand collaborative sensemaking activities in CIS, and to gather user requirements for supporting collaborative sensemaking in CIS .

Chapter 5

Study 2: Investigating the Collaborative Sensemaking Behaviour in Different CIS Tasks

Based on the exploratory study in chapter 4, we form an initial understanding of the collaborative sensemaking process, strategies and challenges in CIS. As we found, the employment of structure-driven and data-driven strategies in collaborative sensemaking is different than in individual sensemaking and the difference might be partly caused by the task. Though previous research (Marchionini, 1989; Kim and Allen, 2002; Vakkari, 2003) has found that the search task is a factor that significantly influences information seeking behaviour, to the best of our knowledge, no studies have looked into the influence of task on collaborative sensemaking behaviour in CIS. In order to gain a better understanding of collaborative sensemaking in CIS, we conducted another study using a topic research task and compared the collaborative sensemaking behaviour of users in this task and in the travel planning task. In section 5.1, we outline the motivation and research questions of this study, and describe the study design and methodology in section 5.2. The findings of this study is presented in section 5.3. Then we discuss the findings in section 5.4 and finally concluded this chapter in section 5.5.

5.1 Motivation and Research Questions

In the exploratory study in chapter 4, we used a travel planning task as it is one of the most common CIS tasks in daily life and it has been extensively used as a representative task in CIS studies (Morris and Horvitz, 2007; Paul and Morris, 2009a; Imazu et al., 2011). While travel

planning is a leisure task which has an common structure, there are types of CIS tasks which are more intellectual demanding and ill-structured, for example, conducting an academic survey or researching a technical problem (Morris, 2008, 2013). In this chapter, we present a comparative study between the travel planning and topic research tasks to further investigate collaborative sensemaking behaviour in different CIS tasks.

As stated in section 2.2, information seeking tasks can be categorised from different aspects. The travel planing and topic research tasks used in our studies were both complex information seeking tasks that required multiple searches. According to the categories described in section 2.2, both tasks might involve subtasks that are known-item (e.g. find a website for booking hotels, find the wikipedia page for globalisation, etc.) or subject (e.g. explore things to do around the destination, learn about the relationship between globalisation and human rights, etc.) tasks. In the travel planning task, some subtasks are also transactional (e.g. book a hotel) tasks. The tasks might be exploratory at the beginning and become focused as they progress.

Information seeking behaviour can be influenced by various characteristics of a task, such as task topic and structure. Toms et al. (2003) found that the domain of task highly influence web search behaviour. They examined the search task in four domains, i.e. consumer health, shopping, travel and general research, and found that different strategies were employed in the search process of different task. In addition, the topic structure of a task is also an important factor which influence information seeking strategies (Vakkari, 1999; Kim, 2007; Pharo, 2004). The travel planning and topic research tasks used in our studies are different in terms of their topic domain and structure. Therefore, we are interested to know that how collaborative sensemaking behaviour are influenced by tasks.

In particular, we would like to address the following research questions with this study:

1. **What are the similarities and differences in the general process of collaborative sensemaking between the travel planning and topic research tasks?**

   In chapter 4, we found that the collaborative sensemaking process of travel planning consists of identifying sub-tasks, optionally dividing labour, individual searching and sensemaking, sharing information, and creating a shared representation. In this study, we are interested in the general process of collaborative sensemaking in the topic research task and how it compares to what we found in the travel planning task. In addition, we would like to see if there are general patterns of collaborative sensemaking for both tasks.

2. **What are the similarities and differences in the strategies for collaborative sensemaking between travel planning and topic research tasks?**

   In chapter 4, we explored the strategies user employed for sensemaking, collaboration and especially for sharing information and creating a shared representation in the travel planning task. As stated in chapter 2, task is an important factor of information seeking strategies. However, to the best of our knowledge, no studies have looked into how task influence collaborative sensemaking strategy in CIS. Therefore in this study, we compare the collaborative sensemaking strategies employed between the travel planning and topic research tasks.

3. **What are the similarities and differences in the challenges of collaborative sensemaking between travel planning and topic research tasks?**

   In chapter 4, we summarised several challenges of collaborative sensemaking in the travel planning task, including managing shared information, creating a shared representation and keeping track of sensemaking progress and collaborators' status. For this research question, we are interested in revealing the common challenge of collaborative sensemaking in both travel planning and topic research task which would be useful for building a general system to support collaborative sensemaking in CIS tasks.

5.2 Study Design

For the purpose of comparing collaborative sensemaking behaviour in the topic research task with travel planning task, we used the same study setting as in the exploratory study in chapter 4, in which participants work together as a group of 3 and each of them using a computer in a separated cubicle. The only difference is the task. However, we recruit new participants for this study because most of the participants in the first study are not reachable and their experience in our previous study might impact their behaviour in this study. In the following, we describe in detail the task, participants, data collection and analysis of the study in section 5.2.1 - 5.2.3.

5.2.1 Task

While travel planning (the travel task) represents the personal/leisure CIS tasks in daily life, in this study, we used another type of common CIS tasks, professional/work task (Morris, 2013). As the participants in our study are mainly university students, we created a topic research task (the

research task) that is close to the form of course assignments. In the task scenario, each group of 3 participants have 1 hour to prepare for the outline of 20-minutes presentation on a given topic. We carefully chose 4 diverse topics for the task, namely (1) the legacy of Margaret Thatcher to the world, (2) the role of social networking in Arab Spring, (3) the effects of globalisation on human rights, and (4) the future challenges of special effects in movies. These topics are general and vague thus participants can interpret the topics and build structure for the task themselves. Table 5.1 shows an example task description given to participants. A complete list of tasks can be found in Appendix 2.1.

Topic	Task
Margaret Thatcher	A chapter of history draws to a close as former British prime minister Baroness Thatcher makes her final journey on April 17th. Accompanied is a controversy over what she leaves behind for us. Your group is preparing for a 20-minutes presentation about what do you think is the legacy of Margaret Thatcher to history, either positive or negative. Now you may want to investigate into the topic on the web and make an outline for the presentation together. Please jot down the main points you would like to make in your presentation and the related information that support your arguments.

Table 5.1: An example of task given to participants

Before starting the task, we asked participants to rate their existing knowledge about the 4 topics in a 5-level Likert scale (1 = low; 5 = high). We then calculated the average score of prior knowledge for each topic in groups and assigned each group the topic for which they had the lowest prior knowledge. Participants were to search the web and discuss the main points they wanted to talk about in their presentation, and at the end of the task produce a written form of an agreed outline.

5.2.2 Participants

We recruited 24 students (14 female, 10 male) from our university to form 8 groups of 3 participants, from different departments of our college via emails. We collected demographic infor-

mation about our participants in pre-task questionnaires. In this study, 80% of the participants reported having experience on collaborative search and 75% of the participants reported having collaborated with others in academic tasks. The demographic information of the participants in this study is presented with the information of participants in the previous exploratory study in Table 5.2. Participants in both study were similarly distributed in terms of age, proficiency in searching and collaborative search experience, which makes our comparison between them valid.

	Topic Research	**Travel Planning**
Age	23.04 years [18-31]	23.47 years [18-29]
Gender (Total)	10 male, 14 female	14 male, 10 female
Self-rated Search Skill (Novice = 1; Expert = 5)	4.01 [SD = 1.5]	3.78 [SD = 0.6]
Collaborative Search Experience	3+ times (8), 1-3 times (12), Never (4)	3+ times (7), 1-3 times (16), Never (1)

Table 5.2: Demographics of participants

5.2.3 Data Collection and Analysis

Same as the study of travel planning task, the data we collected in this study includes screen recordings, chat transcripts, questionnaires and post -task interview notes. Screen recordings allowed us to observe the overall process of collaborative sensemaking in a group context. Chat transcripts provided us insight into the coordination and information sharing activities between collaborators in the collaborative sensemaking process. The questionnaires and interview notes enabled us to investigate further on the reason behind users' collaborative sensemaking behaviour.

In terms of data analysis, we employed a combination of qualitative and quantitative methods. Through applying open and axial coding phase of grounded theory (Glaser and Strauss, 1998) to screen recordings, we categorised participants activities in the process of collaboratively making sense of the CIS task. In order to characterise how participants perform sensemaking together, we investigated their strategy to perform each activity. By mapping users sensemaking behaviours to the activities defined in individual sensemaking (Zhang et al., 2008) and identifying new activ-

ities, we developed the coding scheme in Table 5.3. We also asked another PhD researcher, who is working on supporting cross-modal CIS, to code 17.2 % of the chat messages using the coding scheme. The coding sample we provided to the researcher was excerpt of chat transcript from each group. The inter-coder reliability of our coding is 0.802 (>0.80) using Cohen's Kappa test and is 0.803 (>0.80) using Krippendorff's Alpha test, which means high level of agreement. In

Collaborative Sensemaking Stages	Sensemaking Activities / Strategies
Structuring the task	Identify structure gap
	Build structure
	Identify data gap
Sharing indiviudal findings	Sharing links
	Sharing snippets
	Sharing representations
Creating a shared representation	Combining individual representations
	Synthesising shared information
	Writing together in a shared document

Table 5.3: Coding Scheme

addition, we counted the occurrence of sensemaking activities in each stage of the collaborative sensemaking process. In order to reveal the differences and similarities in collaborative sensemaking behaviour, we compared the occurrence of collaborative sensemaking activities between the travel planning task and the topic research task using statistical test (unpaired t-test).

5.2.4   Limitations

While the study setting of our study allows for investigation and comparison of the collaborative sensemaking behaviour in the two different CIS tasks, it has some limitations.

First, the participants in the two studies are different in the tasks. As such, their collaborative sensemaking behaviour could be different naturally. However, as state in section 5.2.2, the demographic information of our participants in the two tasks has no significant difference in terms of age, gender, self-rated search skill, and collaborative search experience.

In addition, we recruited only 8 groups for each task. The small sample size limited the generalisability of our findings. Therefore when reporting the results, we mainly focus on the behaviours where statistical test shows significant difference.

5.3 Findings

In this section, we present a comparative analysis of the collaborative sensemaking behaviour between the travel planning and topic research tasks. The findings are presented according to collaborative sensemaking activities, strategies and challenges, revealing both similarity and difference between the two tasks.

5.3.1 The Similarities and Differences in the Collaborative Sensemaking Process

In chapter 4, we found that the general process of collaborative sensemaking in the travel planning task consists the activities of identifying sub-tasks, optionally dividing labour, individual searching and sensemaking, sharing information, and creating a shared representation. As shown in Figure 5.1, we found a similar process in the topic research task except that participants usually start from identifying the lack of structure for the task in group and then carrying out a background search to learn the task topic and to find structure for the task before they identifying sub-tasks in group.
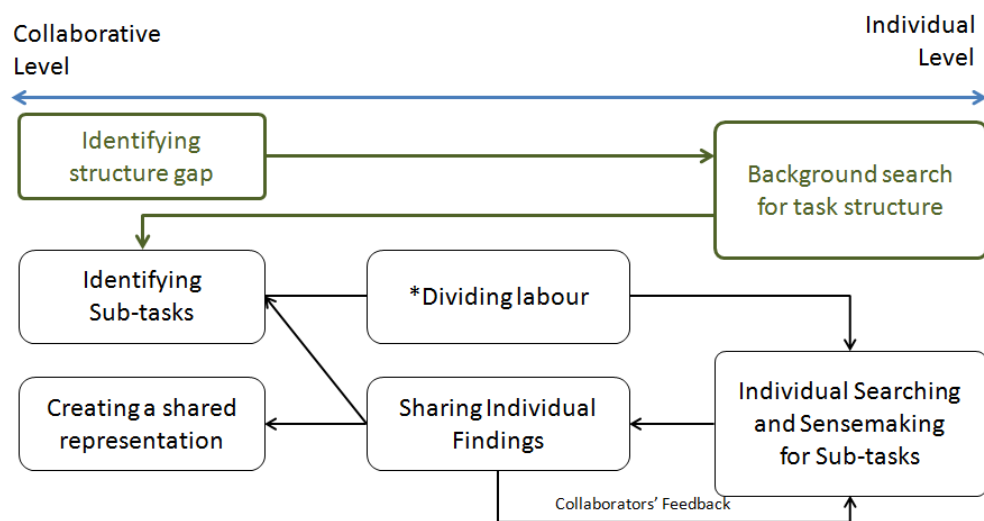
Figure 5.1: The collaborative sensemaking process in the topic research task

Based on our observation of collaborative sensemaking behaviour in travel planning and topic research tasks, the collaborative sensemaking process can be simplified as shown in Figure 5.2. In the process of collaborative sensemaking, two main activities were performed at the collaborative level: structuring the task (including identifying sub-task and identifying structure gaps) and creating a shared representation. Sharing individual findings bridging sensemaking from the individual level to the collaborative level. In the following, we describe and discuss

our findings about collaborative sensemaking activities in everyday CIS setting in relation to the sensemaking activities described in Zhang et al. (2008)'s individual sensemaking model based on professional search.
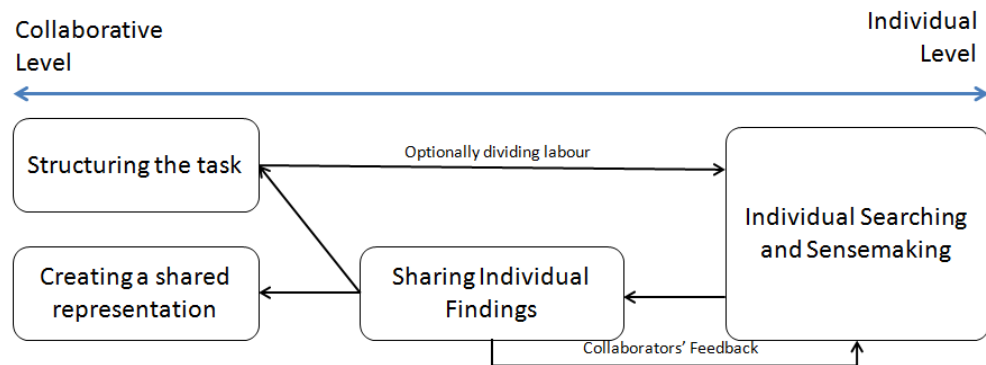
Figure 5.2: The general process of collaborative sensemaking

- **Structuring the task**: In individual sensemaking, sensemakers start their task with a task analysis stage in which they build an initial structure of the task from existing knowledge and decide their strategies to complete the task (Zhang et al., 2008). Likewise, we found a CIS task begins with structuring the task. Participants build an initial structure for the task through identifying sub-tasks and decide the strategy for collaboratively perform the task. In our studies, most groups built a structure for the overall task and then divided labour between group members. In the topic research task, some groups also conducted a background search on the topic as they lack of enough knowledge for building an initial structure, which is described as an exploratory search stage in individual sensemaking process (Zhang et al., 2008). Sensemaking activities involved in this structuring stage are identifying structure gap, identifying data gap and building structure.

- **Sharing individual findings**: In individual sensemaking task, after an initial structure were built, participants entered a focused search stage to find information for specific aspects of the task (Zhang et al., 2008). Similarly, in collaborative sensemaking, participants searching for information separately to make sense of sub-tasks. However, in CIS, participants usually sharing with collaborators the individual findings and understandings for sub-tasks during individual searching and sensemaking.

- **Creating a shared representation**: In individual sensemaking, creation and adaptation of representation might not be an explicit activity (Zhang et al., 2008). Participants update

their mental model (internal representation) throughout the sensemaking process. However in collaborative sensemaking, the final stage of a task is creating a shared representation, in which participants synthesising the information shared by each individual to create an external representation (i.e. a travel plan in the travel task or a presentation outline in the topic research task) for the task.

In the following, we identified users strategies for each collaborative sensemaking activities.

5.3.2 The Similarities and Differences in Collaborative Sensemaking Strategies

In this sections, we outline the similarities and differences in the collaborative sensemaking strategies between the travel planning and topic research tasks. We present the finding according to the strategies for structuring the task, for sharing individual findings and for creating a shared representation.

Strategies for Structuring the Task

Structuring the task is the starting point of collaborative sensemaking, through which participants discuss the task structure in order to clarify their search targets and decide the strategy to approach the task. However, structuring the task can be a repetitive activity in which the task structure was formed as the task proceed. In both tasks, we found participants employed two strategies for structuring the task:

- **Building an overall structure:** Some groups build a overall structure that divides the task into sub-tasks. For example, a group performing the topic research task, whose task topic is the challenges of special effects in movies, divided the task into three parts , i.e. type of technologies used for special effects, development of special effect and future challenges of special effects, and group members take one each.

- **Identifying subtasks step by step:** Other groups identify step by step the subtasks that they can think of from the current state of the task. These subtasks might not completely cover the information needed for the overall task. For example, in a group performing the travel planning task, participants first suggested finding two places for Saturday and Sunday. After they found and decided on the two places, they then identified a new data gap: a place to stay for Friday night.

Both of the two strategies were employed in the travel planning and topic research tasks. However, participants in topic research tend to apply the "building an overall structure" strategy more often while the "identifying subtasks step by step" strategy was employed by more groups in travel planning. More specifically, 3 out of 8 groups in travel planning and 5 out of 8 groups in topic research employed the "building an overall structure" strategy. They built a structure in early stage from either existing knowledge or a background search. For example, a participant in travel planning suggested dividing the task from attractions, food and accommodation of the destination. Each participant in the group then focused on a sub-task in their search and synthesise of related information. Five out of 8 groups in the travel planning task and 1 out of 8 groups in the topic research task) structured the task by identifying specific data gaps based on task status. They suggested specific topics to search for each time. New data gaps were identified through searching and reviewing the collected information. The rest two groups in the topic research tasks employed a combination of the two approaches. They started from identifying specific data gaps, but later on built a structure to decompose the task before composing a shared representation.

In collaborative sensemaking, structuring the task is a collaborative activity which happens in group. As we observed in our user studies, participants explicitly identify subtasks and build structure in group chat. Similar to individual sensemaking, the activities of identifying data and structure gaps and building structure (Zhang et al., 2008) also exist in collaborative sensemaking and reflect user strategies for structuring the task. In the context of collaborative sensemaking, we define these activities as following:

- **Building structure** is the activity in which participants build a structure for the task by decomposing the overall task into several sub-tasks. This reflect the use of the "building an overall structure" strategy for structuring the task.

- **Identifying data gaps** is the activity in which participants specify one or more sub-tasks which need to find information for based on the current states of the task. This reflect the use of the "identifying sub-tasks step by step" strategy for structuring the task.

- **Identifying structure gaps** is the activity in which participants explicitly express the need of a overall structure for the task.

We closely examined the group chat logs and annotated the instances of the three activities which are related to structure the task. Table 5.4 provides examples of the instances of each activity in group chat logs. We counted the number of instances of each activities and compare the number of occurrence of each activity in the travel task and the topic research task. The number of occurrence of each activity in the two tasks are shown in Table 5.5. Unpaired t-test is applied to compare the occurrence of these activities related to structuring the task between the travel task and the topic research task. Significant differences were found in the number of occurrence of each activities. The differences in these activities suggest that participants employed different strategies for structuring the task in different tasks.

	Topic research	Travel planning
Building structure	*"let's just start from the basics: biography, career, death"*	*"so we separate the task? maybe tourist spots/ food/ living place?"*
Identifying data gap	*"let's find a good reliable definition of special effect first"*	*"find a hostel in Cardiff first"*
Identifying structure gap	*"we need a short outline of our topic research, so we can divide it"*	None

Table 5.4: Example instances of building structure, identifying data gap and identifying structure gap in the travel planning and topic research tasks

	Topic research	Travel planning
Building structure	2.625* [2.06]	0.625 [0.98]
Identifying data gap	0.875 [1.22]	3.875** [1.71]
Identifying structure gap	0.75* [0.82]	0

Table 5.5: Average number of occurrence [Standard Deviation] of the sensemaking activities of groups in the travel task and the topic research task (** means very statistically significant at p <0.01, * means statistically significant at p <0.05)

As can be seen from Table 5.5, the average number of occurrence of building structure in a group is significantly more times in the topic research task than in the travel task (t(14) = 2.4797, p = 0.0265). One reason for the difference is that more groups in the topic research task than

in the travel task employed a "building an overall structure" strategy. Once an overall structure is built, participants usually follow a "divide-and-conquer" strategy (Morris, 2008), i.e. divide labour and focus on different part of the task. Five out of 8 groups in the topic research task built an overall structure in early stage of the task and each group members then focused on different sub-tasks, while only 3 out of 8 groups in the travel task do so. Another reason for the difference is that in the topic research task some groups repeated the activity several times until successfully built a structure. On the contrary, as we realised in the exploratory study, travel planning has its inherent structure which makes participants break up the task easily.

Identifying data gaps occurred significantly less number of times in the topic research task than in the travel task (t(14) = 4.0395, p = 0.0012). We found 5 out of 8 groups in the travel task and 1 out of 8 groups in the topic research task followed a step-by-step approach. Participants suggested specific topics to search for each time. New data gaps were identified through searching and reviewing the collected information.

Identifying structure gaps was only found in the topic research task. Participants said they "*can not work without an outline*" in the topic research task. Five out of 8 groups found themselves lack of knowledge to build a structure at the beginning of the task, so they suggested a background search on the topic and then exchange ideas to build structure for the task. This implys that building an overall structure in the topic research task might be more difficult than in the travel task.

One possible reason for the differences in participants strategy of structuring the task might be the nature of the tasks. Travel planning is a well-structured task. Groups that employed divide-and-conquer approach can easily split the task into parts from different aspects of a travel plan, for example, attractions, food, accommodation and transportation, etc. However, these aspects of a trip are highly correlated to each other when producing a travel plan. As we observed, in the two groups employed the strategy of building an overall structure, participants sometimes need to wait for the results of collaborators' sub-task before starting their own sub-task. Although the sub-tasks was undertaken by different individuals, each sub-task was performed in order. For example, the person who is responsible for food needs to find some restaurants near the attractions or accommodations.

In the topic research task, most groups wanted to build an overall structure for the task at beginning. In most groups, participants mentioned "*dividing the task into parts*". A reason for

this could be the high workload in reading and understanding the found information when they were researching the topic. Through building an initial structure and divided labour, participants want to share the workload. However, participants have little prior knowledge of the task topic so they realized the need of searching for structure. For example, one of participants suggests "*look at topics to form an initial idea and then structure the topic research*".

Strategies for sharing individual findings

As we observed from our studies, searching for information is an individual activity in CIS tasks. However, participants share their findings gained in individual search with collaborators. Sharing information during individual search and sensemaking is exclusive to collaborative sensemaking therefore the models of individual sensemaking provide little insight into this activity.

In our studies, we found participants mainly rely on the chat tool to share individual findings with collaborators. Individual findings refers to the information participants found and the understanding gained through searching the task topic. We applied the open and axial coding phase of Grounded Theory procedure (Glaser and Strauss, 1998) to the chat transcripts and found that the individual findings shared in group chat fall into three types:

- **Link to a webpage**: An URL to a specific webpage, usually followed by comments for the webpage.

- **Snippet of a webpage**: A part of the webpage (e.g a paragraph, several sentences and a picture, etc.) extracted from a webpage.

- **Representation for a sub-task**: A summary of information for a sub-task in a structured and meaningful way.

We counted the average number of each type of individual findings that were shared in groups in the topic research and travel planning tasks. As shown in Table 5.6, the total number of individual findings shared in the travel task is significantly higher than in the topic research task ($t(14) = 2.2384$, $p = 0.0420$). Specifically, the average number of links to webpages shared in the travel task is significantly more than in the topic research task ($t(14) = 4.0594$, $p = 0.0012$). In travel planning, the most commonly shared pieces of information are the links to webpages (75.2%) while in the topic research task, participants shared representations for sub-tasks the most (43.3%). The main reason might be that links in travel planning are used not only for sharing useful resources but also for sharing specific activities that users suggest.

	Topic research	Travel planning
Links to webpages	**2.75**** [4.10] (36.67%)	**10.25** [3.24] (75.23%)
Snippets copied from webpages	1.5 [2.33] (20%)	2 [2] (14.68%)
Representations for sub-tasks	3.25 [2.12] (43.33%)	1.375 [2.39] (10.09%)
Total	**7.5*** [6.52]	**13.625** [4.17]

Table 5.6: Individual findings shared by participants in the topic research task and in the travel task (Mean [SD](Percentage), ** means very statistically significant at p <0.01, * means statistically significant at p <0.05)

From the sensemaking perspective, the activity of sharing different individual findings can be mapped to sharing structure and data. The shared links and snippets are merely data, while the sharing of representations presented collected data in structure. In the travel task, participants shared data (12.25) nearly nine times more than structure (1.38). In the topic research task, the numbers of times participants share data (4.25) and share structure (3.25) are nearly the same. These results to some extent indicate the difference in the focus and challenges between the two tasks. Participants focused more on collecting data in the travel task since they can easily break up the task into clear and focused sub-tasks, for example, hotel for Saturday night, activities on Sunday, etc. In the topic research task, participants usually roughly divide the task into three parts so that each person can focus on different aspects. During individual search, participants also build upon the initial structure for their sub-tasks.

Strategies for creating a shared representation

In the later stage of the task, participants create a shared representation of the task together. In individual sensemaking, creation of representation is a process of instantiate structure by fitting data into the structure or building and amending structure based on collected data. The representation could be internal, i.e. a mental model, and the process could be implicitly done during searching. However in CIS, creation of representation is an explicit activity in which participants collaboratively produce an external representation that demonstrate their shared understanding about the task.

In our studies, we observed three strategies that our participants used to synthesise their final representation:

- **Conbining individual representations**: Five out of 8 groups in the topic research task and

2 out of 8 groups in the travel task chose one group member to combine the representations of sub-tasks into a shared representation.

- **Synthesising shared information**: Two of the 8 groups in the topic research task and 4 of the 8 groups in the travel task shared information on the chat tool and choose one person to create a shared representation and synthesise information into it.

- **Writing together in a shared document**: Two groups in the travel planning task and 1 group in the topic research task used an online document (Google Docs) to collaboratively edit the shared representation during the task.

The most commonly used strategy for creating a shared representation are different between in the travel task and in the topic research task. The majority of groups in the travel planning task have one person responsible for synthesising shared information, which means that two group members only search and collect related information while the other group member synthesises all the information into a representation. However, in most of the groups that performed the topic research task, all of the group members composed representations for their sub-topics which constitute parts of the shared representation.

The difference in the synthesising strategy might due to the different workload and the way participants structure the task. Synthesising process in the travel task is not as time-consuming and mental-demanding as in the topic research task. The task was break into clear and focused sub-tasks as they identified sub-topics step by step. Participants only need to collate all the information that was agreed and shared in group. However, in the topic research task, participants usually divided the task to built a initial structure in early stage. They built upon the initial structure for their sub-tasks while they were created a representation for the sub-tasks.

5.3.3 The Similarities and Differences in Collaborative Sensemaking Challenges

In chapter 4, we found that the main challenges of collaborative sensemaking in the travel planning task is managing shared information, creating a shared representation and keeping track of the task progress and collaborators status. In this section, we investigate the similarities and differences in collaborative sensemaking challenges between the travel planning and topic research tasks. We found that creating a shared representation and keeping track of the task progress and collaborators' status are the common challenges for both tasks, while in the topic research

task, building an initial structure for the task is an additional challenge for collaborators. In the following, we discuss each of the challenges in detail.

Creating a shared representation

Creating a shared representation is a common challenges for both travel planning and topic research tasks. We found in the travel planning task that the challenges of creating a shared presentation lies in synthesising the information shared by each group member on the chat tool. This is usually done by one person because there lacks a shared workspaces for collaborators to integrate the shared information into a shared representation together.

Unlike in travel planning, participants usually build an overall structure for the task and divide labour on collaborative searching in topic research. The final representation of the information task (i.e. create 20 minutes presentation) is usually built by combining representations for sub-tasks. This might because that creating a presentation outline might be more difficult and time-consuming than creating a travel plan. Some participants indicated in the post-task questionnaire that they were not satisfied with the shared representation and explained in the interview that the final representation did not include all the points that they discussed. For example, in one group, participants share and discuss the key facts they want to talk about in the presentation on the chat tool. Afterwards, when writing the outline, two person summarise the positive and negative aspects of globalisation respectively. However, they failed to incorporate all the facts they have discussed together. In the post-task interview, participants suggest a shared workspace for creating a shared representation so that they can contribute to others' sub-tasks as well.

Keeping track of the task progress and collaborators' status

In both the travel planning and topic research tasks, we found that participants exchanged with collaborators the status of individual work and the progress of the task on chat tool. Status includes current topic of an individual, webpages being viewed, queries being submitted to search engine, who is working on a specific task. Progress includes the completion of a sub-task and the remaining tasks. Collaborators exchange this information to keep aware of the group sensemaking process.

We categorised the chat messages related to sharing status and progress into four activities: sharing status, checking status, sharing progress and checking progress. Table 5.7 shows the average number of times each group exchanged status or progress in each task. In both tasks, groups exchanged information about status and progress at a similar rate in total. However,

	Topic research	Travel planning
Sharing Status	1.125 [1.73]	2.5 [3.07]
Checking Status	1.125 [1.36]	0.75 [0.89]
Sharing Progress	**0.25*** [0.46]	**1.125** [0.83]
Checking Progress	1.75 [1.58]	2 [2.88]
Total	4.875 [3.73]	6.375 [5.01]

Table 5.7: Exchanging of status and progress in the topic research task and the travel task (Mean [SD], * means statistically significant at p <0.05)

participants shared more progress information in the travel task than in the topic research task (t(14) = 2.6080, p = 0.0207). This might because that the sub-tasks in the travel planning task are correlated therefore the progress of a sub-task might be more important for collaborators to know. In both tasks, participants checked progress more than status. Therefore, we infer that participants were more interested to know the progress of the task than the status of collaborators.

Building structure for the task

In addition to challenges found in the travel planning task, in the topic research task we found building an initial structure for the task is also a challenges for users when they have little existing knowledge of the task topic.

At the beginning of a task, participants usually discuss and agree on the strategy to accomplish the task. Dividing labour is a common strategy collaborators used in CIS to improve efficiency. To divide labour, collaborators need to build an initial structure of the topic to decompose the task into parts. We found this is not very difficult in the travel planning task since the travel planning task has a common structure. Participants structure the task from aspects such as accommodation, attractions, restaurants, transport etc. based on general knowledge about the task. However, in the topic research task, participants have little prior knowledge about the topic, so they spent more time in building an initial structure. They usually need to conduct a background search to learn the topic. We observed that some participants browse the Wikipedia pages of the topic to form an initial structure.

5.4 Discussion

In this section, we discuss our findings from this comparative study of users' collaborative sensemaking behaviour in the travel task and in the topic research task. Firstly, we outline the general process of collaborative sensemaking in CIS in section 5.4.1. We then summarise the most significant differences in collaborative sensemaking behaviour of participants in the two different tasks in section 5.4.2. Finally in section 5.4.3, we discuss the implications of our findings for system design .

5.4.1 The General Patterns of Collaborative Sensemaking Process in CIS

In this study, we compared collaborative sensemaking behaviour in the travel planning and topic research tasks. We found that general patterns exist in the collaborative sensemaking process in both of the tasks. As we described in section 5.3, the collaborative sensemaking process consists of structuring the task, searching and sharing information and creating a shared representation. This process usually starts from structuring the task, through iterative effort of searching and sharing information and finally ends with synthesising information to create a shared representation.

From identifying the collaborative sensemaking activities in the CIS tasks, we formed a thorough understanding of the collaborative sensemaking process in CIS. In the collaborative sensemaking process, structuring the task and creating a shared topic research are performed collaboratively. Searching for information is an individual activity through which users making sense of sub-tasks separately. The sharing activity connect individual sensemaking with collaborative sensemaking thus help collaborators reach a shared understanding of the task. As such the difference of collaborative sensemaking and individual sensemaking activities mainly lies in information sharing between collaborators. Structuring the task and creating a representation are more complex in collaborative sensemaking than in individual sensemaking, because "*three minds are working together*" and they need to explicitly share their mental activity to collaborators. Therefore, CIS systems should facilitate these activities to better support collaborative sensemaking in CIS.

In this study, we chose two CIS tasks, travel planning and topic research among the most common CIS task in daily life (Morris, 2008, 2013). We consider the two tasks are representatives for most of the rest of the task. As discussed in chapter 2, the CIS tasks can be categorised

according their occasion as leisure and professional, and from their purpose as decision/planning and learn/comprehension. Travel planning is a leisure and decision/planning task, similar tasks including online shopping, real estate finding, and social planning. On the contrary, topic research task is a professional and learn/comprehension task, similar task including technical information finding, medical information finding and literature search. Therefore, we think our findings of the general process of collaborative sensemaking can be reasonably generalised to other CIS tasks in daily life.

5.4.2 Differences in Collaborative Sensemaking Strategies Between CIS Tasks

In this study, one of the main purpose is to compare the collaborative sensemaking behaviour of users in the two different CIS tasks. Based on statistical analysis, significant differences were revealed in the collaborative sensemaking behavior of participants in the travel planning task and in the topic research preparation task.

One of the differences appears in structuring the task. We found that the average number of times of building structure in groups in the topic research task is more than in the travel task. From our observation, participants repeated the effort several times in the topic research task to create an initial structure of the task. However, sub-tasks are highly-related (e.g. the hotel depends on the cities and sights they want to visit), many groups go step by step from identifying the specific information they need to search for each time. Therefore, identify data gaps are more often in the travel task than in the topic research task. In addition, participants in the topic research task identified structure gaps but the participants in the travel task did not. This might be because the participants in the topic research task wanted to divide the task, however, they found they lack enough knowledge to build a structure at beginning of the task.

Another significant difference occurred in sharing individual findings with collaborators. Sharing of links to webpages in the travel task is significantly higher than in the topic research task. In the travel task, participants shared the links to webpages to recommend places and activities that are described in the webpages. However, in the topic research task, participants need to form the main points of topic research from the webpages and extract useful information from the webpages. Therefore, participants usually understand and summarize the information before sharing to collaborators. The sharing of links to webpages are usually happened in early stage of the task to share useful information sources with collaborators.

Finally, in terms of creating a shared representation, the most commonly employed approach

in the two tasks are different. In travel planning, synthesising information and writing a representation take little effort and time, so groups can spend more time on searching for information. In topic research, the synthesising activity is more difficult and time-consuming, so all group members have to write part of the representation to increase group efficiency.

The differences in collaborative sensemaking in different CIS tasks suggest that the user need of supporting collaborative sensemaking may vary according to tasks. To design a system that support collaborative sensemaking, the designer should study user requirements in the task context. However, there are common themes for supporting collaborative sensemaking that are revealed in our study. We discuss them in the next section.

5.4.3 Implications for Supporting Collaborative Sensemaking

In this section, we discuss the implications of our findings for supporting collaborative sensemaking in CIS.

Investigating sensemaking challenges according to task

In this study, we compared the collaborative sensemaking behaviour and challenges between the travel planning and topic research task. Results shows that while general patterns exist in the collaborative sensemaking behaviour, the collaborative sensemaking strategies users employ and the challenges users face can be different depending on the task. Therefore, when designing systems to support collaborative sensemaking for CIS task, researchers should thoroughly understand the challenges for the task they focus on.

Supporting different strategies for collaborative sensemaking

In section 5.3.2, we found that although one strategy might be used more frequently than others in a task, in both travel planning and topic research task, multiple strategies were employed for collaborative sensemaking activities. For example, for structuring the task, most groups in the travel planning task employed a "identifying sub-tasks step by step" strategy, while most groups in the travel planning task employed a "building an overall structure" strategy. However, both strategies has been employed by some groups in each task. Therefore, the system designed for collaborative sensemaking should support for multiple strategies employed by users for collaborative sensemaking.

Supporting common challenges

In this study, we found two common challenges for both travel planning and topic research tasks: creating a shared representation and keeping track of group sensemaking process. In this section, we discuss the implications of findings for supporting these two challenges.

Providing a workspace for the creation of a shared representation. From our understanding of the challenges in collaborative sensemaking, building structure for the shared representation is a challenge for collaborators. This challenge is more apparent in tasks that require knowledge of a specialized area, for example,academic research, and health or medicine task.

From our observation, if collaborators have little existing knowledge of the task topic, they spend more time in building an initial structure for their representation. Collaborators argue that they need to have a brief structure to work separately and thus they can finally combine their work together. However, current CIS systems provide little support for structure building. In our studies, we found most groups built or amend the structure for the representation during individual searching stage even though they have an initial structure for the task.

Therefore, CIS tools designed for collaborative sensemaking should help collaborators building structure during searching stage. Based on our studies, senses that have been exchanged are either data or structure. Data is the raw information collected from searching. Structure is ideas and sub-topics to organise information. Collaborators usually incorporate information into their representation as they find it. A possible way might be extracting topic keywords from collected information and help collaborators organise their shared information according to topics in a common place. In this way, collaborators can easily manage information in structure for the final representation.

Providing awareness of task progress and collaborators' work. In our studies, we found that collaborators want to keep awareness of the collaborative sensemaking process. Supporting awareness is an important issue not only in CIS but in all collaborative work (Schmidt, 2002; Dourish and Bellotti, 1992; Shah and Gonzalez-Ibanez, 2010). Mainstream CIS tools already provide different level of awareness of collaborators' activities. Coagmento (Gonzlez-Ibez and Shah, 2011), a CIS application that has been used in both research studies and real life, supports awareness through a history component in a sidebar. Queries, bookmarks and snippets by all group members are all shown in this history area. SearchTogether (Morris and Horvitz, 2007) has awareness mechanisms of query histories and visitation information of webpages. CoSense

(Paul and Morris, 2009a), which is built on SearchTogether to support sensemaking, support action and context awareness by providing 4 different views, namely search strategies, timeline, chat-centric and workspace view. According to an evaluation study of CoSense presented by Paul and Morris (2009a), collaborators used the search strategies view and its tag clouds feature most frequently in synchronous search. The tag clouds show the groups and individuals keywords of their queries and webpage URLs. Querium (Diriye and Golovchinsky, 2012), a newly designed session-based collaborative search system, provides session summary view of queries, documents and comments.

However, our studies suggest that collaborators need more straightforward awareness of the progress made in collaborative sensemaking process. As we found in our studies, providing awareness of the sensemaking process should inform users not only of their collaborators current activities such as submitted queries, viewed webpages and shared document etc., but also of the overall sensemaking progress as a group, i.e. what they achieved and what is left to do. Participants want to know the topics each group member has covered and information collected corresponding to each topic instead of just a list of queries and webpages. Designing for awareness of the group sensemaking process, CIS systems should provide awareness of collaborators' current activities, summarisation of topics that have been covered by collaborators and visualization of the group sensemaking progress.

5.5 Summary

In this chapter, we presented a comparative study between the collaborative sensemaking behaviour of users in a travel planning task and in a topic research preparation task. The purpose of this user study is to extend our understanding about the collaborative sensemaking patterns and challenges from the exploratory study. The findings of this comparative study revealed the difference in collaborative sensemaking behaviour according to CIS tasks. It also enabled us to build an comprehensive understanding of the general process of collaborative sensemaking in CIS. Our understanding about how users perform collaborative sensemaking and the common challenges of collaborative sensemaking in CIS lead to the design of a system that support collaborative sensemaking in CIS in chapter 6.

Chapter 6

MakeSenseTogether: A Tool for Collaborative Sensemaking in CIS

From the user studies described in chapters 4 and 5, we established a better understanding of how users perform sensemaking activities collaboratively in CIS tasks and the common challenges they face. Based on this understanding, we proposed a tool, MakeSenseTogether, to support collaborative sensemaking in CIS. More specifically, the tool focuses on supporting the common challenges of collaborative sensemaking in CIS tasks, namely creating a shared representation and keeping track of the task progress.

The design process of MakeSenseTogether contains two iterations of prototyping and evaluating until it reaches the final product. In the first iteration, we produce paper prototypes to present our initial design ideas, and evaluate the prototypes with users in a scenario-based interview. In the second iteration, we developed an interactive prototype of our tool and evaluate it with users in order to identify usability issues and to refine our design.

In this chapter, we first explain the design concepts of MakeSenseTogether in section 6.1. In section 6.2, we present the scenario-based interview using paper prototypes. In section 6.3, we present an interactive prototype of MakeSenseTogether and a formative evaluation of the prototype to reveal usability issues is described in section 6.4.

6.1   Design Concepts

In chapter 5, we discussed the common challenges of collaborative sensemaking that users face in CIS tasks. As we found, the most challenging aspects of collaborative sensemaking are creating a shared representation and keeping track of the group sensemaking process. Therefore, when designing MakeSenseTogether, we focus on supporting these aspects.

Firstly, to create a shared representation, users employed three approaches: (1) combining individual representations, (2) synthesising information by one person and (3) using a shared online documents (Google Docs). All of the three approaches need to rely on external editing tools and users constantly change between the web browser, the chat tool and the editing tool.

When using approach (1), participants search for information separately and create individual representations for what they found in word documents. At the end of the task, they share the individual representations on the chat tool and choose one person to combine the representations together to make a shared representation. We found that it is difficult for the person to combine individual representations if they did not build an overall structure for the shared representation and divide labour according to the structure. This is because that when composing individual representations, participants were not aware of the structure of the representations created by collaborators.

However, sometimes participants were not familiar with the task topic thus it is hard for them to build an overall structure in the early stage of the task. Therefore, participants build the structure step by step during the search process and employed approach (2) to create a shared representation. In this approach, only one person create a word document and synthesise shared information into a single representation. The other two persons share information and ideas of structure on the chat tool. From our observation, the shared information on the chat tool were not always immediately checked and thus not incorporated into the representation, because the person who is responsible for composing the representation might miss the notification when switching between the chat tool and the word document. Also, the two group members who shared information on the chat tool can not see the word document so they often ask what need to be done next and what is the document looks like now.

To address the challenges in creating a shared representation, we designed MakeSenseTogether as a web browser extension which has a sidebar and topic-related features that allow users to search, share and organise information in a shared space and make the overall structure visible

to all the group members. The topic-related features are a series of features which allow users to add or edit topics in the sidebar any time during the task and organise shared information according to topics. Thus, participants can build structure for the representation together throughout the search process. The design of topic-related features is inspired by the fact that users usually identify subtasks before searching for information and create subheadings to organise information in a word document as we observed in users studies.

Secondly, in terms of keeping track of the group sensemaking process, we found that participants asked for the current status of collaborators and the task progress on the chat tool because they wanted to know the search topics that their collaborators are focusing on and the progress of the overall task or a sub-task taken by collaborators. Therefore, the design of MakeSense-Together also facilitates awareness of task progress through visualising the shared information according to user-identified topics in the sidebar. In this way, users can get an overview of the progress of the whole task as well as of each topics. MakeSenseTogether were also designed to enhance awareness of collaborators search topics through colour coding the shared information by person, so that users can easily tell from the shared information that who is working on what topics.

The design process of MakeSenseTogether followed an iterative design cycle of prototyping and evaluating. In the following, we describe two main iterations of the design process which lead to the final version of MakeSenseTogether. In section 6.2 we present the iteration 1: a scenario-based interviews using paper prototypes in and in section 6.4, we describe the second iteration: a formative evaluation of an interactive version of MakeSenseTogether.

6.2   Iteration 1: A Scenario-based Interview Using Paper Prototypes

The design process of MakeSenseTogether begins with creating paper prototypes to convey design idea and evaluating the design ideas in a scenario-based interviews with users. Based on the user requirements that we gathered through studies 1 and 2, we designed features to support users in the most challenging activities of collaborative sensemaking in the CIS process, that is, creating a shared representation and keeping track of the group sensemaking progress. To make sure that we understand the user needs correctly and develop usable tools, we involved potential users from the early stage of our design process.

6.2.1   Paper Prototypes

After establishing user requirements from users studies, we created paper prototypes of Make-SenseTogether for an initial evaluation of design ideas by users. The paper prototypes of Make-SenseTogether consists of static interfaces which describe the key features of the tool.
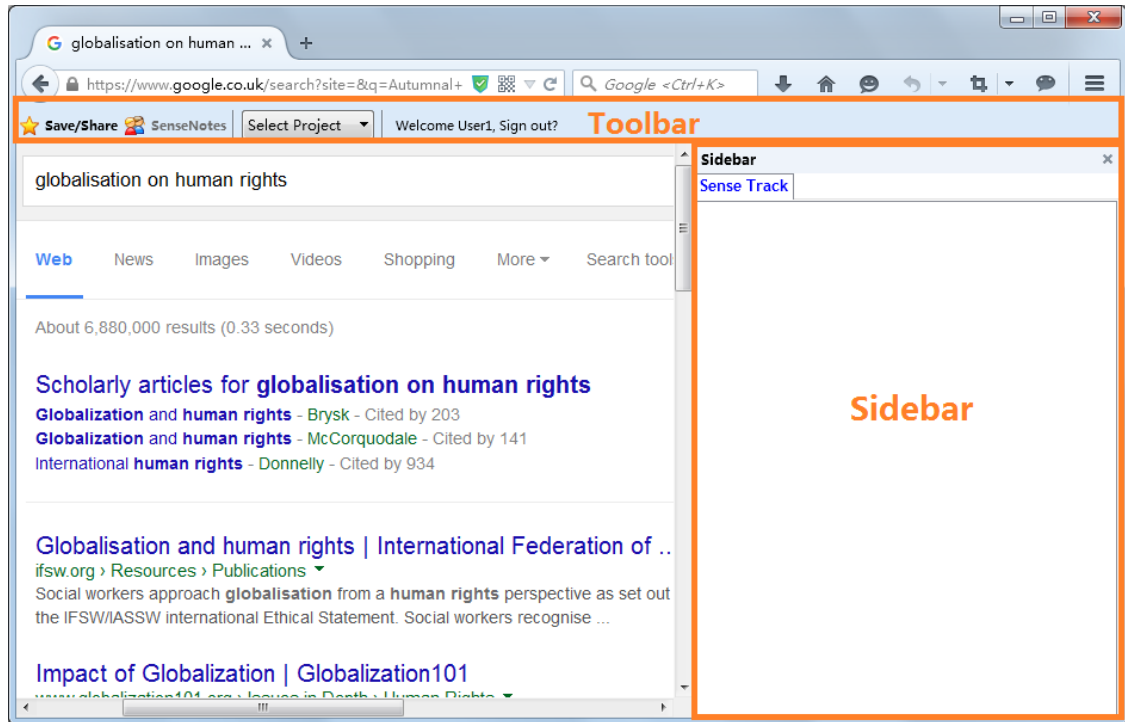
Figure 6.1: Paper prototype of the user interface of MakeSenseTogether

Figure 6.1 shows the main interface of MakeSenseTogether. As the design goal of Make-SenseTogether is to support collaborative sensemaking in common CIS tasks, MakeSenseTo-gether is designed as a web browser extension which is composed of a toolbar and a sidebar. Users can still search and browse the web as they usually do while MakeSenseTogether provide a shared workspace for them to make sense of the task and information found together.

In order to address the challenges of creating a shared representation, we designed the "Saving/Sharing" feature and the "SenseNotes" component, which enable users to identify topics for the task and to share and organise information according to topics. In the tool bar, there is a "saving/sharing" button which allows users to save/share snippets to collaborators. When selecting the sentences on a webpage and clicking on the button will open the dialogue as shown in Figure 6.2. When saving/sharing information, users can specify a topic for the information to be shared either by choosing from the existing topics or typing a new one in the topic field.

Figure 6.2: Paper prototype of the "Save/Share" feature

Another feature which can be accessed from the toolbar is the "SenseNotes" button. Clicking on the button opens the SenseNotes space which all the information collected by group members are shown according to topics. Figure 6.3 and 6.4 shows the SenseNotes space before and after expanded. In SenseNotes, users can manage the shared information using four functions: "Add a topic","Delete topics", "Expand all" and "Collapse all".
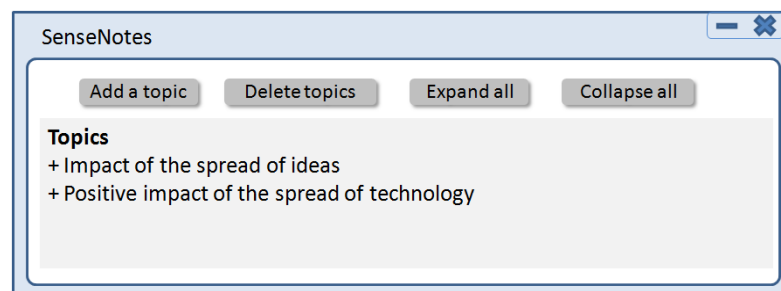
Figure 6.3: Paper prototype of the "SenseNotes" feature (Collapsed)

In addition, we designed a "SenseTrack" component in the sidebar to address the difficulty in keeping aware of the group sensemaking process, especially keeping aware of collaborators' search topic. As shown in Figure 6.5, the queries and topics of each group member will be shown in "SenseTrack".
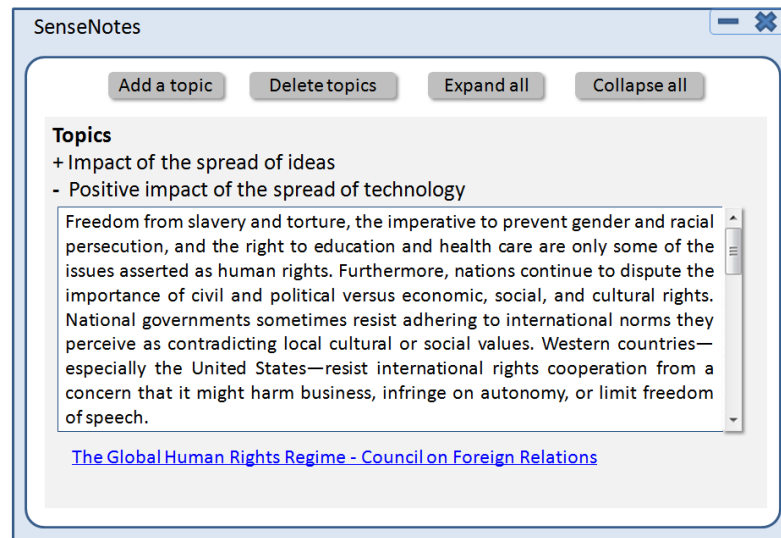
Figure 6.4: Paper prototype of the "SenseNotes" feature (Expanded)

Figure 6.5: Paper prototype of the "SenseTrack" component in the sidebar

6.2.2 Evaluation Methods

After the paper prototypes of MakeSenseTogether were produced, we used them to evaluate our initial design ideas of MakeSenseTogether through interviews with potential users. We also established usage scenarios around the features of MakeSenseTogether to provide a context in which our tool aims to support. Three scenarios (sharing information, organising shared information and keeping aware of group sensemaking process) were constructed where user interacts with MakeSenseTogether in the general context of accomplishing a CIS task in a group. A detailed description of each scenario can be found in Appendix C.

In the interview, we demonstrated the paper prototypes to participants, described the corresponding usage scenarios, and asked them what they think of the features. For example, to

evaluate our design of the "SenseNotes" component, we first described to participants the context that "*after researching on the task for a while, you want to view all the shared information and start composing the final representation*". Then we present to them the paper prototype of "SenseNotes" as shown in Figure 6.3 and 6.4 and asked them what they thought of the way information was presented and whether the topics were helpful for them to build structure for a shared representation of the task. (For detailed description of scenarios and interview questions, please see Appendix C .)

Four participants who volunteered to take the interview were recruited through emails. The four participants come from various academic backgrounds (2 from computer science, 1 from physics and 1 from sports therapy). Two of them had participated in our previous user studies. Three of the interviewees reported having collaborative information seeking experience at a frequency of once/twice per year and one interviewee conducted collaborative information seeking tasks once every two weeks. During the interview, we walked through the scenarios and presented users with paper prototypes of the related system features that could be interacted with in each scenario. All the interview sessions were audio recorded for analysis.

6.2.3   Evaluation Results

Several pieces of useful feedback and suggestions were gained from the interviews, including both suggestions for improving the proposed features and new design ideas. In the following, we list some important feedback from users which led to a refinement of our original design.

- **The "saving/sharing" feature**

  Participants' feedback for the "saving/sharing" feature falls into three aspects. Firstly, the "saving/sharing" feature was designed to allow users to choose whether to save a piece of information for their own or share it with collaborators. In the interview, participants thought it is not necessary to have the "save for your own" option because they would like to know what each other have found. Secondly, in the "saving/sharing" dialogue (as shown in Figure 6.2), users' comments for a piece of information were added to the shared content directly. Some participants suggest to have a separate field for comments. Thirdly, participants said that they also want to share general notes about the task that are not linked to specific webpages. According to users' feedback, we change the "saving/sharing" feature into three separate features for users to share different types of information: "bookmark",

"snippet", "notes". We describe these features in detail in section 6.3.

- **The "SenseNotes" component**

  The "SenseNotes" component was designed to provide an shared workspace where users can manage shared information according to topics and have an overview of the task progress. Participants liked the design ideas of "SenseNotes" but found it not convenient to access this component from the toolbar. They stated that as the "SenseNotes" component can be very useful and need to be accessed frequently, it should be presented in the sidebar so that they can see what topics have been identified and what information have been shared in real time. Participants also want a clear indication of who has shared which piece of information in the presentation of "SenseNotes". Some participants suggested using name tags to differentiate who has contributed which piece of information. In addition, one participant suggested to provide a preview of the information collected under a topic when the mouse moves over a topic.

- **The "SenseTrack" component**

  The "SenseTrack" is designed to provide awareness of the search topics that each group member works on. Participants said that visualising collaborators' search activities would be more useful in multi-session and asynchronous tasks, as it can remind them of previous search. However, in synchronous collaboration they would only want to know the current topic and it does not need to be presented in the sidebar. One of the participants explained that "*we do not need much information about the search queries. We mainly want to know what information has been collected*". Some participants also pointed out that sometimes they might not want collaborators to see their search queries.

Through the user interviews using scenarios and paper prototypes, we refined the design of MakeSenseTogether. We then implemented a interactive version of MakeSenseTogether according to the paper prototypes.

6.3   MakeSenseTogether

After the user interview with paper prototypes, we developed an interactive prototype of MakeSenseTogether according to the refined design ideas. In this section, we introduce the features of MakeSenseTogether and how they were designed to support collaborative sensemaking in CIS.

6.3.1 Framework of MakeSenseTogether

To build MakeSenseTogether as a web browser extension, we used the framework of Coagmento-Collaboratory[1]. CoagmentoCollaboratory is a modularised and extendible version of Coagmento (Shah, 2010) which provide a framework for researchers to develop tools. As shown in Figure 6.6, the framework of MakeSenseTogether consist of two part, the client side and the server side. The client side is a Firefox extension which can be installed to the Firefox browser. The server side constitute a MySQL database and the PHP code of web services, both are situated on a server of our department[2].
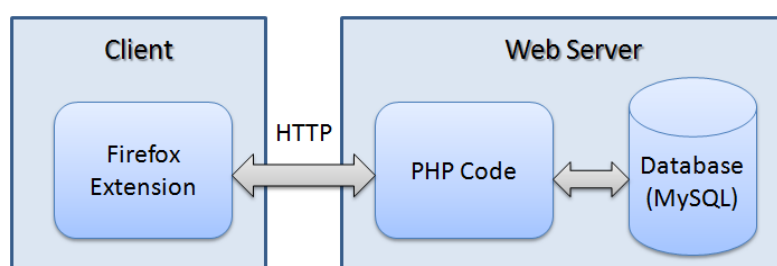
Figure 6.6: The framework of MakeSenseTogether

6.3.2 Features of MakeSenseTogether

In general, MakeSenseTogether is implemented as a Firefox extension, which includes two components - a toolbar and a sidebar. As seen in Figure 6.7, in the toolbar, it has three buttons for users to share different types of information, including bookmarks, snippets, and notes. The shared information will be shown on the sidebar where all collaborators can see. In the sidebar, users can collaboratively organise the shared information around topics. In section 6.3.2, we will describe the features of MakeSenseTogether in detail. MakeSenseTogether enable users to share information, build structure for the task, organise information and adjusting structure and create a shared representation. In this section, we describe the features according to their design purpose.

- **Construction of task structure: adding topics and editing topic**

  In the sidebar, we provide a button for users to add topics of the task. A new topic can be added at any time of the task. When sharing information, users were asked to specify a topic for each piece of information that is to be shared. In the sidebar, shared information

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[1]http://github.com/InfoSeeking/CoagmentoCollaboratory
[2]https://webprojects.eecs.qmul.ac.uk/info/
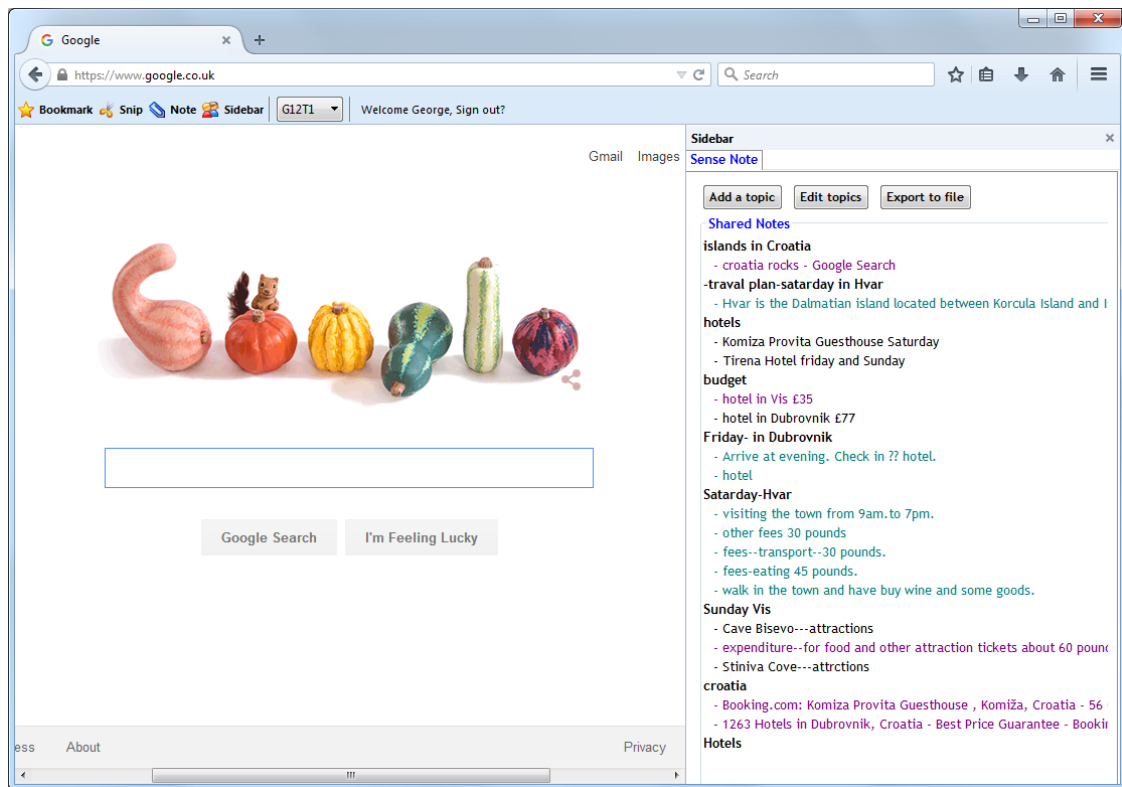
Figure 6.7: MakeSenseTogether, a Firefox extension consists of a toolbar and a sidebar

is displayed in the "SenseNotes" space according to topics. Figure 6.8a shows the dialogue for adding a new topic.

After adding a topic, users are free to modify the name of the topic through double-clicking the topic. They are also able to delete topics and merge topics through clicking on the "Edit topics" button. Figure 6.8b shows the "edit topics" feature of "SenseNotes".

- **Sharing of information: bookmark, snippet and notes**

  In the toolbar, we provide features for users to share different types of information to the "SenseNotes" space in the sidebar (as shown in Figure 6.9). Users can specify the topic for shared information so that they can group the information with the same topic. For example, users can share a webpage as a bookmark through clicking on the "Bookmark" button on that webpage. As shown in Figure 6.9a, a window will pop up which shows the link of the page the user chose to share. Comments can be added to this bookmark. Users are also asked to specify the topic of this bookmark, either through choosing from a list of existing topics or through identifying a new topic (default topic is the query that leads to current webpage). Similarly, users can share a piece of text which is selected from a
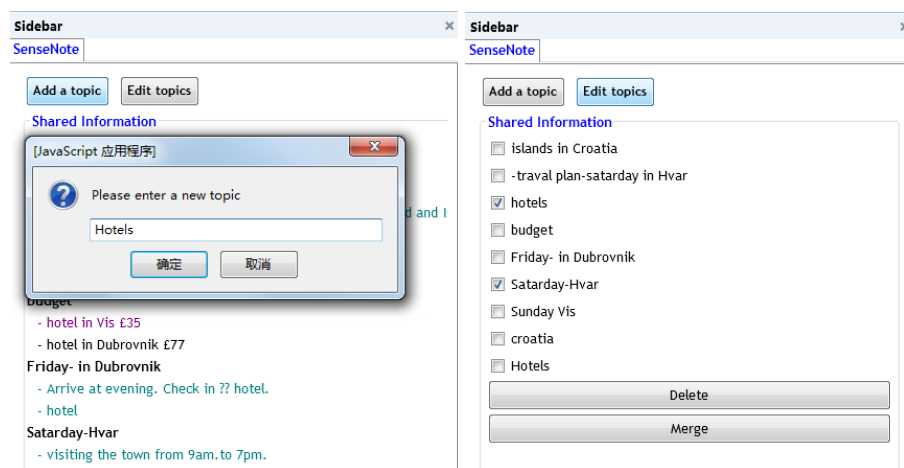
(a) Adding a topic to "SenseNotes" (b) Editing topics in "SenseNotes"

Figure 6.8: The topic-related features for building structure and organise information in "SenseNotes"

webpage as a snippet and share their thoughts about the task as a note. Bookmarks and snippets are linked to webpages, but notes are not.
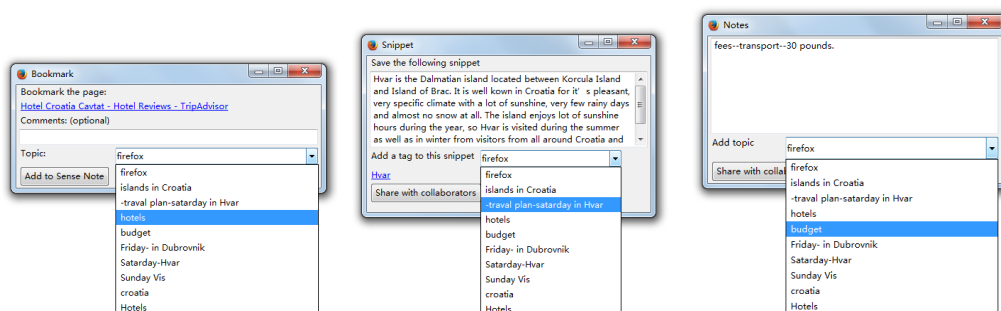
(a) Bookmark (b) Snippet (c) Notes

Figure 6.9: The features of sharing a bookmark (a), snippet (b) and note (c). A drop down list provides the existing topics to choose from.

- **Creation of a shared representation: editing shared information**

  From Figure 5 we can see that, the context menu also including edit and delete shared information. Therefore, after sharing a piece of information, the content of the shared information can be edited afterwards.

- **Awareness of collaboraters' work: color-coded text according to person**

  In "SenseNotes", the shared information are color-coded according to group members. The information shared by the user self is presented in black, and the information shared
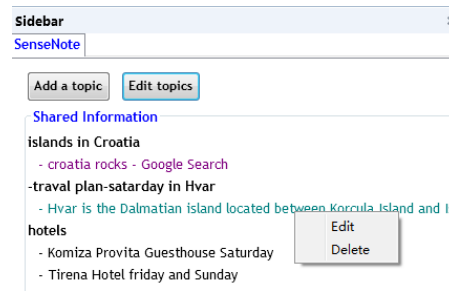
Figure 6.10: The context menu of "SenseNotes"

by others are presented in different colors in order to help users tell what has done by each group member.

6.4 Iteration 2: A Formative Evaluation of MakeSenseTogether

We conducted a formative evaluation of the interactive prototype of MakeSenseTogether with 8 groups of 3 participants (24 participants in total). During the study, each group performed a CIS task using MakeSenseTogether. We aim to get user feedback on the usability of design features. After the study, we finalised our design of MakeSenseTogether based on user feedback from this formative evaluation.

6.4.1 Participants

We recruited 8 groups of 3 participants from our university through emails. None of the participants in this evaluation were involved in our previous studies. In Table 6.1, we present the demographic information of our participants.

Age	19.71 years [17-22]
Gender (Total)	8 male, 16 female
Academic Background	Business management(6), Geography (5), Languages(5), Computer science(3), Economics(3), Law(1), Politics(1)
Self-rated Search Skill (Novice = 1; Expert = 5)	3.83 [SD = 0.76]
Collaborative Search Experience	3+ times (9), 1-3 times (14), Never (1)

Table 6.1: Demographics of participants

6.4.2 Procedure

The evaluation study consists of two parts. The first part is performing a CIS task using Make-SenseTogether. MakeSenseTogether is designed to address the collaborative sensemaking challenges that we found in both travel planning and topic research tasks. Therefore in this evaluation study, half of the group performed the travel planning task while the other half performed the topic research task. Before the task, we introduce the features of MakeSenseTogether to participants. When participants complete the task, we enter the second part of the study. We stopped participants at 1 hour if they still had not finish the task. The second part of the study is an semi-structured interview to discuss with participants the usability issues they found during the task and suggestions for improving current features of MakeSenseTogether to better support collaborative sensemaking.

6.4.3 Results

In this section, we discuss user feedback on the features of MakeSenseTogether for collaborative sensemaking. In general, participants liked the idea of adding topics to build structure for the task and organise shared information. They explained that one of the positive effect of the topic-related features (i.e. adding topics and sharing information according to topics) is making the process of collaboratively making sense of the task more organised. More specifically, participants said that "*the topics remind us what we have to sort out*" and "*it [the "SenseNotes"] was like a group discussion board where the topics were the threads*".

Providing awareness of collaborators' work is another positive aspect of MakeSenseTogether. For example, participants said "*everyone's research can be seen and put together under topics*" and "*the name of the group member who shared the information were shown in each piece of information, so we were able to see what has been done by other groupmates*".

While the design ideas of MakeSenseTogether were appreciated by most users in general, there were some issues reported by participants when using it to perform the CIS tasks. According to users feedback, we refined MakeSenseTogether. More specifically, the following changes were made in MakeSenseTogether to address the main issues identified by participants:

- **Moving information between topics**

  During the task, participants sometime want to change the topic of a piece of shared information. Thus, participants suggested that the tool should allow them to move the shared

formation between topics to reorganise information in "SenseNotes". To support this requirement, we created another option "move to" in the context menus of "SenseNote". As shown in Figure 6.11b, a list of existing topics will be given for users to choose which topic they want the selected information to move to.

(a) Before   (b) After

Figure 6.11: The context menu of "SenseNotes"
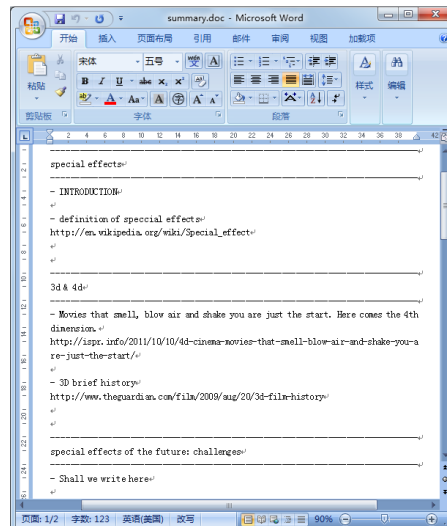
Figure 6.12: An example of the exported file

- **Exporting information to file**

  For creating a shared representation, participants want to compose the final representation based on the information collected in "SenseNotes". However, they found it was not

convenient because they cannot copy information from the sidebar to a document. Therefore, we provide a new feature in the sidebar which allow users to export the information in "SenseNotes" to a document. By clicking on the "export to file" button in the "SenseNotes" space, all the information shared in "SenseNotes" will be exported to a word document on the desktop. Figure 6.12 is an example of the exported file. In this file, information were listed according to topics.

6.5 Summary

In this chapter, we explained the design of MakeSenseTogether, a tool for collaborative sensemaking in CIS. Based on the user requirements that we learned from the studies reported in chapter 4 and 5, we outlined the design concepts of the tool we proposed for supporting collaborative sensemaking in CIS, and introduced the framework and main features of MakeSenseTogether. We also described the iterative design process which involved scenario-based interviews using paper prototypes and a formative evaluation study. In the following chapter, we describe a summative evaluation study of MakeSenseTogether and the influence of topic features in collaborative sensemaking.

Chapter 7

Study 3: Evaluating MakeSenseTogether in CIS tasks

In this chapter, we present the evaluation of MakeSenseTogether, the tool we developed to support collaborative sensemaking behaviour in CIS tasks. We carried out a user study with 12 groups (36 participants) to evaluate the features of MakeSenseTogether designed for collaborative sensemaking. The aim of this study is to examine how users interact with these features in CIS tasks and to get user feedback on the usefulness of each feature. In addition, we investigate the influence of the novel topic-related features (including adding topics, sharing information according to topics, editing topics and moving information between topics) on different aspects of collaborative sensemaking, such as structuring the task and creating a shared representation. We also use the findings from user studies in chapter 5 about the general patterns of collaborative sensemaking in CIS tasks to explore the differences in users' collaborative sensemaking behaviours between using MakeSenseTogether and using a standard web browser.

In section 7.1, we outline the motivation and research questions of this evaluation study. We then describe the study design in section 7.2. In section 7.3, we present the results of this evaluation study and we discuss the implications of our findings in section 7.4. Finally we summarise the important findings of this chapter in section 7.5.

7.1 Motivation and Research Questions

Based on our study findings about the main challenges of collaborative sensemaking in CIS, we designed a tool called MakeSenseTogether to support users collaborative sensemaking activities of the task, mainly in building structure for a shared representation and keeping track of task

progress. As described in chapter 6, we iteratively refined the design of features according to user feedback during the development process of MakeSenseTogether. In this chapter, we conducted a summative user evaluation (Preece et al., 2011) of the final product of the design process, i.e. MakeSenseTogether, to study how the tool assists users in the challenging activities of collaborative sensemaking, such as building structure and creating a shared representation, and how our proposed features influence the collaborative sensemaking behaviour of users.

MakeSenseTogether provides support for sharing individual findings (including bookmarks, snippets and notes) with collaborators during the search process. Most CIS systems (Shah, 2010; Morris and Horvitz, 2007; Diriye and Golovchinsky, 2012) provide similar support for information sharing between collaborators because sharing of knowledge is a basic requirement of CIS (Foley et al., 2010). However, rather than presenting shared information according to time or person, MakeSenseTogether introduces a set of novel features (referred to as topic-related features in the rest of the chapter), including adding and editing topics and moving information to other topics, which allow users to identify topics of the task and manage shared information according to topics. Therefore, in this study we focus on how users make use of topic-related features to structure the task and create a shared representation for the task. We are also interested in the impact of topic-related features on the collaborative sensemaking behaviour of users. More specifically, we address the following research questions:

RQ1. How do users interact with MakeSenseTogether to perform collaborative sensemaking activities, such as sharing information, build structure for the task, etc.?
As presented in section 6.3.2, MakeSenseTogether includes features to support sharing information, building structure for the task, organising information and adjusting structure, creating a shared representation and keeping track of group sensemaking process. For this research question, we are interested in how users interact with the related features of MakeSenseTogether to perform these collaborative sensemaking activities. In particular, we explore user interaction with the novel topic-related features of our tool that were designed to help users build structure for the task and organising shared information. We also investigate users perception of the usefulness of the features of MakeSenseTogether and how they think the tool supports them in collaborative sensemaking activities.

RQ2. What is the influence of topic-related features on the collaborative sensemaking behaviour of users?

In MakeSenseTogether, we designed novel topic-related features to support the most challenging activities of collaborative sensemaking that we discussed in chapter 5, namely, building structure for the shared representation and keeping track of the task progress. Therefore, in this study, we want to examine the influence of topic-related features on the collaborative sensemaking behaviour of users, especially how the features influence the most difficult collaborative sensemaking activities. We created a simplified version of MakeSenseTogether called ShareTogether which has identical features as MakeSenseTogether except for the topic-related features. Instead of using an existing CIS system, we create ShareTogether as the baseline tool for several reasons. Firstly, MakeSenseTogether is built from scratch and focuses on the collaborative sensemaking aspect of CIS so it has different design goals and unique features compared to most CIS systems. Hence, it might not be comparable to existing CIS systems. Secondly, by creating ShareTogether, we can control the impact of any other factors, such as the influence of an integrated chat box and different sharing mechanism, and thus focus on the influence of the topic-related features alone. In this study, we investigate the influence of topic-related features by comparing collaborative sensemaking behaviour using MakeSenseTogether (referred to as 'MakeSenseTogether group' in the rest of the chapter) with using ShareTogether (referred to as 'ShareTogether group' in the rest of the chapter).

RQ3. What are the differences in collaborative sensemaking behaviour between using MakeSenseTogether and a standard web browser?

In this study, we are also interested to investigate the influence of MakeSenseTogether on user behaviour of collaborative sensemaking. In chapter 5, we studied collaborative sensemaking behaviour using standard web browser and other tools such as the chat tool and editing tool. We compare collaborative sensemaking using MakeSenseTogether with the general patterns of collaborative sensemaking using standard web browsers in terms of the strategies for structuring the task, searching and sharing information, creating a shared representation and keeping track of collaborators' work and task progress. Since the settings of this study are not exactly the same as those of previous studies, there are some limitations for this comparison (described in detail in section 7.2.6).

7.2 Study Design and Methodology

In this section we present the design and methodology of the evaluation of MakeSenseTogether which enables us to address the research questions outlined in section 7.1. In the following, we describe in detail the participants, the tasks, the tools, the study procedure, the method for data analysis, and the limitations of this study.

7.2.1 Participants

We recruited 36 participants (12 groups) from our university through emails for this evaluation study. All groups were self-formed and none of the participants were involved in our studies before. The demographic information of participants is provided in Table 7.1. The distribution of participants is similar as in our previous studies in terms of age, gender, self-rated search skill and collaborative search experience (see Table 5.2 for more detail as a comparison).

Age	22.22 years [18-38]
Gender	18 male, 18 female
Academic Background	Computer Science (13), Economics and Finance (6), Business Management (5), Languages (5), Electronic Engineering (3), Maths (1)
Self-rated Search Skill (Novice = 1; Expert = 5)	3.89 [SD = 0.78]
Collaborative Search Experience	3+ times (15), 1-3 times (17), Never (4)
Use of CIS systems	Never (34), Rarely (2)

Table 7.1: Demographics of participants

In addition, we collected information about users' academic background and use of CIS systems. Almost all of our participants (94%) reported that they have never used a CIS system, except for 2 participants who described they have used Facebook Group to work on a collaborative project. However, 89% of participants have experience on collaborative information seeking in daily life. Among them, 78% have collaborated with classmates/colleagues, 72% have collaborated with friends and 38% have collaborated with family members. We also asked participants to specify the type of tasks included in their CIS experience according to the categories suggested by Morris (2008). The CIS tasks they have performed in daily life include academic/technical

information (63%), travel planning (60%), shopping (44%), entertainment (44%), news/current events (34%) and health/medical information (19%).

7.2.2 Tasks

In this study, we used the same tasks (i.e. travel planning and topic research) as in the studies described in chapters 4 and 5. This is because we want to be able to compare with the strategies users employed for collaborative sensemaking in previous studies to reflect on the impact of MakeSenseTogether on collaborative sensemaking behaviour.

Travel Planning (Croatia)	You are planning to spend the next weekend together in the Croatian islands. The flight tickets are already booked. You will arrive at Dubrovnik on Friday evening and back to London from Dubrovnik on Monday morning. Now you want to plan the trip together. You would like to choose 2 ISLANDS in Croatia to visit and stay, 1 for Saturday and 1 for Sunday. At the same time, you want to find information about the 2 islands and plan for things to do around these places. The budget is £500 per person. At the end, your group should agree upon a plan with a rough schedule for your trip.
Topic Research (Special Effects)	Special effects are very common in today's movies. The technology of special effects in movies has changed throughout the years. Your group is preparing a 20-minutes presentation on the future challenges of special effects in movies. Now you want to collect information on the web and make an outline for the presentation together. At the end, your group should agree upon an presentation outline which includes the key points your group would like to make and related information that would be useful in the presentation.

Table 7.2: An example of tasks given to participants

The study consists of two sessions. In each session participants were asked to complete either a travel planning task or a topic research task. Both tasks were presented to participants in a simulated work task situation (Borlund, 2003), example task scenarios are given in Table 7.2. We prepared two destinations (Wales or the Croatian islands) for the travel planning task and two topics (globalisation and human rights or special effects technology) for the topic research task in case some participants had too much prior knowledge about a destination or topic. Paticipants

rated their prior knowledge for each destination and topic in the prior knowledge questionnaire (see Appendix D.2). We gave participants the destination and topic for which their group had the lower average score of prior knowledge. We also avoided the topic and destination which one of the group members had significant prior knowledge (rating greater than 3 in a scale of 1-5). If the scores for the topics or destinations are the same, we allow participants to choose between them.

7.2.3 Tools

The main purpose of this study is to evaluate MakeSenseTogether, especially the novel topic-related features that we proposed to support users in structuring the task and creating a shared representation. We created a simplified version of our tool without the topic-related features called ShareTogether to serve as a baseline. Interfaces of MakeSenseTogether and ShareTogether are shown in Figure 7.1. In Table 7.3, we outline the difference in features between MakeSenseTogether and ShareTogether. During the study, each group used MakeSenseTogether and ShareTogether to perform two different tasks.

Features	MakeSenseTogether	ShareTogether
Sharing bookmarks, snippets and notes	Yes, presented according to topics	Yes, presented in chronological order
Adding, deleting and merging topics	Yes	No
Editing and deleting shared information	Yes	Yes
Moving the shared information between topics	Yes	No
Exporting information to file	Yes	Yes
Color coding according to person	Yes	Yes

Table 7.3: Differences between MakeSenseTogether and ShareTogether

7.2.4 Study Procedure

In this study, we have two independent variables, which are the task (travel planning/topic research) and the tool (MakeSenseTogether/ShareTogether) and therefore we have 4 different conditions in total. For the purpose of reducing the effects of the order of conditions on participants'
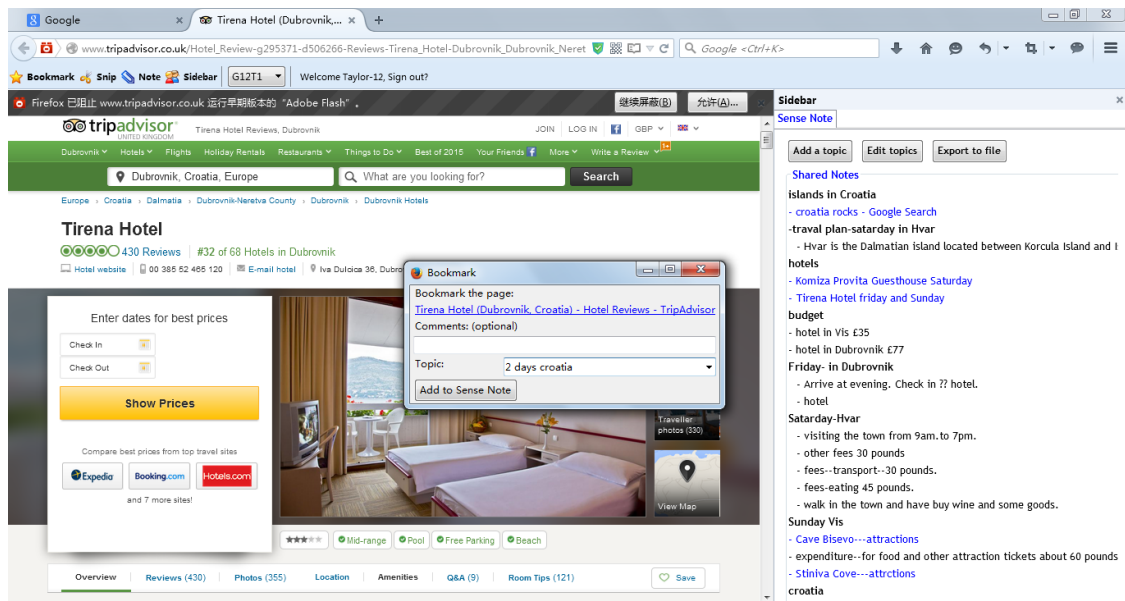
(a)
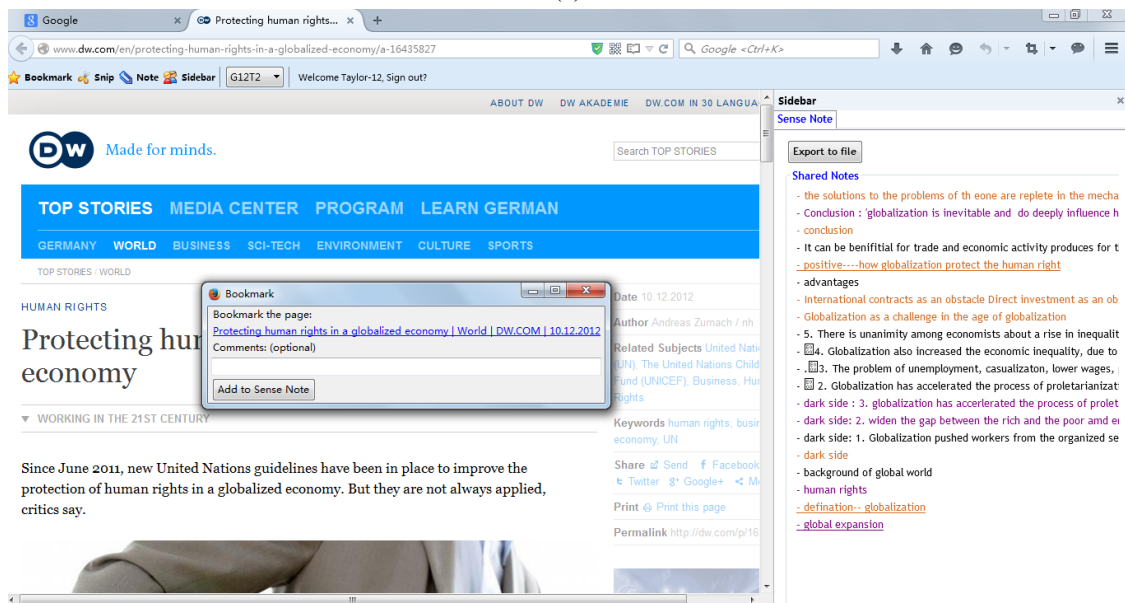
(b)

Figure 7.1: The interface of tools used in the study: (a)MakeSenseTogether, (b)ShareTogether.

behaviour, we present the tasks and tools to participants in different order. As shown in Table 7.4, we planned the combinations of tasks and tools for each group in each session.

For each group, the evaluation process consists of the following steps:

1. The evaluation started with participants signing a consent form based on reading the information sheet and listening to our brief introduction about the study in terms of purpose,

Group NO.	Session 1	Session 2
G1, G5, G9	TP/S	TR/M
G2, G6, G10	TR/S	TP/M
G3, G7, G11	TR/M	TP/S
G4, G8, G12	TP/M	TR/S

Table 7.4: The combinations of tasks and tools for each group in each session. (TP = travel planning task, TR = topic research task, M = MakeSenseTogether, S = ShareTogether)

duration, tasks and the data collected during the study.

2. As participants agreed to continue, we distributed a pre-task questionnaire to collect demographic information of participants and a prior knowledge questionnaire which is used to decide the specific topic of each task for the group (criteria described in section 7.2.2), i.e. whether the destination is Wales or Croatia in the travel planning task, and whether the presentation topic is about globalisation and human rights or special effects in the topic research task.

3. We then assigned the first task to participants and demonstrate the tool they were asked to use during the task. We went through all the features of the tool with participants by making examples. In addition, we provide a user manual for participants to refer to during the task. Participants were also allowed to ask questions about how to use a specific feature of the tool during the task.

4. Participants had maximum 1 hour to complete the task in a group. Their interaction with our tool was recorded using CamStudio[1] (a screen recorder software). We also observed them while they are performing the task. After 1 hour, we stopped the participants and handed out a post-task questionnaire about user perception of the task and the tool.

5. Participants were then given the second task and we illustrated the difference of the tool they were going to use in this task compared with the tool they used in the first task. We then repeated step 4 for this task.

6. After the second task, we conducted a semi-structured interview with participants to investigate user experience of using MakeSenseTogether to collaboratively make sense of the

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[1] http://camstudio.org/

task, compared to using ShareTogether.

7.2.5 Data Analysis

In the study, we collected both qualitative and quantitative data mainly via screen recordings, questionnaires interviews, web server logs and chat logs. We analysed the data according to the three research questions of this evaluation.

Firstly, for the research question of how users interact with MakeSenseTogether in collaboratively making sense of the task (RQ1), we used the data from web server logs, screen recordings and questionnaires. The web server logs were from the database of MakeSenseTogether. They recorded lists of bookmarks, snippets, notes and topics created by participants for each task. As such, we can measure the total number of topics and shared information in a task. The screen recordings allow us to gain an understanding of participants' usage of MakeSenseTogether for collaborative sensemaking activities, for example, when participants created topics, how they interact with the topics and create a shared representation for the task. In the questionnaire, we asked users their perceptions of the usefulness of the features in MakeSenseTogether and the helpfulness in different aspects of collaborative sensemaking.

Secondly, to investigate the influence of topic-related features on the collaborative sensemaking behaviour of users (RQ2), we compared users experience of collaborative sensemaking between MakeSenseTogether group and ShareTogether group. We applied the open coding and axial coding phases of Grounded Theory (Charmaz, 2007) to the data from screen recordings in order to identify theme in terms of difference. In addition, we compared user ratings in post-task questionnaire about the level of support MakeSenseTogether and ShareTogether provided from different aspects of collaborative sensemaking.

Finally, for the difference of collaborative sensemaking behaviour between using MakeSenseTogether and using normal search engine (RQ3), we analysed the screen recordings of this study in ELAN [2] according to the activities and patterns that we identified in previous studies.

We also note that one group in our study did not perform the travel planning task normally. One of the participants just opened a document and made up the plan without searching the web for information. For example, the participant wrote in the travel plan that "*in the morning we are going to a dolphin show*" without actually checking for the detail about a dolphin show in the destination. Also, this participant did not discuss the task and share information with any

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[2] http://www.lat-mpi.eu/tools/elan/

group member. Therefore, we believe that the behavioural data collected form this group were not representative for common users and we excluded this data in the analysis of user behaviour.

7.2.6   Limitations

One of the limitations for this study is that our tools (MakeSenseTogether and ShareTogether) are new to participants. As indicated in Table 7.1, most of our participants have not used CIS systems before. In the post-task interviews, some participants said they could make better use of the tools if they had used it for several times. Due to the time limit of the study, we did not provide a training task for participants to get familiar with the system. Instead, before starting the task, we briefly demonstrate how to access the features of the tools through examples. We also encouraged participants to ask questions about the usage of the tools at any time during the task.

Another limitation of this study is using the findings from our previous studies to investigate the impact of MakeSenseTogether on the collaborative sensemaking behaviour of users. Participants and study settings in this study are different from previous studies in several ways. First of all, the number of participants in each study were different. In previous studies, we used 8 groups for each task, but in this evaluation study, we used 6 groups for each task. Secondly, in this study each group performed two tasks while in previous studies each group performed one task. Participants' behaviour in the second task might have changed because of fatigue or practice. However, in this study we changed the order of different types of tasks intending to control the influence of order effects.

7.3   Findings

We present our findings from the evaluation study according to the research questions we outlined in section 7.1. We first report participants' usage of MakeSenseTogether for collaborative sensemaking activities in section 7.3.1. In section 7.3.2, we discuss the influence of topic-related features through comparing users' collaborative sensemaking behaviour using MakeSenseTogether with using ShareTogether. Finally, we outline the difference in users collaborative sensemaking strategy between using MakeSenseTogether and using normal search engine in section 7.3.3.

7.3.1   User Interaction with MakeSenseTogether

In this section, we present our findings about how participants use MakeSenseTogether to perform collaborative sensemaking activities in the evaluation study. In general, participants found MakeSenseTogether "*very useful for group tasks*". For example, participants explained that "*the system is very useful to share information with others*","*this system is really good when you want to organise your information*" and "*the summary system is good for making a report*". In the post-task questionnaire, we investigated user satisfaction with MakeSenseTogether in respect of the ease of use and the level of support for the CIS process. As shown in Figure 7.2, most participants agreed or strongly agreed that MakeSenseTogether was easy to use (72.2%) and that it supports the task well (75%). In the following, we report the usage of MakeSenseTogether during the evaluation study and user feedback for the features that support different activities of collaborative sensemaking.
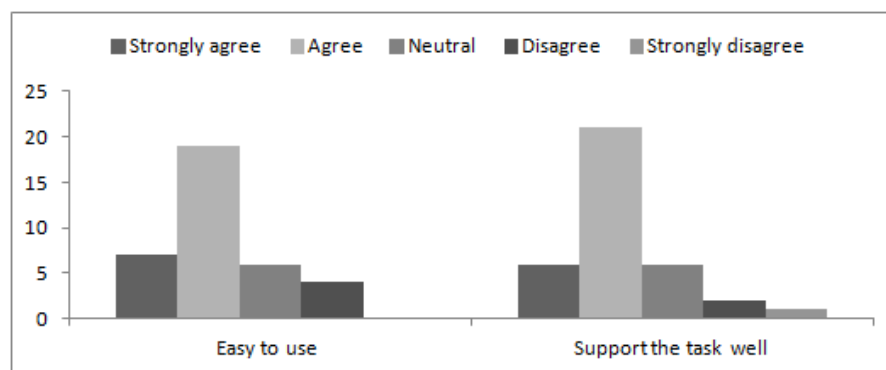
Figure 7.2: User satisfaction with MakeSenseTogether

Adding and Editing Topics

The most distinctive features of MakeSenseTogether are the topic-related features which are designed for users to structure the task and organise information according to topics during the CIS task. MakeSenseTogether enables users to add a topic of the task either through the "Add Topic" button in the "SenseNotes" or when sharing information from the toolbar. In this study, we found that all participants have added topics. Each group created an average of 8.6 topics (SD = 2.97) during a task. From our observation, 61.2% of the topics were added before searching for information in order to specify "*what need to research*", and 38.8% were added when a piece of information is to be shared.

In terms of features for editing topics, MakeSenseTogether enables users to delete or merge

topics from the 'edit topic' button in the sidebar and modify the name of the topic through double clicking a topic. The most commonly used feature is 'delete topic', which was used 13 times by 9 participants in 7 groups, followed by 'merge topics', which was used 6 times by 6 participants in 5 groups, and modify topics, which was used 3 times by 3 participants in 3 groups.

Overall, participants thought the topic-related features were very useful. In the post-task questionnaires, participants were asked to rate the usefulness of the topic-related features in scale of 1 (not useful at all) to 5 (very useful). We can see from Figure 7.3 that 'add topic' is the most useful feature of MakeSenseTogether as rated by participants (Mean = 4.36, SD = 0.80) and edit topics is the second useful feature (Mean = 3.92, SD = 1.02). In the post-task interview, participants explained "*the topic features were very useful because they made the information more clear and structured*", "*I found it really useful. The task was organised better and not messed up*" and "*it helped us split up the task*". However, some participants also suggested that "*it should allow changing the order of topics*".
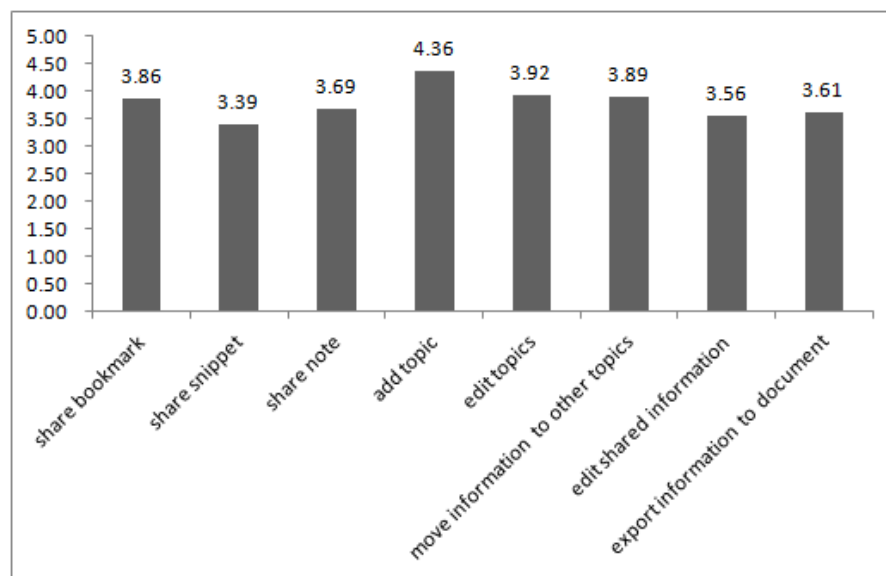
Figure 7.3: Usefulness of MakeSenseTogether features

Sharing Bookmarks, Snippets and Notes

MakeSenseTogether aims to provide an easy way for users to share three different types of information, namely bookmark, snippet and note in the toolbar. From our observations, bookmark is the most frequently used sharing feature in the toolbar and 91.7% of participants have used it. Each group shared an average 10.8 bookmarks during a task (SD = 3.76). Among all the bookmarks shared by participants, 51.5% were added with comments. Participants found adding

comments to bookmarks very useful because doing so helps them "*know what the webpage is about without clicking it*". Sharing notes is the second most popular feature of the toolbar and 55.6 % of participants used it. Each group shared an average of 3.92 notes during a task (SD = 4.74).

The use of snippets in groups varies according to tasks. In the travel planning task, 27.8% of participants shared snippets while 50% of participants shared snippets in the topic research task. As shown in Table 7.5, in travel planning, the average number of snippets shared by groups is significantly less than in topic research (t(10)= -2.303, p = 0.044).

	Bookmarks	**Snippets**	**Notes**
Travel Planning	10.17 [2.32]	**1 [1.10]***	5 [6.29]
Topic research	11.50 [4.97]	9 [8.44]	2.83 [2.64]
Overall	10.83 [3.76]	5 [7.10]	3.92 [4.74]

Table 7.5: Average number of times each sharing feature was used in groups [SD] (* means statistically significant at p <0.05)

As shown in Figure 7.3, bookmark is considered most useful among the three sharing features, followed by note and snippet. More specifically, as shown in Figure 7.4, the majority of participants thought that bookmarks (69.4%) and notes (61.1%) were useful or very useful and no participant thought bookmarks were not useful at all. However, the participants opinion on the usefulness of snippets were varied. 50% of participants thought that sharing snippets was useful or very useful while 27.8% of participants considered it as not very useful or not useful at all. In the interview, some participants pointed out one reason for the less use of snippets is that sometimes they can use the bookmark and note instead, especially for the travel planning task. For example, one participants said that "*I didn't really use the 'snippet' function as we just summarised information under the 'note' section*". We also observed that some participants selected and copied important information from a webpage and shared it as a comment with bookmark instead of using the 'Snip' function. Other participants found sharing snippets very useful because "*in the end we don't want the link of bookmarks, we need to get the useful information from it*".

Editing Shared Information

In the "SenseNotes", users can manage the shared information through a context menu. The context menu provides users the options to modify the content of a piece of information ("Edit"),
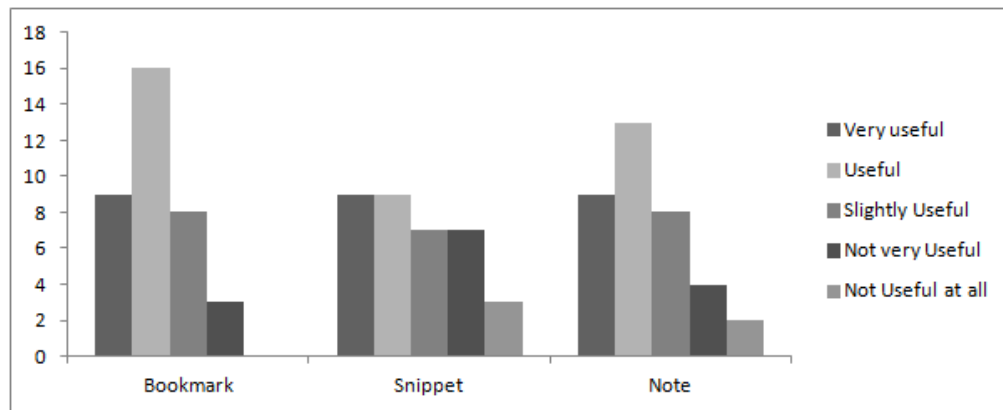
Figure 7.4: Usefulness of Bookmark, Snippet and Note

delete a piece of information ("Delete") and move a piece of information to other topics ("Move To"). As observed in this evaluation study, "Move To" was used more commonly by 38.9% participants, while 30.6% of participants have edited information and 19.4% of participants have deleted information. In addition, we found that "Move To" was used greater number of times by participants in topic research than in travel planing (t(34) = 2.204, p = 0.034). In the ques-
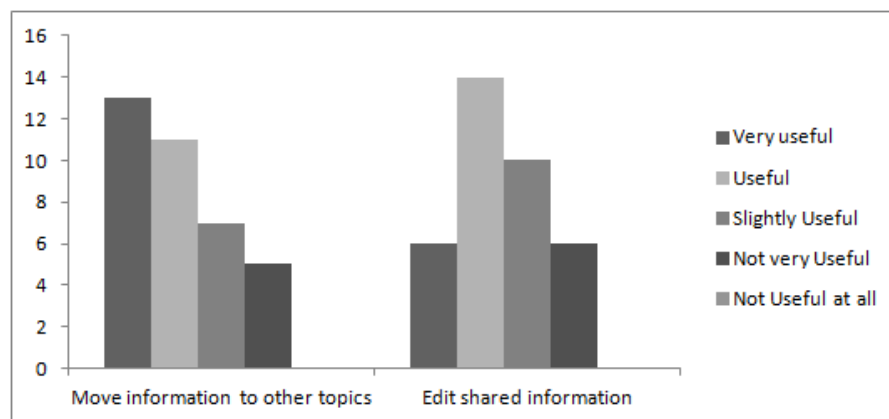
Figure 7.5: Usefulness of features for editing shared information

tionnaires, participants were asked about the usefulness of "move information to other topics" and "edit shared information" (including edit and delete information). As shown in Figure 7.3, "move information to other topics" is the third useful feature of MakeSenseTogether after "add topic" and "edit topics". As can be seen in Figure 7.5, 36.1% and 30.6% of participants indicated "move information to other topics" very useful and useful, and no participant found it not useful at all. "Edit shared information" is found very useful and useful by 16.7% and 38.9% of participants respectively, and no participant found "edit shared information" not useful at all.

Exporting Information to File

In order to assist users in the creation of a shared representation during CIS tasks, we designed a novel feature through which users can export a summary of the information shared in the "SenseNotes" to a file. In the topic research task, 94.4% of participants used the "Export to file" features while only 22.2% of participants used it in the travel planning task. As we observed, in the travel planning task, participants usually share bookmarks and summarise the key information in the comments area of bookmarks. Some participants also use notes to summarise the plan for each day. Therefore, they did not need further modification of the exported file to create a plan. However in the topic research task, participants used the "SenseNotes" mostly for collecting information. In the later stage, when they thought the collected information was enough, they exported the file to discuss the outline together. Some groups edit directly in the exported file to highlight the key points, change the order of topic sections and better format the representation. Other groups found the exported file presents information in a good format, so they decided to modify the shared information in the "SenseNotes" and exported it again at the end of the task.
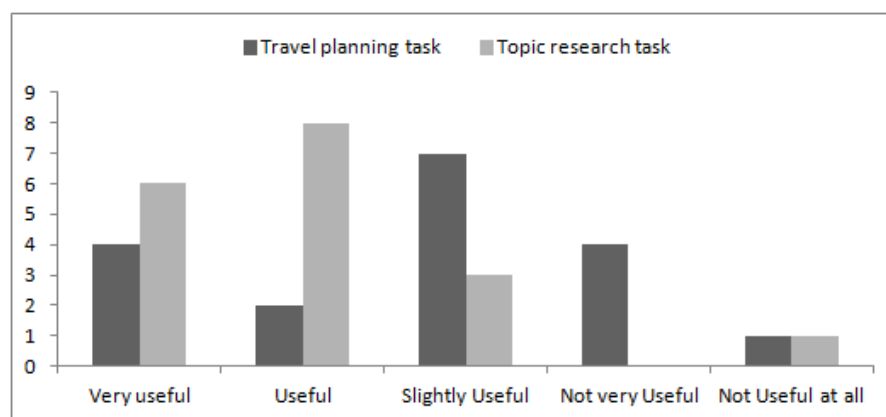
Figure 7.6: Usefulness of exporting file in different tasks

As can be seen in Figure 7.6, participants' ratings of usefulness for 'export information to file' are significantly different according to tasks (t(34) = 2.0726, p = 0.0459). In the topic research task, most participants found it useful because "*exporting is easier for us to summarise an outline*", "*the exported file looks nice, with references*" and "*the summary document would be useful for later use, for example, creating slides for the presentation*". In the travel planning task, some participants also found "Export to file" useful because "*all the information in the same file and we can edit it as we want*". However some participants think it less useful because they mainly shared bookmarks during the task, thus "*the exported file were mainly links of bookmarks,*

but in the end we just need to get useful information from it to summarise".

7.3.2 The Influence of Topic-related Features in Collaborative Sensemaking

In this section, we focus on the research question about the influence of topic-related features in collaborative sensemaking. Based on our study settings, we investigated this question by comparing user behaviour of collaborative sensemaking when using MakeSenseTogether and ShareTogether to perform CIS tasks.
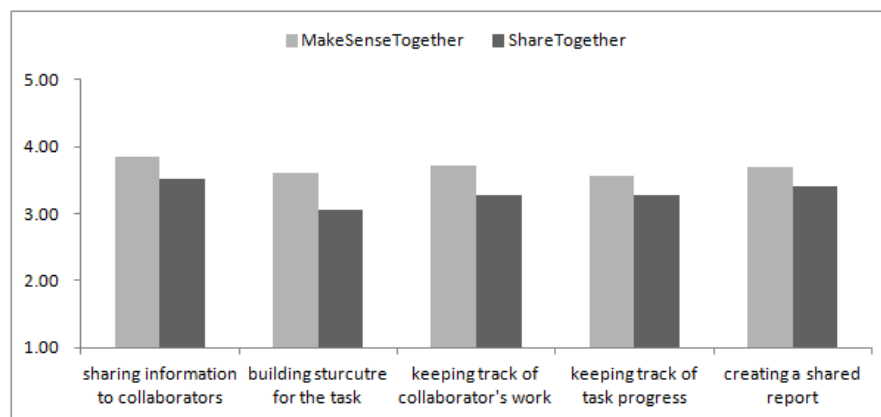
Figure 7.7: Users' perception of the level of support provided by MakeSenseTogether and ShareTogether in different aspects of collaborative sensemaking

In general, participants found MakeSenseTogether to be more useful than ShareTogether because the topic-related features allow them to "*define categories and group the information with same topic*" and "*to split up the task and track the sub-tasks*". In post-task questionnaires, participants were asked to rate how well MakeSenseTogether and ShareTogether respectively supporting different aspects of the task from 1 (very poor) to 5 (very well). As shown in Figure 7.7, users' average ratings about MakeSenseTogether are higher than ShareTogether in all aspects, including sharing information to collaborators, building structure for the task, keeping track of collaborators' work, keeping track of task progress and creating a shared report.

Table 7.6 shows user interactions with the features that are present in both MakeSenseTogether and ShareTogether. Differences exists in the use of common features of MakeSenseTogether and ShareTogether and in collaborative sensemaking behaviour. In the following, we discuss the differences in collaborative sensemaking behaviour in terms of structuring the task, sharing information and composing a shared representation.

	Travel Planning Task		Topic Research Task	
	MakeSenseTogether	ShareTogether	MakeSenseTogether	ShareTogether
Share bookmark	10.17 [2.32]	12.50 [3.99]	11.50 [4.97]	9.17 [3.13]
Share snippet	1 [1.10]	0 [0]	9.00 [8.44]	5.17 [3.31]
Share notes	5 [6.29]	1.67 [1.97]	2.83 [2.64]	7.17 [6.68]
Edit shared info	4.33*[3.78]	0.33 [0.52]	4.17 [6.59]	3.00 [2.28]
Export to file	0.67 [1.21]	0.67 [0.82]	3.33*[0.52]	1.67 [1.51]

Table 7.6: Average number of times each activity was performed in ShareTogether and Make-SenseTogether groups [SD] (* means statistically significant at p <0.05)

Structuring the Task

In terms of structuring the task, we identified two strategies in previous studies, i.e. building an overall structure and identify subtasks step by step. In this evaluation study, we found that users employed different strategies in the travel planning task when using MakeSenseTogether and ShareTogether. As shown in Table 7.7, when using MakeSenseTogether, more groups used the "identifying subtasks step by step" approach. On the contrary, when using ShareTogether, more groups used the "building an overall structure" approach. The reason for this could be that MakeSenseTogether provide a way for users to record the identified subtasks and jointly working on them afterwards. By adding topics, users can add subtasks anytime during the task and anyone in the group can share information under each topic. However, ShareTogether does not provide the facility for user to organise shared information according to topics. Therefore, more groups divide the task and each participant take responsible of one part of the task.

Furthermore, when using ShareTogether, participants build an initial structure at an early stage usually stick to the structure during the task. Each group member takes responsibility for different part of the task from searching for information to composing the final representation. However when using MakeSenseTogether, users amend the initial structure during the task through adding new topics and editing existing topics.

	Travel Planning Task		Topic Research Task	
	MakeSenseTogether	ShareTogether	MakeSenseTogether	ShareTogether
Dividing the whole task	33.33%	83.33 %	50%	50%
Identifying subtasks step by step	66.67%	16.67 %	50%	50%

Table 7.7: Strategy for structuring the task using MakeSenseTogether and ShareTogether

Searching and Sharing Information

As seen in Table 7.6, there is not much difference in the average number of bookmarks shared in each group when using MakeSenseTogether and ShareTogether between tasks. However, the average number of snippets and notes shared between using MakeSenseTogether and ShareTogether were quite different in both task. In travel planning task, participants shared more snippets and notes when using MakeSenseTogether than using ShareTogether. No participants shared snippets when using ShareTogether. From our observation, the reason for the difference might be that when using ShareTogether most groups only use the sidebar to share webpages for collaborators to view but in MakeSenseTogether, participants also use the snippets and notes to record important information for the travel plan with the help of topic-related features.

In the topic research task, users shared more notes in ShareTogether than in MakeSenseTogether. As we observed, when using ShareTogether participants usually collect information and compose representation for their subtasks in a word document. At the end of the task, they share the content in the word document as notes in the sidebar.

In addition, when using ShareTogether, 70% of bookmarks were shared with comments, which is more than that in MakeSenseTogether (51.5%). We found participants specify in the comments area the content of the shared bookmark and why it was shared as there were no topics to categorise shared information and prompt the content of information. Also, when using ShareTogether, some groups specify the topic of shared information. For example, in one of the groups, participants wrote '-POSITIVE' and '-NEGATIVE' at the beginning of each piece of information in order to categorise the shared information.

Creating a Shared Representation

As described in chapter 5, there are three approaches that participants employed to create a shared representation:

1. **Combining individual representations** is the approach in which participants divide the task between them and each participant create a representation for the sub-task they focused on in an external document (e.g. Word document). At the end of the task, they combine the representations to create a shared representation.

2. **Synthesising the shared information** refers to the approach in which one group member compiles all the shared information into a representation, while the other two group members only provide information.

3. **Composing together in a shared document** means that all of the group members compose the representation together in a shared online document (e.g. Google docs).

In all three approaches, participants used external editors to compose a shared representation.

When using MakeSenseTogether and ShareTogether, we found that no groups used the third approach, i.e. composing together in a shared document. This might be because our tools provide a shared workspace (SenseNotes) in the sidebar which allows users to share free-from notes to record their thoughts and decisions. In addition, the "export to file" feature enables users to create a shared representation based on the information collected in SenseNotes. In some groups, participants collect and edit information in the "SenseNotes" during individual search and export the information to a document in the later stage of the task. We call this approach "using the 'SenseNotes'".

We can see from Table 7.6 that in the topic research task, the "export to file" feature was used more commonly in MakeSenseTogether than in ShareTogether. In fact, as shown in Table 7.8, most groups use the "SenseNotes" to compose the final representation, while the majority of the groups employed the "combining individual representations" approach when using shareTogether. We believe that the topic-related features is the main reason that leads to the difference in the approach participants employed for creating a shared representation. In MakeSenseTogether, participants can structure the shared information with topics during the individual searching and sharing stage. As a result, the information was organised in a structured form which can be directly used to create the final representation. In ShareTogether, the shared information is listed in chronological order. In order to create a shared representation, the shared information needs to be further edited and presented in a meaningful way. Therefore in ShareTogether, the sidebar is mainly used to share information resources. Participants created external word document to compose the representation.

In the travel planning task, one group using ShareTogether did not finish the task in 1 hour so we did not observe any activities in this group related to creating a shared representation. The majority of the other groups used the "combining representations" approach when using ShareTogether, while most groups use the SenseNotes when using MakeSenseTogether. In both tasks, "SenseNotes" is most commonly used in MakeSenseTogether to create a shared representation. This indicates that without the topic-related feature, the SenseNotes in ShareTogether provided little help on the creation of shared representation.

	Travel Planning Task		Topic Research Task	
	MakeSenseTogether	ShareTogether	MakeSenseTogether	ShareTogether
Combining representations	None	50%	16.67%	50%
Synthesising information	33.33%	33.33%	None	16.67%
Using the SenseNotes	66.67%	None	83.33%	33.33%

Table 7.8: Strategies for creating a shared representation using MakeSenseTogether and Share-Together in travel planning and topic research tasks

7.3.3 Differences in Collaborative Sensemaking Behaviour Between Using MakeSenseTogether and Using Standard Web Browser

In this section, we present findings about the collaborative sensemaking behaviour of participants using MakeSenseTogether compared to the findings from our previous studies in which participants used a normal search engine. In the following, we report the main differences we observed form two aspects, building structure for the shared representation and keeping track of group sensemaking process.

Building Structure for the Shared Representation

In previous studies, we observed two strategies that participants built structure for the task. Some group used a "divide-and-conquer" strategy, i.e. building an overall structure which decomposes the task into parts. Another strategy is identifying sub-tasks step by step. In this evaluation study, we found that more groups used the "step-by-step" approach compared to in previous studies. Some groups divided the task roughly at the beginning in the chat tool but created more topics in the sidebar as the task proceed. In addition, in the previous study, we found that participants usually take responsible for different sub-tasks. However, in this study we found that using MakeSenseTogether, participants collaboratively searching for information for 28.8% of topics.

In terms of creating a shared representation, we observed three approaches in previous studies. The first approach, which is used most commonly in the topic research task, is that each participants create a representation for different subtasks of the task in word document and they finally combine the representations together. The second approach, which is used most commonly in the travel planning task, is to choose one person to summarise shared information and write the final representation. Besides, some group also used Google Docs to create a shared document and edit the representation together. In this evaluation study, most groups used the

'export to file' feature of MakeSenseTogether to create a shared representation and modified the exported file. All of the shared information in the sidebar was exported to a word document and listed according to topic sections. Some participants also write in a separate word document. However, in all the groups every participant has contributed to the final representation. No groups used the second approach. This could because the "export to file" feature of MakeSenseTogether provided an easier way for collaborators to create a shared representation together.

Keeping Track of Group Sensemaking Process

In our previous studies in which participants used normal search engine, we observed that participants checked task progress and collaborators' status on the chat tool. In this evaluation study of MakeSenseTogether, we found that checking task progress and collaborators' status appeared less frequently on chat tool. As shown in Table 7.9, checking status and checking progress in this study in which participants used MakeSenseTogether were both less than in previous studies in which participants used a normal search engine.

	Travel Planning Task		Topic Research Task	
	MakeSenseTogether	Normal Search Engine	MakeSenseTogether	Normal Search Engine
Checking Status	0.5 [0.55]	0.75 [0.89]	0.67 [0.82]	1.125 [1.36]
Checking Progress	0.33 [0.52]*	2 [1.77]	0 [0]*	1.75 [1.58]
Total	0.83 [0.75]*	2.75 [1.85]	0.67 [0.82]*	2.825 [1.93]

Table 7.9: Checking status and progress in groups using MakeSenseTogether and normal search engine [SD] (* means significant different at p <0.05)

The differences in the behaviour of checking status and progress could partly be caused by different participants in these studies. However, as indicated in Figure 7.7, participants found that the topic-related features helped them in keeping track of collaborators' work as well as the task progress. Therefore, we believe that the main reason for the difference is that the topic-related features in MakeSenseTogether have enhanced participants' awareness of the sensemaking progress and thus most of the time they do not need to ask about this information on the chat tool.

7.4 Discussion

In this section, we discuss the findings from this evaluation study according to the research questions proposed in section 7.1.

7.4.1   How do Users Interact with MakeSenseTogether to Perform Collaborative Sensemaking Activities?

Based on our understanding of users' challenges in collaboratively making sense of the task and information in CIS from user studies, we designed MakeSenseTogether which includes features to assist users in sharing information, building structure for the task, organising information and adjusting structure, creating a shared representation, and keeping aware of collaborator's work as described in chapter 6. In general, from the evaluation study we found that most of the proposed features were very positively received by users.

In particular, participants found topic-related features most useful. The topic-related features of MakeSenseTogether include adding topics, editing topics and moving information to other topics. Adding topics was designed to address the difficulty of building structure for the task in CIS, while editing topics and moving information to other topics help users to organise shared information according to the structure and adjusting structure to fit information. We found that most participants in the evaluation study liked the way of using topics to organise the task because it allow them to build on the topic structure throughout the task and organise shared information in a clear and structured way. However, some participants suggested the need of additional features for adjusting the structure and creating a more complex structure, for example, changing the order of topics and creating subtopics under a topic.

Creation of a shared representation is another challenging collaborative sensemaking activity in CIS. In CIS tasks, participants usually need to create a task product together, such as a report or a plan. We designed "Export information to file" in MakeSenseTogether to facilitate easy and quick generation of a shared representation. As the shared information was organised under topics in the sidebar, the exported word document presents shared information according to topic sections. In this evaluation study, participants liked the style of exported file as it was structured around topics and includes the link of bookmark and snippet as references. In addition, participants found "Export to file" were especially useful in the topic research task, because they used the sidebar mainly for collecting related information and identify topics in the early stage of the task, thus they need to further modified the exported file to summarise the presentation outline at the end of the task. However, in travel planning, participants mainly use the sidebar to record decisions, therefore they did not need to edit in the exported file.

7.4.2   What is the Influence of Topic-related Features on the Collaborative Sensemaking Behaviour of Users?

In order to investigate this research question, we divided participants in two groups which used MakeSenseTogether and ShareTogether respectively to perform different CIS tasks. Compared with MakeSenseTogether, the only difference is that ShareTogether does not have topic-related features. As such, we address this research question through comparing how MakeSenseTogether and ShareTogether assisted the two groups of participants in collaborative sensemaking. The findings showed that MakeSenseTogether provided better assistance than ShareTogether in respect of sharing information to collaborators, building structure for the task, keeping track of collaborators' work, keeping track of task progress and creating a shared report. This means that topic-related features has improved users experience in collaborative sensemaking from all the aspects that we have considered. As participants said, both travel planning and topic research tasks need the topic-related features. Since each group used MakeSenseTogether to complete a task and used ShareTogether to complete another, participants thought they would like to use MakeSenseTogether in the other task and thus they might perform better.

As shown in Figure 7.7, the biggest influences exist in building structure and keeping track of collaborator's work. Firstly, the topic-related features helped participants build structure for the task as they can add and edit topics to organise information at any time of task. Secondly, the topic-related features contributed to awareness of collaborator's work, because the shared information were color coded according to persons in MakeSenseTogether. As a result, participants can see who was working on which topic and how much does each person done for a topic.

7.4.3   What are the Differences in Collaborative Sensemaking Behaviour between using MakeSenseTogether and Normal Search Engine?

For this research question, we compared collaborative sensemaking behaviour using MakeSense-Together with the findings from our previous study about the general patterns of collaborative sensemaking behaviour using normal search engine (described in chapter 5). This comparison shed a light on how MakeSenseTogether influenced collaborative sensemaking behaviour.

According to our findings from this comparison, the main differences exist in two sense-making activities: building structure for the shared representation and keeping track of group sensemaking process. In respect to building structure for the shared representation, when using

normal search engine, participants usually divide the task into parts in early stage and then each person take responsible of different parts of the task. With the help of MakeSenseTogether, participants built upon the initial structure of the task incrementally and multiple users contributed to a topic of task at the same time. As a result, some topics were done by multiple users collaboratively. In addition, since MakeSenseTogether provide the function of export information to word document, participants' strategy for creating shared representation has also changed. No groups chose one participants to compose the final representation like the participants did when using normal search engine, because MakeSenseTogether provided them a easier way to collaboratively create a shared representation.

As for keeping track of group sensemaking process, we found that participants used to check collaborators' work and task progress in chat tool in the studies using normal search engine. However, in this study, we observed less instances of checking status and progress in chat tool. This could because that in MakeSenseTogether, shared information were colour coded according to person and presented according to topics in the sidebar, thus users know the information about group sensemaking process, such as what information were shared by which group member, who is mainly working on which topic and the progress of each topic and the overall task.

7.5   Summary

In this chapter, we present the evaluation study of MakeSenseTogether, the tool we designed for supporting collaborative sensemaking activities of users in CIS as described in chapter 6. MakeSenseTogether was designed to address the challenges of collaborative sensemaking for users in the CIS process which we learnt from user studies. Therefore in this evaluation study, we examined three research questions: Firstly, we explored how users interact with MakeSenseTogether to perform collaborative sensemaking activities. Secondly, we investigated the influence of the novel topic-related features that we proposed for supporting users in building structure for the task and creating shared representation through a comparison between MakeSenseTogether and ShareTogether. Finally, we discussed the collaborative sensemaking behaviour of users using MakeSenseTogether with our findings about the general patterns of collaborative sensemaking behaviour in previous studies where users were using normal search engine. As such, we provided insights into how MakeSenseTogether impact collaborative sensemaking behaviour.

As MakeSenseTogether were designed through a user-centred approach, therefore this eval-

uation study is to examine how users interact with it and how useful users found it in CIS tasks. In addition, the findings of the evaluation study contribute to our understanding of how the topic-centred approach, like MakeSenseTogether supported, influences collaborative sensemaking behaviour of users, especially the most difficult activities such as building structure and creating shared presentation. Altogether, the evaluation study provided us insights into the benefits and drawbacks of our approaches to support collaborative sensemaking activities in CIS tasks.

Chapter 8

Conclusions and Future Work

Collaborative sensemaking is an challenging yet not well supported aspect of CIS. This thesis sought to understand the collaborative sensemaking behaviour and challenges in CIS tasks and to design supporting tools to address the challenges. Through two user studies on different CIS tasks (travel planning and topic research), we explored the common challenges users face in collaborative sensemaking and identified the general patterns as well as the differences in collaborative sensemaking behaviour. The findings of these studies contribute to our understanding of the collaborative sensemaking process and challenges in CIS tasks. Based on this, we designed and evaluated MakeSenseTogether to address the research question about how to support collaborative sensemaking in CIS.

In this chapter, we conclude the work of this thesis by firstly addressing the research questions of this thesis in section 8.1, then highlighting the contribution of this thesis in section 8.2, and discussing the limitations of this thesis in section 8.3. We also present directions for future work in section 8.4.

8.1 Addressing the Research Questions

In this section, we bring together the findings from our user studies and discuss the findings to answer the research questions of this thesis that were proposed in chapter 3.

RQ1: How do Users Collaboratively Make Sense of the Search Task in CIS?

Previous work (Paul and Reddy, 2010) has investigated the characteristics and triggers of collaborative sensemaking in CIS. However, the literature provides limited insights into the collaborative sensemaking process and strategies. In this thesis, we address this gap by two user studies (Study 1 and 2).

The findings of our studies demonstrate that the collaborative sensemaking process in CIS generally involves four : structuring the task, individual searching and sensemaking, sharing individual findings and creating a shared representation. Structuring the task and creating a shared representation are performed collaboratively, sharing individual findings transfer the sensemaking activities from individual to collaborative level. As shown in Figure 8.1, the collaborative sensemaking process of a CIS task usually starts from structuring the task. Users employed two strategies to structure the task: either building an overall structure, or identifying data gaps step by step. Then users might focus on different aspects of the task when searching for information. Information found and sense made through individual searching and sensemaking is shared with collaborators. In the later stages of the task, users create a shared representation together in three ways, including combining individual representations, synthesising shared information by one person and writing together in a shared document.
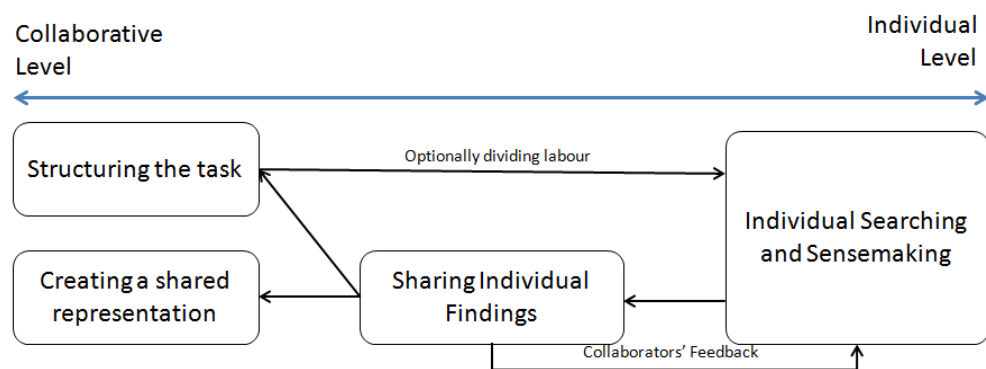
Figure 8.1: The collaborative sensemaking process for CIS tasks (repeated here for easy reference)

Although in both travel planning and topic research tasks, the collaborative sensemaking process in general consists of similar activities as described above, the strategies users employed for each activity were different depending on the task. For example, for structuring the task, most groups in travel planning identified data gaps step by step while in topic research most groups built an overall structure once and for all. Therefore, we believe that the strategies for

collaborative sensemaking are influenced by CIS tasks.

RQ2: What Challenges do Users Face for Collaborative Sensemaking?

An important part of this thesis is to investigate ways to support collaborative sensemaking in CIS. To design supporting tools for collaborative sensemaking activities, a thorough understanding of the challenges users faced in collaborative sensemaking is essential.

From study 1 and 2, we found that the challenges of collaborative sensemaking can be different depending on task as users employed different strategies. The findings of our studies also reveal the common challenges users face in the process of collaborative sensemaking, i.e. creating a shared representation and keeping track of the task progress and collaborators' status. One of the most challenging activity for users is to build structure for a shared representation. As users want to divide labour in CIS, shared representation is usually build upon individual representations. Therefore, supporting users to incorporate their individual representations into a shared representation which demonstrates their shared understanding is important. With no specific support, creating a shared representation can be difficult. In addition, when participants have little knowledge about the task topic, building a structure for the shared representation is difficult for then at an early stage of the task. Therefore, some groups also build structure step by step through searching and learning the topic. Supporting the construction of the representation structure from collected information is also important.

Another challenge is to keep track of the task progress and collaborator's activities. Awareness issues have been addressed in many CIS systems, mostly through presenting the activities of collaborators, such as queries and viewed webpages, in chronological order. This approach was found overwhelming by users when there was too much information and this information itself imposed burden on users sensemaking effort (Paul and Morris, 2009a). In our studies, we found that the most important information users want to have access to is the overall progress of the task and the topic that collaborators is working on.

RQ3: How to Support Collaborative Sensemaking in CIS?

In this thesis, we investigated ways of supporting collaborative sensemaking in CIS. Based on our understanding of the challenges that users face in collaborative sensemaking, we designed and implemented MakeSenseTogether, and proposed topic-related features to support collaborative sensemaking behaviour, especially in building structure for a shared representation and keeping

track of task progress. Results of user evaluation show that the topic-related features not only improve user experience in terms of building structure for the task and creating a shared representation, but also have the potential to enhance the sharing of information between collaborators and awareness of collaborators' work and task progress. This might because that topic-related features can help users organise shared information according topics and make the task progress and collaborators' work visible.

8.2 Contributions

The findings from two user studies described in chapter 4 and chapter 5 expand our theoretical understanding of the collaborative sensemaking behaviour of users in CIS, including the challenges and general patterns of collaborative sensemaking and the differences in collaborative sensemaking behaviour according to tasks. The understanding of challenges in collaborative sensemaking also have implications for the design of tools to support collaborative sensemaking activities. In addition, the design and evaluation of MakeSenseTogether provide insight into the influence of the topic-related features we proposed on collaborative sensemaking behaviour in CIS. Overall, this thesis has four main contributions:

8.2.1 A thorough understanding of the collaborative sensemaking challenges in CIS

Based on a formative evaluation of SearchTogether, Paul and Morris (2009b) identified sensemaking challenges in using a state-of-art CIS system to perform collaborative web search, which are understanding the sensemaking trajectories, awareness of actions and contexts and handing off the sensemaking product between search sessions. However, CIS system were not commonly used in everyday CIS tasks (Morris, 2008, 2013) and therefore the system itself might create sensemaking challenges for users. As there were no studies in literature investigate the challenges in common CIS tasks, in this thesis, we conducted two observational users studies using two common CIS tasks, travel planning and topic research. In both studies, participants used a normal search engine, chat tool and other tools of their choice (e.g. editing tools). Our findings of the studies demonstrate the common challenges for collaborative sensemaking as well as the different challenges in different types of tasks. These findings about the challenges in collaborative sensemaking have implications for design of CIS systems to support collaborative sensemaking.

8.2.2 A model of the collaborative sensemaking process for CIS tasks

To address the gap that there is a lack of a model for the collaborative sensemaking process in CIS, in our studies we investigated general patterns of collaborative sensemaking behaviour. According to our findings, the collaborative sensemaking process mainly involves structuring the task, individual searching and sensemaking, sharing of individual findings and creating a shared representation. Structuring the task and creating a shared presentation are performed collaboratively, while searching for information is an individual activity through which users making sense of different aspects of the task separately. Sharing individual findings bridges individual sensemaking and collaborative sensemaking and enable collaborators to reach a shared understanding of the task. Our findings about the general patterns provide a guide for studying the collaborative sensemaking behaviour of users and provide a foundation for a model of the collaborative sensemaking process in CIS.

8.2.3 An investigation of the differences in collaborative sensemaking behaviour according to task

Another important contribution of this thesis is that we investigated the difference in collaborative sensemaking behaviour in two different tasks, travel planning and topic research. These two tasks are common CIS tasks in daily life Morris (2008, 2013). Travel planning represent the leisure and decision/planning task, while topic research represent the professional and learning/comprehension task. We found that users employed different strategies for collaborative sensemaking in terms of structuring the task, sharing individual findings, and creating a shared representation. The comparative study between travel planning and topic research tasks revealed not only the general patterns, but also the difference in strategies according to tasks. Therefore, the findings from the comparative study revealed that the design of collaborative sensemaking support should take into consideration of the task.

8.2.4 A prototype with novel feature to support collaborative sensemaking in CIS

Last but not least, the design and evaluation of MakeSenseTogether explored the ways to support collaborative sensemaking activities in CIS. This part of the thesis has implications for the design of CIS system to support collaborative sensemaking activities. In particular, we examined the approach of using topics to assist users in building structure and organising shared information with the novel topic-related features in MakeSenseTogether. Results implied the potential of enhanc-

ing user experience of collaborative sensemaking from the point of sharing information, building structure, keeping track of the task process, and creating a shared report through introducing such topic-related features in CIS systems. The design and evaluation of MakeSenseTogether has implications for the design of tools to support collaborative sensemaking in CIS.

8.3   Limitations

In this section, we discuss the main limitations of the work presented in this thesis.

Firstly, sampling is always a crucial issue in user studies. Participants of our studies are mainly recruited from our university for the convenience of accessing participants and conducting studies. Also, the sample size of our studies are small. However, as we aims to explore user behaviour of collaborative sensemaking and the challenges they face in common CIS tasks, instead of to test a theory, the sample can reasonably represent the population that we aim to understand. We have also discussed the limitation of sample size to the findings of our studies in Chapter 4, 5, 7.

Secondly, all of our studies were conducted in a lab setting which simulates a synchronous and distributed collaboration. In this way, we can better observe users when the were doing the task. Due to the time limit of the lab study, some participants might be under pressure during the task as they want to finish the task in time. This might has some influence in their behaviour. As some participants stated, they usually have more time to research on the task before they enter the phase of discussion and creation of final products.

In addition, we used two common CIS tasks in daily life, i.e. travel planning and topic research. We believe that travel planning is a representative of leisure and decision making/planning tasks and professional and topic research is a representative of professional and information gathering/learning task. There are other tasks, such as online shopping and medical information research, which might lead to different behaviour of collaborative sensemaking. Therefore, the general patterns of collaborative sensemaking which were summarised in this thesis need to be further examined and verified in other CIS tasks. The aim of this thesis is not to justify a model of collaborative sensemaking, but to understanding the general patterns in user behaviour and to provide insights into how users perform collaborative sensemaking activities in CIS.

8.4 Future Work

In this section, we discuss areas related to the work of this thesis that are worth s further exploration.

8.4.1 Modelling the Collaborative Sensemaking Behaviour in CIS

While collaborative sensemaking behaviour has been explored in a collaborative web search context in terms of its triggers and characteristics (Paul and Morris, 2009b), there lacks a comprehensive model of collaborative sensemaking process in CIS. In this thesis, we addressed this gap in literature by investigating the activities and strategies of collaborative sensemaking in two different CIS tasks and summarised the general process of the collaborative sensemaking in CIS. Our findings include a model of collaborative sensemaking process in CIS. It might be worthy of further investigate and verify this model with more CIS tasks. This model provide guidance for researchers to analyse and support collaborative sensemaking behaviour in CIS. We are also interested to have a systematic understanding of the difference in collaborative sensemaking for different tasks.

8.4.2 Supporting Collaborative Sensemaking Activities in CIS

Since most CIS systems focus on enhancing awareness between collaborators, when designing MakeSenseTogether we mainly focused on supporting building structure for a shared representation. However, as our studies demonstrate, other activities such as sharing individual findings, composing a shared representation and keeping track of the task progress would also need to be better supported by CIS systems.

In addition, the evaluation of MakeSenseTogether shows that the topic-related features have the potential to improve collaborative sensemaking experience, especially in building structure for the task. However, users provide valuable suggestions for improving MakeSenseTogether, for example, allow adding sub-topics and reordering the topics. It would be worth to learn the impact of such advanced features on collaborative sensemaking behaviour. Another possible direction is to develop automatic topic extraction features to help users build structure from the information shared.

8.4.3 Measuring Collaborative Sensemaking in CIS

In CIS, collaborative sensemaking is a complex process and different users might have different experience of the collaborative sensemaking process in the group task. Users' judgement for success in a CIS task are influenced by multiple factors, for example, user engagement, level of agreement and quality of the final product etc.. To better support collaborative sensemaking behaviour in CIS, it is important to understand users criteria for a successful collaborative sensemaking experience in CIS task.

8.5 Conclusions

In this thesis, we conducted user studies to expand our understanding on collaborative sensemaking behaviour in CIS. The findings of these studies highlighted that:

- In CIS, the challenges of collaborative sensemaking mainly exist in creating a shared representation and keeping track of task progress and collaborators' work. CIS systems should assist users to collaboratively build structure for the shared representation, as well as facilitate awareness of the task progress and collaborators' work during the task.

- The collaborative sensemaking process of CIS generally consists of structuring the task, searching and sharing information, and creating a shared representation. In terms of searching and sharing information, users share their individual findings gained through searching as well as exchange information about their status and task progress. Supporting collaborative sensemaking behaviour in CIS should consider these activities.

- The collaborative sensemaking behaviour of users in CIS can be different depending on the search task. Users employ different strategies for collaborative sensemaking in travel planning and topic research tasks in terms of structuring the task, sharing individual findings and creating a shared representation. Therefore, when designing systems to support collaborative sensemaking for specific task, the designer should understand user behaviours in the context of specific task.

In addition, we designed and evaluated MakeSenseTogether with topic-related features to investigate ways to support collaborative sensemaking in CIS. The findings of the evaluation study demonstrated that:

- The topic-related features in MakeSenseTogether increased users' collaborative sensemaking experience in terms of sharing information, building structure, keeping track of collaborator's work and task progress and creating a shared representation.

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Appendix A

Materials for Study 1

This appendix contains materials from the user study 1 described in Chapter 4. It includes an ethic approval letter for the study, the participants instruction sheet, pre-task and post-task questionnaires and the questions asked in the semi-structure interview after the task.

A.1 Ethic Approval for the Study

Queen Mary
University of London

Queen Mary, University of London
Room E16
Queen's Building
Mile End Road
London
E1 4NS

Queen Mary Research Ethics Committee
Hazel Covill
Research Ethics Committee Administrator
Tel: +44 (0) 20 7882 2207
Email: h.covill@qmul.ac.uk

c/o Dr Tassos Tombros
CS 411
Department of Computer Science
Queen Mary, University of London
Mile End Road
London   E1 4NS

7th March 2012

To Whom It May Concern:

Re: QMREC 0728 – Electronic sensemaking behaviour in collaborative information seeking.

I can confirm that Ms Yihan Tao has completed a Research Ethics Questionnaire with regard to the above research.

The result of which was the conclusion that her proposed work does not present any ethical concerns; is extremely low risk; and thus does not require the scrutiny of the full Research Ethics Committee.

Yours faithfully

Ms Hazel Covill
Research Ethics Committee Administrator

Patron: Her Majesty the Queen
Incorporated by Royal Charter as Queen Mary
and Westfield College, University of London

Figure A.1: Ethic Approval Letter

A.2 Participant Instruction Sheet: Travel Planning Task

You have a **maximum of 60 minutes** to finish the travel planning task below in your group of 3. We expect you to search collaboratively on the web to complete the task. Please think aloud, feel free to express your own opinions and do it as normal as you are planning a holiday.

You are going to spend the next weekend in Wales. The train tickets are already booked. You will arrive at Cardiff Central station on Friday evening and back to London from Cardiff on Monday morning. Now you want to plan the trip together. The budget is 300 per person. You want to find 2 places (village/town/city) in Wales to stay **APART FROM** Cardiff, 1 for Saturday and 1 for Sunday. Find information about the 2 places to plan what you are going to see and do around these places. At the end, your group should agree upon a plan with a rough schedule for your trip. (See the example plan of weekend in London as reference.)

Each of you has a computer. You are **not allowed to talk** to each other. Temporary Skype IDs are created for you to use. You can only type but not call each other. Your group members are added to each others list. You can freely choose the search engines and use any other tools during the task (e.g. Office, Google Docs)

A.3 Pre-task Questionnaire

1. Age:

2. Gender: ☐ Male ☐ Female

3. Major or Occupation:

☐ Undergraduate ☐ Postgraduate

4. How long have you been using a computer?

☐ Less than 1 year ☐ 1-5 years ☐ 5-10 years ☐ More than 10 years

5. How often do you use search engines to seek information?

☐ Rarely ☐ 1-2 times a month ☐ 1-2 times a week ☐ Once a day ☐ Several times a day

6. How experienced do you think yourself in searching information on the Web?

novice ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 expert

7. Have you ever collaborated with others to search information online before?

☐ Never ☐ Several times (1-3) ☐ Many times (3+)

8. If yes, who do you collaborate with?

☐ Family ☐ Friends ☐ Classmates ☐ Colleagues ☐Other_____

Please specify your tasks

☐ Travel planning ☐ Shopping ☐ Literature/Technical information

☐ Social planning ☐Other_____

9. How well do you think you will do in performing the travel planning task?

☐ Very well ☐ Well ☐ Average ☐ Poor ☐ Very poor

10. How often do you use online search engines to plan holidays?

☐ Never ☐ Rarely ☐ Occasionally ☐ Frequently ☐ Always

11. Have you collaborated with anyone to plan a holiday abroad?

☐ Never ☐ Several times (1-3) ☐ Many times (3+)

12. How much do you know about attractions in Wales?

☐ Very little ☐ Only a few ☐ Quite a bit ☐ A lot

A.4 Post-task Questionnaire

1. How difficult did you find the travel planning task?

☐ Very difficult ☐ Difficult ☐ Not so difficult ☐ Easy ☐ Very easy

2. How much do you know about attractions in Wales after doing the task?

☐ Very little ☐ Only a few ☐ Quite a bit ☐ A lot

3. How satisfied do you feel about the plan of your group?

☐ Extremely satisfied ☐ Very satisfied ☐ Moderately satisfied ☐ Slightly satisfied ☐ Not at all
satisfied

4. Do you find the links shared by your collaborators useful?

☐ Very Useful ☐ Useful ☐ Moderately Useful ☐ Of little use ☐ Not useful at all

5. How useful is it for you to know queries submitted by your collaborators?

☐ Very Useful ☐ Useful ☐ Moderately Useful ☐ Of little use ☐ Not useful at all

6. How useful is it for you to know webpages viewed by your collaborators?

☐ Very Useful ☐ Useful ☐ Moderately Useful ☐ Of little use ☐ Not useful at all

7. How useful is it for you to know the opinion and comments of your collaborators for examined
webpages?

☐ Very Useful ☐ Useful ☐ Moderately Useful ☐ Of little use ☐ Not useful at all

8. Which of the following activities describe your contribution to your group?

(You can choose more than ONE option)

☐ Organise and coordinate the whole process ☐ Suggest ideas and structure for the plan

☐ Synthesise information and writing the plan ☐ Search for related information ☐ Other_____

9. What do you think is the main contribution of each group member to the task?

Member Name   Main Contribution

A.5 Semi-structured Interview

1. Briefly describe the whole process of how you approach the task. How did you split the work? Is there any challenges or problems you faced in the process?

2. Were you aware of what others are doing? Did you want to know and why? (Q5, 6, 7 in post-task questionnaire)

Search and Sensemaking Activities:

Formulation of Query

3. How did you come up with queries or topics to search for? Did you get any help from your collaborators?

4. Do you know what topics did your collaborators searched?

Examination of results, extracting useful information and sharing

5. Did you find the shared contents from your collaborators useful and why? (Q4 in post-task questionnaire)

6. Whether it is easy for you to know what a link is about? Did they share with their comments or summaries? Or just a link. Did you feel confused when seeing a link shared by collaborators since you don't know which part do they want you to see?

7. Do you think sharing part of the webpage (picture or several sentences) instead of the whole webpage will be better?

Organising and synthesizing information, reformulate the structure

8. Did you take notes while searching? How did you save and organise useful webpages and snippets? Did you face any challenges?

9. How did you synthesize found information into a shared plan? Did you do it together or by one of you?

Supporting tools

10. Do you think Instant Messengers such as Skype helps you communicate with each other efficiently? Do you feel it inconvenient to switch between Communication tool, web browser and editing tool ? Any other inconvenient you found in the process?

11. What support do you need in the process?

Appendix B

Material for Study 2

This appendix contains materials from the user study 2 described in Chapter 5. It includes an ethic approval letter for the study, the participants instruction sheet, pre-task and post-task questionnaires and the questions asked in the semi-structure interview after the task.

B.1 Academic Tasks

Optional Topic 1: Margaret Thatcher

A chapter of history draws to a close as former British prime minister Baroness Thatcher makes her final journey on April 17th. Accompanied is a controversy over what she leaves behind. Some people said "her legacy is of public division, private selfishness and a cult of greed, which together shackle far more of the human spirit than they ever set free", while others argues that "If Britain is still Great, it is because of this greatest of Britons".

Your group is preparing for a 20-minutes presentation about what do you think is the legacy of Margaret Thatcher to history, either positive or negative. Now you may want to investigate into the topic on the web and make an outline for the presentation together. Please jot down the main points you would like to make in your presentation and related information that support your points.

Assuming that you are working in different place, you are NOT ALLOWED TO TALK to each other while doing the task. Each of you has a computer. You can only type on Skype to communicate. Temporary Skype IDs are created for you to use and your group members have been added to each others' list. You can use your favorite search engine and any other tools (e.g. editing tools) during the task.Please fully express your ideas in your groups and perform the task as normal.

Optional Topic 2: Special Effects in Movies

Special effects is very common in todays movies, and the technology of special effects in movies has changed throughout the years. Your group is preparing a 20-minutes presentation on special effects and its future challenges. Now you want to investigate into the topic on the web and make an outline for the presentation together. Please jot down the main points you would like to make and the facts that support your points.

Assuming that you are working in different place, you are NOT ALLOWED TO TALK to each other while doing the task. Each of you has a computer. You can only type on Skype to communicate. Temporary Skype IDs are created for you to use and your group members have been added to each others list. You can use your favorite search engine and any other tools (e.g. editing tools) during the task. Please fully express your ideas in your groups and perform the task as normal.

Optional Topic 3: Arab Spring

"The importance of the role of social media on the Arab uprisings has been largely debated. Some say that social media was the main instigator of the uprisings, while others claim that it was merely a tool".

Your group is preparing a 20-minutes presentation on what do you think is the role of social network websites (e.g. Facebook and Twitter) in the Arab Spring. Now you may want to investigate into the topic on the web and agree upon an outline for the presentation together. Please jot down the main points you would like to make and the facts that support your points.

Assuming that you are working in different place, you are NOT ALLOWED TO TALK to each other while doing the task. Each of you has a computer. You can only type on Skype to communicate. Temporary Skype IDs are created for you to use and your group members have been added to each others' list. You can use your favorite search engine and any other tools (e.g. editing tools) during the task. Please fully express your ideas in your groups and perform the task as normal.

Optional Topic 4: Globalisation and Human Rights

Your group are preparing a 20-minutes presentation on how has the global expansion of ideas and technologies influenced human rights. Now you want to investigate into the topic on the web and make an outline for the presentation together. Please jot down the main points you would like to make and the facts that support your points.

Assuming that you are working in different place, you are NOT ALLOWED TO TALK to each other while doing the task. Each of you has a computer. You can only type on Skype to communicate. Temporary Skype IDs are created for you to use and your group members have been added to each others' list. You can use your favourite search engine and any other tools (e.g. editing tools) during the task. Please fully express your ideas in your groups and perform the task as normal.

B.2 Pre-task Questionnaire

1. Age: _____

2. Gender: ☐ Male ☐ Female

3. Nationality: _____

4. Department or field of study: _____

Degree level: ☐ Undergraduate ☐ Postgraduate

5. What is your level of proficiency in using a computer?

Novice   Expert

☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

6. How experienced do you think yourself in searching for information on the Web?

Novice   Expert

☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

7. Have you ever collaborated with others to search for information online before?

☐ Never ☐ Several times (1-3) ☐ Many times (3+)

If yes, who do you collaborate with?

☐ Family ☐ Friends ☐Classmates ☐Colleagues ☐Other_____

And please specify your tasks

☐ Travel planning ☐ Academic/Technical information ☐Shopping

☐ Health/medicine information ☐News/current events ☐Entertainments

☐ Other _____

8. How often do you use online search engines to solve academic tasks?

☐ Never ☐Rarely ☐Occasionally ☐Frequently ☐Always

9. Have you collaborated with anyone to solve academic tasks?

☐Never ☐Several times (1-3) ☐Many times (3+)

10. What browser do you use most commonly?

☐IE ☐ Firefox ☐ ☐Safari ☐Chrome ☐ Else specify_____

11. What search engine do you use most frequently?

☐ Google ☐ Bing ☐Yahoo!Search ☐ Else specify_____

B.3 Prior Knowledge Questionnaire

1. How much do you know about the former British prime minister Margaret Thatcher?

Very Little   A Lot

☐ 1   ☐ 2   ☐ 3   ☐ 4   ☐ 5

2. How much do you know about the Arab Spring?

Very Little   A Lot

☐ 1   ☐ 2   ☐ 3   ☐ 4   ☐ 5

3. How much do you know about the influence of globalization on human rights?

Very Little   A Lot

☐ 1   ☐ 2   ☐ 3   ☐ 4   ☐ 5

4. How much do you know about special effects in movies?

Very Little   A Lot

☐ 1   ☐ 2   ☐ 3   ☐ 4   ☐ 5

B.4   Post-task Questionnaire

1. How do you think of the task?

Difficulty

Very easy   Very difficult

□ 1 □ 2 □ 3 □ 4 □ 5

Specificity of required information

Very vague   Very clear

□ 1 □ 2 □ 3 □ 4 □ 5

2. How much do you know about the topic after doing the task?

Very little   A lot

□ 1 □ 2 □ 3 □ 4 □ 5

3. How satisfied do you feel about the work of your group?

Not satisfy at all   Very satisfy

□ 1 □ 2 □ 3 □ 4 □ 5

Please explain what you are not satisfied with

4. How similar was your behaviour in the task compared to your normal behaviour in group work?

Not similar at all   Very similar

□ 1 □ 2 □ 3 □ 4 □ 5

Please specify the difference

5. What do you think is not well-supported by current search engine and assistive tools in the process? From technical perspective, what do you think can be done to better support the process?

B.5 Post-task Interview

General process

1. What do you think of the task in general? Do you think it is easier or more difficult to work together than individually in similar task? How did you coordinate the process? Is there any challenges or challenges you faced in the process? Do you think it is well supported by chat tools?

2. Were you aware of your collaborators action during the task? What kind of information do you want to know about your collaborators while doing the task? For example, queries they submitted, webpages they were viewing, what information have been collected, what topic did they covered etc.

Structure building

3.How did you come up with the ideas of your outline and discuss with your collaborators? Did you find the process difficult? What kind of support do you suggest?

Role and division of labour

4. Did you split up the task? Do you think there is a leader in your group? What did the leader do?

5. Do you think all of you share a same understanding of the topic by the end of the task? Does every points got discussed and agreed? How do you judge the success of a collaborative task?

Information sharing

6. When will you share information to your collaborators? What kind of information did you share?

7. How did you update the sense have been made in your group?

Supporting tool

8. What kind of support in particular you think would be helpful in the collaboration process?

Practices of CIS in daily life

9. When youre doing collaborative work in your daily life, what collaboration tools do you use commonly? e.g. Dropbox, Google docs

10. What would be different in your ways of collaboration in daily task compared to in this task?

Appendix C

Scenario-based Interview using Paper Prototypes

You and your two colleagues is using our tool to preparing for a 20-minutes presentation about the influences of globalization on human rights. You are working synchronously but not at the same place.

Our tool is built as a web browser extension which is composed of a toolbar and sidebar. This tool is mainly designed to help users collaboratively create a structural representation of the collected information and stay aware of group sensemaking process.

Scenario 1: Collecting information during individual search

Neither of you are familiar with the presentation topic, so you decide to carry out a brief research on the Web. While searching the Web to learn about the topic, you come across a webpage and would like to save several paragraphs for later use.

The tool provides you with a "save/share" feature in the toolbar. When selecting the paragraphs you would like to save or share and then press the "save" button, the dialogue in Figure C.1 will show up:

Your need to specify a topic for the piece of shared information by either choosing from a list of existing topics created by you and your collaborators or type a new one.

Q1.1: Do you want the system to suggest topic keywords from your search query?

Q1.2: When you save/share information under a topic, do you want to see the existing content saved under the topic?

If you want to keep the piece of information to yourself and share it later, you can click the "save for your own" button, else you can press "share with collaborators".

Figure C.1: Paper prototype of the "Save/Share" feature in the toolbar

Q1.3: Do you think the choice of "Save for your own" necessary?

Assuming that you want to share this piece of information with your collaborators, so you click the "Share with collaborators". Your collaborators can view the shared information in the SenseNotes space. The SenseNotes space can be accessed from the "SenseNotes" button in the toolbar.

Q1.4: In general, how do you feel about the "Save/Share" function? How would you like to improve it? Do you think arranging snippets around topics is helpful to build structure for your task?

Scenario 2: Editing shared information to create the presentation outline

After half an hour, you think you have collected enough information and form a basic understanding about the topic, so you want to see the information has been collected and the topics has been formed by your group. You open the SenseNotes as shown in Figure C.2. The SenseNotes provide functions including expanding all the topics, adding and deleting topics. Each topic can be doubleclicked to expand or fold with the detailed information.

Q2.1: Any other functions you suggest?

Q2.2: How do you feel about the way information is presented in SenseNotes?

Scenario 3: Masking sense of collaborators sensemaking activity

You have searched the web for 20 minutes. You looked at the SenseNotes but found nothing shared by your collaborators.

Figure C.2: Paper prototype of the SenseNotes component (expanded)

Q3.1: What information of collaborators do you want do know during the task (e.g. queries, viewed webpages)?

As shown in Figure C.3, the SenseTrack component of our tool presents the search queries and topics created by each group member. The SenseTrack is present in the sidebar, so you can view collaborators' activities all the time during the task without press any button.

Figure C.3: Paper prototype of the SenseTrack component in the sidebar

Q3.2: What do you think of the SenseTrack space? How would you like it to be improved?

Finally, some questions in general:

Q4: Can you think of other features in such a system that would be useful?

Q5: If the system is used in asynchronous search, what feature would you suggest?

Appendix D

Materials for Study 3

This appendix contains materials from the user study 3 described in Chapter 7. It includes an ethic approval letter for the study, the participants instruction sheet, pre-task and post-task questionnaires and the questions asked in the semi-structure interview after the task.

D.1 Task

Task1: Travel Planning (Wales or Croatia)

Wales: You are going to spend a weekend together in Wales. The train tickets are already booked. You will arrive at Cardiff Central station on Friday evening and back to London from Cardiff on Monday morning. Now you want to plan the trip together. You would like to find 2 places (village/town/city) in Wales to visit and stay APART FROM Cardiff, 1 for Saturday and 1 for Sunday. At the same time, you want to find information about the 2 places and plan for things to do around these places. The budget is £300 per person. At the end, your group should agree upon a plan with a rough schedule for your trip.

Croatia: You are planning to spend the next weekend together in Croatian islands. The flight tickets are already booked. You will arrive at Dubrovnik on Friday evening and back to London from Dubrovnik on Monday morning. Now you want to plan the trip together. You would like to choose 2 ISLANDS in Croatia to visit and stay, 1 for Saturday and 1 for Sunday. At the same time, you want to find information about the 2 islands and plan for things to do around these places. The budget is £500 per person. At the end, your group should agree upon a plan with a rough schedule for your trip.

Task2: Topic Research (Special effects or Globalisation)

Special Effects in Movies: Special effects are very common in todays movies. The technology of special effects in movies has changed throughout the years. Your group is preparing a 20-minutes presentation on the future challenges of special effects in movies. Now you want to collect information on the web and make an outline for the presentation together. At the end, your group should agree upon an presentation outline which includes the key points your group would like to make and related information that would be useful in the presentation.

Globalisation and Human Rights: Your group is preparing a 20-minutes presentation on how has global expansion of ideas and technologies influenced human rights. Now you want to collect information on the web and make an outline for the presentation together. At the end, your group should agree upon an presentation outline which includes the key points your group would like to make and related information that would be useful in the presentation.

D.2 Prior Knowledge Questionnaire

1. How much do you know about the influence of globalization on human rights?

Very little   A lot

    1   2   3   4   5

2. How much do you know about special effects in movies?

Very little   A lot

    1   2   3   4   5

3. How are you familiar with the cities and attractions in Wales?

Not familiar at all   Very familiar

    1   2   3   4   5

4. How are you familiar with the cities and attractions in Croatia?

Not familiar at all   Very familiar

    1   2   3   4   5

D.3 Pre-task Questionnaire

1. Age:_____

2. Gender: Male   Female

3. Nationality:_____

4. Department or field of study:_____
Degree level: Undergraduate   Postgraduate

5. What is your level of proficiency in using a computer?
Novice   Expert
    1   2   3   4   5

6. How experienced do you think yourself in searching for information on the Web?
 Novice   Expert
    1   2   3   4   5

 7. Have you ever **collaborated with others** to search for information online before?
Never   Several times (1-3)   Many times (3+)
If yes, who do you collaborate with?
Family   Friends   Classmates   Colleagues   Other_____
And please specify your tasks
Travel planning   Academic/Technical information   Shopping
Health/medicine information   News/current events   Entertainments   Other_____

8. Have you used any collaborative search systems (e.g. Coagmento, SearchTogether, SearchTeam) to solve tasks?
Never   Rarely   Occasionally   Frequently   Always
Please specify the name of the system
_____

9. What browser do you use most commonly?
IE   Firefox   Safari   Chrome   Else specify_____

11. What search engine do you use most frequently?
Google   Bing   Yahoo! Search   Else specify_____

D.4 Post-task Questionnaire

Post-task Questionnaire for MakeSenseTogether:

1. Please indicate your feeling about the **task**:

	Very Low	Low	Medium	High	Very High
Level of task difficulty	1	2	3	4	5
Knowledge level of the topic after task	1	2	3	4	5
Level of satisfaction with your collaboration	1	2	3	4	5
Level of satisfaction with the final report	1	2	3	4	5
Level of rushness of the pace of the task	1	2	3	4	5
Level of stress and discourage during the task	1	2	3	4	5

2. Please indicate your level of agreement with the following statement about the **supporting system**:

	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
It was easy to use	1	2	3	4	5
It enabled us to complete the task more quickly	1	2	3	4	5
It provided good support for us to do the task together	1	2	3	4	5

3. How well do you think the system support in the following aspect?

	Very poor	Poor	Acceptable	Well	Very well
Sharing information to collaborators	1	2	3	4	5
Building structure for the task	1	2	3	4	5
Keeping track of collaborator's work	1	2	3	4	5
Keeping track of task progress	1	2	3	4	5
Creating a shared report	1	2	3	4	5

4. How useful was the following features in the task?

	Not useful at all	Not very useful	Slightly Useful	Useful	Very useful
Share bookmark with comments	1	2	3	4	5
Share snippet	1	2	3	4	5
Share note	1	2	3	4	5
Add topics to organise information	1	2	3	4	5
Edit (merge & delete) topics	1	2	3	4	5
Move information to other topics	1	2	3	4	5
Edit shared information (context menu)	1	2	3	4	5
Export information to document	1	2	3	4	5

5. Have you got any other comment about the system? (e.g. any particular feature you like or do not like, suggestions for improving it, additional features you would like it to have, etc.)

Post-task Questionnaire for ShareTogether:

1. Please indicate your feeling about the task:

	Very Low	Low	Medium	High	Very High
Level of task difficulty	1	2	3	4	5
Knowledge level of the topic after task	1	2	3	4	5
Level of satisfaction with your collaboration	1	2	3	4	5
Level of satisfaction with the final report	1	2	3	4	5
Level of rushness of the pace of the task	1	2	3	4	5
Level of stress and discourage during the task	1	2	3	4	5

2. Please indicate your level of agreement with the following statement about the system:

	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
It was easy to use	1	2	3	4	5
It enabled us to complete the task more quickly	1	2	3	4	5
It provided good support for us to do the task together	1	2	3	4	5

3. How well do you think the system support in the following aspect?

	Very poor	Poor	Acceptable	Well	Very well
Sharing information to collaborators	1	2	3	4	5
Building structure for the task	1	2	3	4	5
Keeping track of collaborator's work	1	2	3	4	5
Keeping track of task progress	1	2	3	4	5
Creating a shared report	1	2	3	4	5

4. How useful was the following features in the task?

	Not useful at all	Not very useful	Slightly Useful	Useful	Very useful
Share bookmark with comments	1	2	3	4	5
Share snippet	1	2	3	4	5
Share note	1	2	3	4	5
Edit shared information (context menu)	1	2	3	4	5
Export information to document	1	2	3	4	5

5. Have you got any other comment about the system? (e.g. any particular feature you like or do not like, suggestions for improving it, additional features you would like it to have, etc.)

D.5 Semi-structure Interviews

What was your strategy to perform the tasks collaboratively? is there any difference when using MakeSenseTogether and ShareTogether?

How do you feel about the topic-related features in MakeSenseTogether? Did you think it helpful for you to structure the task and create a shared representation? Why?

Did you think MakeSenseTogether provide better assistant than ShareTogether for understanding the group sensemaking process? Why?

Is there anything you would like to improve in MakeSenseTogether?