Sensemaking Handoffs: Why? How? and When?

by

Nikhil Sharma

A dissertation submitted in partial fulfillment
of the requirements for the degree of
Doctor of Philosophy
(Information)
in The University of Michigan
2010

Doctoral Committee:

Professor George W. Furnas, Co-Chair
Professor Michael D. Cohen, Co-Chair
Professor Karl E. Weick
Professor Judith Spencer Olson, University of California- Irvine
Daniel M. Russell, Google

Acknowledgements

I am very grateful for the following:

- **George Furnas** without whose support and encouragement this dissertation would have never come to a fruitful completion.
- **The rest of my committee: Michael Cohen, Judy Olson, Karl Weick & Dan Russell** for invaluable feedback.
- **Fellow doctoral students, especially: Yan Qu, Emilee Rader & Rick Wash** for thoughts and comments.
- **NSF grant IIS-0325347-ITR**, **Rackham Graduate Student Research Grant** & **School of Information** for financial support
- **School of Information-Computing, especially Mike Doa** for computing support
- **Maria Slowiaczek** for editorial guidance

Table of Contents

List of Figures

List of Tables

List of Appendices

Chapter 1

Introduction

As the name suggests, 'sensemaking' is the act of making sense of the world around us, often in the service of some task or goal. A typical sensemaking scenario has people asking themselves *'what is going on here?'* This can happen when a doctor is trying to diagnose and treat an unknown condition, when a detective is working on a tough case or when a computer support expert is troubleshooting a novel problem. In sensemaking situations, like the ones above, people may have a gap in understanding and may not be sure how to act. They must collect information about the problem at hand. For example the doctor may get diagnostic tests done, the detectives may collect evidence and the support expert may ask questions about what the user was trying to do. As information is collected, it needs to be organized somehow using a conceptual structure so that it can be understood. All these activities make sensemaking an activity that is difficult to conduct and often requires support.

Sensemaking is often done collaboratively with others. For example in the scenarios described above, a team of resident doctors, various forensic experts and a group of support personnel might be working on the respective problems instead of individuals. While collaboration in sensemaking can take place in many modes like synchronous and asynchronous collaboration, this research focuses on one mode of collaboration:

'handoffs'. Handoffs are a form of collaboration where someone working on a task stops working and a subsequent person later picks up the task to continue working on it. In handoffs, the collaboration is not only asynchronous but also serial. For example in all three situations mentioned earlier, sensemaking may be handed-off to another individual or a team that must continue the work begun by its predecessor. Handoffs require special attention because they often result in discontinuity of work and thus have the possibility of introducing errors. For example, Landrigan (2007) has brought attention to the fact that handoffs resulting from shift changes in hospitals have been known to introduce errors when not done very carefully. Patterson & Woods (2001) have noted similar concerns regarding handoffs in Space Shuttle Mission Control.

Sensemaking and handoffs are difficult on their own, but together they are even more challenging. The need for sensemaking often arises when routines break down and when people realize their current infrastructure is insufficient to proceed. In such a situation there may be no special procedures and structures for supporting handoff. Handoffs are more challenging in the environment of unanticipated breakdowns and variabilities of sensemaking. For example, the presence of frequent variabilities in healthcare situations has been noted (Gregory, 2006) during efforts to standardize handoffs. Handoffs can introduce errors in many sensemaking cases. . Also, since sensemaking occurs in many critical situations like health care where errors can be very costly, it is very important to make sure handoffs in such situations proceed efficiently. The main goal of this dissertation is to find ways of making sensemaking handoffs better.

In this work unless otherwise stated, "sensemaking handoff" refers to the handoff of sensemaking. A related but distinct topic is that is not covered here is making sense of

handoffs that can occur in all kinds of situations including routine/non-sensemaking situations. A narrow definition of handoff would assume an intentional transfer of a task or situation directed towards a recipient or group of recipients. However, a broader definition of handoff sensemaking would include those situations where handoffs may be non-directed, that is, handoffs with no particular recipient in mind. This broad definition would include cases of reuse of sensemaking material made available to subsequent sensemakers. Within this broad definition, handoffs can vary depending on elements that are handed off (task responsibility, task environment or just task material), whether or not the handoff was intended and whether or not it was directed towards a particular recipient. For example in shift changes, the whole task responsibility and the task environment including all task material are directed towards a particular recipient group. In referral handoffs, the task responsibility and task material are directed towards a recipient but a task environment is not shared. The broader definition allows us to study intent and handed-off elements as variables.

Sensemaking can be demanding and one possible direction of sensemaking support is utilizing the work done by others on the related problem. Scientific discovery for example is usually non-directed towards a specific individual or group and task responsibility and task environment are not handed off while some task material in the form of written articles may be available to the recipient. Amateurs can also do this type of non-intended and non-directed sensemaking handoff. Using the internet, sensemakers can post and share finished and unfinished sensemaking work that can be picked by a subsequent sensemaker working on the same or similar topics.

However, non-directed sensemaking handoffs can also be challenging. In the case of non-directed handoffs, the recipient might not be able to derive an advantage from the earlier work or indeed they might even waste time if they have trouble understanding the earlier work.

1.1 Research Goal

This dissertation is a part of a larger research program that attempts to support collaboration in sensemaking by utilizing information systems. The focus here is on studying sensemaking handoffs with the goal of ultimately developing information-system interventions that may aid them. More specifically the goal is to first understand the unique nature of sensemaking and consequently the various factors that affect sensemaking handoffs and then to use this understanding to provide implications for support systems.

The primary research question here is *what factors impact the effectiveness of a sensemaking handoff and how?* Does sensemaking have special qualities as a process that affect its handoff? A better understanding of these factors can direct future research, provide implications for those designing support systems for sensemaking handoffs and provide guidelines to practitioners engaged in sensemaking handoffs.

1.2 Approaches

This research project employs a mix of qualitative and quantitative methods in various steps to answer the research questions.

(1) In the first round of exploration, based on a literature review from different fields like human-computer-interaction (HCI), organizational behavior and

library science a set of sensemaking task attributes were identified. These attributes in turn guided the choice of appropriate tasks to study sensemaking handoffs later. A review of collaboration and handoff literature was also used to develop a list of crucial collaboration elements that might impact sensemaking handoffs.

(2) A qualitative field study of sensemaking handoffs was conducted to study the sensemaking handoff practices of computer support helpdesk experts at the University of Michigan.

(3) Laboratory studies of sensemaking handoffs were conducted where participants worked on sensemaking tasks. In some conditions work by an earlier participant was handed off to another participant. These studies revealed the micro-structure of sensemaking, the effectiveness of sensemaking handoffs and the role of artifacts in sensemaking handoffs.

(4) The findings from all the studies were used to draw design implications and suggest features for handoff support systems.

1.3 Contributions

This dissertation makes the following contributions:

(1) *Integrates theories of sensemaking.* This work helps to integrate the various theories of sensemaking with each other and with the existing research on general collaboration and handoff. This integration will expand the understanding of sensemaking handoff and identify what is missing in the literature.

(2) *Derives the essential attributes of sensemaking.* The understanding of sensemaking gained through examination of sensemaking theories and other relevant literature was used to derive the essential attributes of sensemaking. These attributes will be useful in choosing and designing tasks/scenarios to study sensemaking.

(3) *Lists the crucial collaboration elements that impact sensemaking handoffs.* This list was derived from a literature review of prior work on collaboration while keeping in mind the unique nature of sensemaking expressed by the sensemaking attributes.

(4) *Improves understanding of sensemaking handoffs through empirical studies.* The qualitative study of sensemaking handoffs in the real world found answers to why and when people choose to engage in sensemaking handoffs and what practices make sensemaking handoffs effective. Three lab-studies conducted in the dissertation provided insights regarding the role of artifacts in sensemaking handoffs. They found evidence for the effectiveness of artifact-focused handoff, illustrated the role of quality in usage of handoff-artifacts and compared usage of handoff-artifacts to other information resources available to a recipient in a handoff.

(5) *Suggests recommendations that make handoff easier and more efficient.* The outcome of the empirical work will be used to develop recommendations regarding sensemaking handoffs for sensemakers as well as designers of sensemaking handoff support systems.

1.4 Chapter Arrangement

Chapter 2 introduces the various sensemaking theories that form the theoretical base for the work that follows. The essential attributes of sensemaking as a process are derived from the sensemaking theories. The literature pertaining to the construction and evolution of external representations in sensemaking is discussed thereafter. Research related to handoff and collaboration is also discussed. The findings from the literature regarding sensemaking and handoff in general are synthesized to list some factors involved in sensemaking handoffs.

Chapter 3 describes a qualitative study of sensemaking handoff in the context of computer helpdesks. Here general findings regarding handoff reasons, hand off time and handoff materials are discussed. These general findings shed light on non-shift change directed handoffs.

Chapter 4 describes two laboratory studies conducted to observe how recipients use sensemaking artifacts. Main findings regarding the evolution of representations and use of handoff material are discussed.

Chapter 5 describes a laboratory study of handoff artifact use and the relationship to artifact use to other available resources during sensemaking.

Chapter 6 summarizes the research, its contributions and provides recommendations for information systems.

Chapter 2

Sensemaking and Handoffs

This chapter presents existing literature on sensemaking and handoffs, and extracts various relevant variables and issues from a synthesis of this literature review. First a literature review of work related to sensemaking is presented. Next, I use the literature to develop the essential attributes of sensemaking. Then existing research on handoffs and collaboration in general is presented. After this, I list the factors that affect sensemaking handoffs drawn from an examination of research on handoffs and collaboration in general while keeping in mind the unique nature of sensemaking. Finally conclusions are presented.

2.1 Sensemaking & related topics: literature review

Problem solving has been a topic of interest to cognitive scientists for a long time (Duncker, 1945; Newell & Simon, 1972). More recently there has been a focus on sensemaking and various theories, models and characteristics of sensemaking have been developed. In this section I discuss some literature on sensemaking and on problem solving.

2.1.1 Sensemaking theories

There are several theories of sensemaking, with roots in fields including human computer interaction (HCI), information science and social/organizational psychology. Though these theories explicate aspects of the same phenomenon, they are disparate and

unconnected due to their different roots. Amongst other things, HCI has focused on the cognitive aspects, information science has focused on the affective aspects of sense and social/organizational psychology has focused on inter-personal aspects of sensemaking.

I conceptualize sensemaking as the act of building knowledge structures that enable action. Russell, Stefik, Pirolli & Card (1993) developed a model of sensemaking that involved building a 'representation'. Consequently this work draws more from this model of sensemaking than other existing theories and models.

Russell et al (1993) proposed a theory of sensemaking where the cost structure of actions guides behavior. Sensemaking is characterized in their theory as "*the process of searching for a representation, and encoding data into that representation, to answer task-specific questions"* (p.269).

According to this model sensemakers begin by processing the requirements of the task. Then sensemakers search for a good representation that can be used to organize information needed for the task. Then sensemakers can also use this represent to identify information of interest and incorporate it into the representation, a process called 'encoding'. The current representation may need to be modified or 'shifted' to reduce the cost that various sub-tasks like searching for representations, searching for information and encoding information into representations impose on cognitive and external resources. . For example some information that may not fit in the current information may build as 'residue'. Once this residue becomes too costly to ignore the representation may need to be modified. Modifications can take the form of the addition of new categories as well as the splitting or merging of existing ones. Once a representation has been coded sufficiently it can be used to enable action on the task at hand. Figure 2.1

from (Russell et al, 1993, p. 273) highlights the various sub-tasks in the model (processing requirements, searching representations, encoding and using encoded representations).

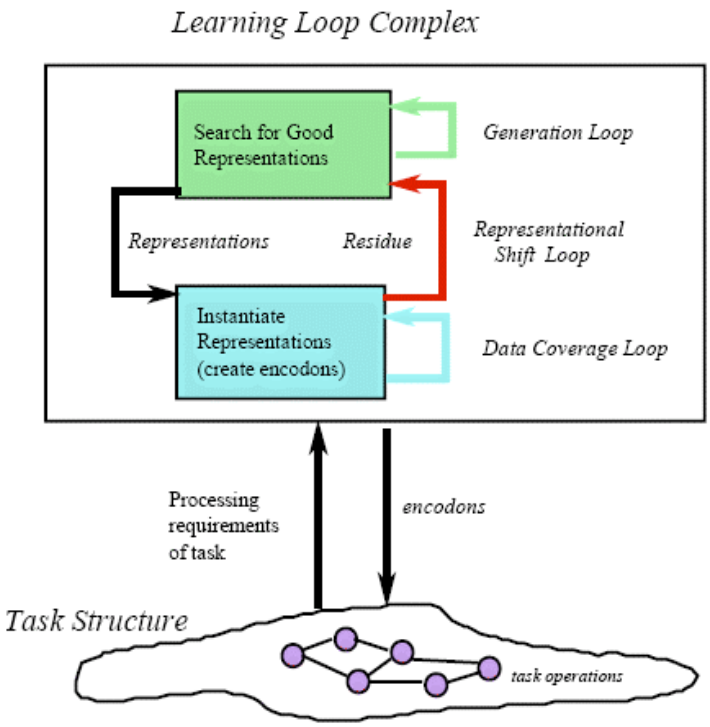


Figure 2.1: Learning Loop Model from Russell et al.(1993)

Russell et al.'s model is useful for understanding sensemaking in many ways. Firstly, the model lists the various subprocesses involved in sensemaking like processing task requirements, searching for representations, encoding data, shifting representations and using the encodons (encoded representations). Secondly, the cost structure principle provides useful behavioral insight into when the various processes listed above are chosen. Thirdly, the model's focus on representations is relevant for sensemaking handoffs because representations when externalized can form the basis of handoff.

Other research has elaborated upon the Russell et al. model. Pirrolli & Card (2005) adapted the Russell et al. model to the sensemaking practices of intelligence analysts and found that cognitive biases resulted in people fitting evidence to existing representation somehow even when other better representation may have been more appropriate. This suggests that sensemakers may need support in overcoming their cognitive biases.

Qu & Furnas (2005) studied where people get representation ideas from their own knowledge and experience as well as from other people's work. They also found that when people had no sources of structure they built their representation bottom up from the information gathered. It was also noted that the activities involved in sensemaking like information gathering and representation construction were closely coupled. The finding regarding prior knowledge echoed an earlier finding of Rogers and Scaife (1997) that prior knowledge plays a big part in how representations are used.

Nelson, Held, Pirolli, Hongm Schiano & Chi (2009) examined the use of social annotation in sensemaking tasks and found that annotations created by others helped people learn better. This suggests that annotations created by others can be a good source of representation for people.

Besides Russell et al. there are other valuable theories. Weick has defined sensemaking as "the ongoing retrospective development of plausible images that rationalize what people are doing" (Weick, Suttcliffe & Obstfeld, 2005). Weick's theory of sensemaking can help us understand the micro-interactions between an individual and the group during sensemaking. Weick's characterization of sensemaking has some implications about handoff as well. The most important implication is that rather than shifting their

representation, people often become committed to their representation and handoffs can be a possible mechanism to have representation shifts. Weick cites Kiesler (1971) saying that people can get committed to their beliefs if the actions following from their beliefs are explicit, public and irrevocable. Weick says that in such a situation selective attention is paid to information that confirms the beliefs and non-compliant information may be ignored. This finding also reinforced by Pirrolli & Card (2005) above, implies that people may need special support in identifying the need to modify representation.

Dervin's (1998) sensemaking theory has been influential in the communications and library science domain. Here the central metaphor is of a human traveling through time/space and coming out of situations with a history. A person arrives at new situations, faces gaps, builds bridges across those gaps, evaluates the outcome and moves on. Dervin considers sensemaking to be a very personal activity that is very specific to the situation of the sensemaker. This reinforces the implication from Russell et al that a change in the situation and the sensemaker can make reuse or handoff of sensemaking difficult. For handoffs, this problem will be compounded in non-shift change cases where the whole sensemaking situation is not handed off or in shift change cases where the situation is very dynamic.

The sensemaking theories have some common themes as well as some variations. One common theme in all the definitions of sensemaking is the creation of structures of knowledge or understanding (representation, images or bridges) that help deal with the situation at hand. All three acknowledge individual and contextual aspects of sensemaking as well. In Russell et al.'s model the individual aspect comes from the cost-structure and the representation repertoire of the sensemaker. In Weick's sensemaking the

individual aspect comes from "identity creation" which is one of the seven characteristics of sensemaking and is related to how sensemakers view their needs and values. In Dervin's theory, individual history and past experience is stressed. The contextual factors in Russell et al.'s model come from the task requirements and available resources. In Weick's sensemaking, the environment and the social aspect of sensemaking make up the contextual factors. The situation and the gap make up the contextual aspect in Dervin's sensemaking.

Along with the similarities and common themes, there are some variations in the sensemaking theories as well. While Russell et al suggest that residue can drive representations to shift, Weick is cautious about representation changes because people often ignore residue even when the cost of ignoring it is high. Weick suggests that arguing and negotiation can prompt change in some conditions where sensemakers are ignoring residue.

2.1.2 Problem solving

Problem Solving (PS) has been a much-researched concept and is similar to sensemaking in many ways. Both sensemaking & PS have a similar goal: to resolve an impasse. Both are often aided by representations. Both sensemaking & PS also require decomposition of the task at hand into sub-tasks like problem definition, adoption of representation and representation usage & update. To compare sensemaking and PS it is useful to first consider two different types of problems: well-defined and ill-defined problems.

Minsky (1961) introduced the concept of a problem being 'well defined' where many aspects of the problem are specified including: the initial state, the allowable operations and the goal state. Another property of well-defined problems is that a solution, often

unique is known to exist for them. There are many examples of well-defined problems like water jar problems, towers of Hanoi and the 'hobbits and orcs problem'.

Reitman (1966) points out that a majority of problems we see in daily lives fail to meet Minsky's criteria. These problems have been termed 'ill defined'. A problem may be considered ill defined if the starting position, the allowable operations or the goal state is not clearly specified, or if a unique solution cannot be shown to exist. Ill-defined problems include design and planning (Carroll, 2002), like planning a vacation to an unknown destination.

Funke (1991) studied problems like taking over the management of a shop or a small town-complex under the label of 'complex problems', a concept very similar to ill-defined problems. What makes Funke's work useful is that he lists the features that characterize 'complex' problems and sets them apart from well-defined problems. Here are the features he specifies:

1. *Intransparency*- Complex problems have variables, symptoms and states that are not observable. There are too many variables and relevant ones are hard to select.
2. *Polytely*- Complex problems have many goals, including some that may be contradictory.
3. *Complexity of situation*- Complex problems require the identification and regulation of many variables.
4. *Connectivity of variables*- Complex problems have variables with a high degree of connectivity. This means that change in the value of a single variable results in the change of many others and the consequences of manipulations are not clear.

5. *Dynamic developments*- There is unpredictability in complex problems which often induces stress.
6. *Time delayed effects*- The effects of actions are delayed.

Sensemaking is akin to ill-defined PS and complex PS in many ways but is much different from well-defined PS. Practical problem solving does not necessarily require understanding and people can stumble to the goal state or the solution. PS is defined by the outcome of solving the problem. Sensemaking in contrast is defined by what is done along the way (making sense). Sensemaking can be considered a special case of generalized PS similar to ill-defined PS and complex PS. This relationship is further explored in Appendices A, B and C where prototypical cases of each are discussed.

2.2 Attributes of sensemaking tasks

The existing sensemaking theories help us understand how people engage in sensemaking but not what makes a situation or a scenario 'sensemaking'. In order to select tasks and scenarios to study sensemaking we need to understand what distinguishes sensemaking from other activities. In this section, I define the attributes of a sensemaking task that are proposed as a suite of ideas and corresponding tests for identifying and exploring sensemaking tasks. This in turn can be useful for not only choosing tasks that have a high amount of sensemaking for studying sensemaking but can also be useful in modifying tasks to make them more appropriate for studying sensemaking. Activities high on all attributes should be prototypical examples of tasks involving substantial sensemaking; those low on all attributes should not. Note that sensemaking can take place in lightweight forms even in activities with low scores on some of the attributes. While

tasks low on most attributes might entail some sensemaking, they would not be very good candidates if researchers are interested in situations with a high degree of sensemaking.

The five attributes are presented in two groups in this section. There are three attributes related to *knowledge structure creation:* representation novelty requirement, encoding difficulty and broader applicability. There are two other attributes that are related to the *complexity* of sensemaking tasks: representation search space and subtask-interdependence.

Knowledge structure creation attributes

In the course of examining various sensemaking theories a common theme emerged: the creation of knowledge structures. These knowledge structures were referred to as 'representations' by Russell et al (1993), as 'images or frameworks' by Weick (1995) and as 'bridges' by Dervin (1998). This essential characteristic of sensemaking tasks can be elaborated using three attributes. Two of these attributes are aspects of the knowledge structure that is created and the third is a capability supported by the resulting structure. Since knowledge structures include a schema for organizing information as well as information that is encoded into the schema (Russell et al., 1993), it can be argued that structure creation can have two aspects that can cause the need for sensemaking: either a novel representation may be required or encoding information into the representation may be difficult. The presence of one or both of these two aspects can be used to argue the case for existence of non-trivial sensemaking. What is termed as "broader applicability" here is a capability supported by the created knowledge structure and its presence is a strong indicator of sensemaking.

2.2.1 Representation novelty required

The first attribute proposed in this group reflects the idea that sensemaking activity differs from routine activity in that new structures of knowledge ("novel representations") must be created to provide the understanding needed for the tasks at hand. The notion of novelty is not simple since the knowledge structure for sensemaking is never created from scratch; it is at least partially appropriated from elsewhere (Qu, 2005). If the sensemaker has access to good pre-existing representations, the need for novel representation, and consequently the need for sensemaking, is reduced. Representation ideas can come from the sensemaker's own existing knowledge as well as from representations created by others working on a similar task (Qu, 2005).

To decide how much representation novelty a sensemaking process requires we will thus need to articulate the following: (1) some approximation to the knowledge or understanding that must ultimately be achieved, (2) the sensemakers' existing knowledge and their access to representations created by others, and (3) some assessment of the amount of new work needed to move from (2) to (1). The larger that amount of work entailed, the stronger the case that the task involves substantial amounts of sensemaking.

2.2.2 Encoding Difficulty

The second structure creation attribute associated with substantial sensemaking involves the extent of non-trivial encoding required. Encoding was the term used by Russell et al. for the process of putting information specific to the task instance at hand into the representation or framework the sensemaker is trying to use for the task. Russell et al (1993) identify encoding as one of the processes in sensemaking that can involve significant costs. I propose that encoding information into a good representation can be difficult, and sensemaking can consequently be more substantial, for at least three

reasons. First, the overall relevance of various information at hand to the current task may not be known (e.g., a detective trying to make sense of a case wondering, "Is Joe involved in this at all? Is Al?") Second, the precise relationship of known-to-be-relevant information to the representation in use may not be known (detective: "I am sure Joe is involved in the plot, but I do not yet know how.") Finally, encoding may be difficult when the roles of items cannot be evaluated independently, and instead many pieces of information need to be compared simultaneously for a match against many parts of the representation. ("Joe, Al, and Mike are both involved, but who is calling the shots, and who is going to actually do the deed?"). Insofar as we can articulate how any of these difficulties arise, we will have a stronger case that the degree of sensemaking involved is high.

2.2.3 Broader Applicability

The third structure creation attribute concerns an emergent capability of the final structure. Sensemaking differs from problem solving per se, in that it creates understanding, not just a solution. For example, one might simply stumble upon a solution by luck or brute force and in that sense "solve" a problem, while never having really understood, i.e., made sense of it. We take as one core criterion for sensemaking, that understanding is achieved. Genuine understanding is inherently generative and captures regularities in the situation in a way that supports many inferences, including those yielding a solution. Importantly, however, it supports other inferences as well. True understanding can be used to solve a whole suite of related problems, not just the original one. Therefore one candidate operationalization of understanding (i.e., of sensemaking accomplished) is a notion of "broader applicability." Broader applicability

is suggested as an attribute because in the course of exploring many sensemaking scenarios I observed that sensemakers were gaining the means to address a wider range of issues than the one presented with. For example, consider the contrasting case of two tourists in a new city: the first asks a resident about the way from the bus-station to the hotel, follows the advised turns and reaches; the other studies a map to figure out the way. While both are successful and both 'solved' the problem in the primary task the second tourist will also be able to find his way to other parts of the new city since he has 'made sense' of the city.. It must be noted that representations or knowledge structures may not always be created with the intent for multiple uses and broader applicability, but if we can make the case that some activity builds a capability that allows success in broader re-use, in multiple scenarios, we will have substantive evidence that such generative structure was created and that the activity entailed considerable sensemaking.

Process Complexity Attributes

Sensemaking is inherently difficult and even stressful, due in part to the complexity involved in making sense of a new situation. Two possible reasons for complexity in sensemaking are: (1) the difficulty in searching the space of possible representations and (2) the interdependent nature of sub-tasks involved in the sensemaking process. We have elaborated these two aspects as attributes of complexity. Funke's (1991) work on complex problem solving has been adapted to elaborate the complexity attributes presented here.

2.2.4 Representation Search Space

Comparing and contrasting many candidate sensemaking tasks led us to the first process complexity attribute whose presence indicates more substantial sensemaking. This

attribute concerns the nature of the "space" of possible representations through which the sensemaker must "search" to find one suitable for the task. The space of representations used in a prototypical sensemaking scenario can be difficult to search, and hence the sensemaking more substantial, for at least three possible sets of reasons. First, as suggested by Funke's (1991) work on complex problems, there may be factors contributing to combinatorial complexity in the design space, arising from a high number of representation elements, difficulty in identifying possible elements, and any interdependence of these elements. Second, I propose that there may be problems in evaluating candidates in the search space: difficulties of observation, manipulation, or assessing the heuristic search value of items. Third, Funke's (1991) work on complex problem solving suggests that there may be dynamic complications, where a continually evolving situation is forever changing the problem to be solved, making the space of relevant representations itself dynamic. The more these three aspects are present in the task, the more difficult the needed representation space will be to search, and hence the more the task will involve non-trivial amounts of sensemaking.

2.2.5 Subtask Interdependence

Russell et al (1993) characterized sensemaking as an "interlocking set of different types of subtasks." "Interlocking" implies that subtasks in sensemaking cannot be separated. I further propose that sensemaking tasks can be complex because these sub-tasks are simultaneously active and occur in interleaving threads that are closely coupled. To argue that a task involves serious sensemaking, one should be able to identify simultaneous threads of activities that must rely on information from each other to guide them, and that

considerable coordination and communication between the activities is needed for their successful execution.

These attributes are used to evaluate several test cases in Appendix A, B and C. It should be noted that the attributes presented above are not crisply dichotomous, but rather are more continuous. Thus they are more suitable for creating a graded, "family resemblance" categorization (Rosch, 1975) rather than being used to make a binary decision about whether a task absolutely is sensemaking or not. It should also be noted that many tasks involve a little sensemaking where a small knowledge structure is added to our existing knowledge structure. Here the phrase "sensemaking task" or "scenario" refers to a task involving non-trivial sensemaking where the addition to knowledge structure is either sizable in number of concepts, degree of novelty or the effort needed.

2.3 Collaboration & Handoffs: literature review

There has been considerable research on collaboration in general, some of which has important implications for handoff. Johansen (1988) laid out collaboration types across space and time (Table 2.1).

Place\Time	**Synchronous**	**Asynchronous**
Collocated	Lab-mates working together	**Hand-off** in hospitals, labs and crime scenes
Distributed	Shared workspace, conference tools	Open-source, message boards

Table 2.1 Typology of Collaborative situations. Source: Johansen, 1988

Johansen characterized handoffs as asynchronous and collocated. However handoff is not only asynchronous but also serial. Collocated handoffs usually involve a shift change and occur in a place of work. Johansen did not consider non-shift-change handoffs, which can

be asynchronous and distributed. An example would be referrals made in hospitals or transfer of tickets in support helpdesks. The modified table (Table 2.2) places this other kind of handoffs into Johansen's framework.

Place\Time	**Synchronous**	**Asynchronous**
Collocated	Lab-mates working together	**Hand-off (shift change)** in hospitals, labs and crime scenes
Distributed	Shared workspace, conference tools	**Hand-off (referrals)-medical referrals to an expert in a different department,** Open-source, message boards

Table 2.2 Modified Typology of Collaborative situations.

Handoffs can thus be collocated or distributed. Teasly & Olson (2000) studied 'radical collocation' where members of a team work together for extended periods of time and found that closely coupled tasks had increased productivity due to radical collocation. Since sensemaking tasks are often closely coupled, collocation would help sensemaking handoff. In other words, if handoff is distributed it may put more demands on the sensemakers.

Olson & Olson (2001) identified factors that influenced success of distributed collaboration such as high common ground, collaboration readiness and high technical readiness. Common ground can be thought of as the overlap between the contextual factors involved. According to (Clark & Brennan, 1991):

> *"Common ground is reflected in the amount of work needed in order to manage the communications for a joint activity. As common ground builds mutual knowledge, beliefs and assumptions, participant's communications become coded and abbreviated, and economical"*

Since the close-coupled nature of sensemaking tasks needs considerable communication, high common ground can help by managing the communication and making the communication more efficient.

Klein (2006) also lists common ground as one of the central concepts for coordinated joint activity. Klein says that team members in a joint activity need to be predictable to each other and calibrate their perspectives to sustain common ground that can be degraded over time. Another central concept according to Klein is the ‘Basic Compact’ or intent to work together and align goals. Klein says that from this compact comes interdependence, expectation of resilience and adaptiveness to unexpected events. ‘Basic Compact’ seems analogous to the collaboration readiness concept in Olson & Olson. Both are related to how much intent exists to share resources and effort for common or aligned goals.

Gioa & Chittipeddi (1991) have also written about the aspect of intent in groups engaged in sensemaking, specifically the intent to influence the sensemaking and meaning construction of others toward a preferred redefinition of organizational reality" in the context of a strategic change in a large university. According to Gioa and Chittipeddi, sensemaking involves the dissemination of a 'vision' to a recipient which they refer to as ‘sensegiving’. This concept seems to be closely related to sensemaking handoffs. Firstly, sensegiving can be considered a special kind of handoff where it is the intention of the provider to influence the sensemaking of the recipient. Secondly, sensegiving can be considered a special component of a sensemaking handoff. In a sensemaking handoff, besides sensegiving which involves transfer of the ‘sense’ or ‘vision’ which maybe the equivalent of a ‘representation’, other elements may be involved instead or in addition like other useful sources of information, information not yet encoded in representations and actions taken until the handoff.

High common ground and intent seem to be important factors in managing a closely coupled activity like sensemaking. In cases where common ground is lacking, other information sharing mechanisms may help to coordinate the situation by allowing close-coupled activities, such as awareness, deliberate structuring and shared physical spaces.

Dourish & Bellotti (1992) found that awareness information allows users to move smoothly between close and loose collaboration. Awareness refers to knowledge of group and individual activities. Thus awareness can also help supplement common ground and help coordinate the closely coupled tasks in sensemaking.

When common ground and collaboration readiness are lacking, structured management may also be of some help (Kiesler & Cummings, 2002). Structured management involves modularizing work to reduce interdependence, increasing autonomy (divide and conquer). According to Kiesler and Cummings, structured management can provide task decomposition, common ground and reduce uncertainty in joint activity. It is not clear if structuring can help in task decomposition in sensemaking however. As we have noted before, sensemaking has high subtask interdependence, which implies that sensemaking tasks are not easy to divide and conquer.

Handoffs may work better when there is a shared physical environment or when the whole sensemaking environment is handed off rather than just task. Suchman found that physical environments are mutually constituted and structured to enable joint work (Suchman, 1988). This means that the physical space is another important contextual factor in the sensemaking handoff picture. When physical space is not shared the sensemakers may have access to divergent sets of physical cues from their environments that may cause calibration problems amongst team members.

The concept of information re-use is also closely related to handoffs since recipients of handoffs often engage in reuse of artifacts created by the provider. Markus (Markus, 2001) lists the additional costs involved in preparing information for reuse. These costs include cleaning, packaging the information along with appropriate level of context, and actually distributing the information. Markus also stresses that due to the cost involved in making reusable knowledge, a producer will be reluctant in preparing for reuse for others. Preparation for reuse is more likely when providers see themselves using the material later as well or when the benefit to the recipient is immediate. Reusable material may also be produced as a byproduct of their work. Otherwise special incentives and norms need to be developed to help reuse when the above conditions are missing.

The existing literature on collaboration offers some insights based on the type of process on which collaboration is taking place. Sensemaking is a complex, closely coupled activity. Thus collaboration in sensemaking requires robust mechanisms for coordinating close-coupled tasks as well as a strong intent to collaborate. High common ground, awareness information and shared physical space provide mechanisms for coordinating tasks in sensemaking and thus would help in sensemaking handoffs.

Some past research has looked at handoffs more generally and this research may offer aspects relevant to sensemaking handoffs. Often the term used in the literature is 'handover' instead of handoff. Handover research has focused mainly on handoffs due to shift change. Most of these studies have attempted to find variables that help the receiver come up to speed in order to have a smooth shift change.

Efficient communication was found to be an important factor in many of these studies. Communication here means interactions besides the transfer of handoff material. A

literature review of handover (Clinical Handover and Patient Safety Literature Review Report March 2005) in the medical domain found communication to be an important factor in handoff efficiency. For example it was observed that adverse events increased when communication was hindered between specialist services outside a hospital environment and the inpatient system.

Other studies in the health care domain have suggested creating roles (Shrake, et al., 1994) and formal communication and handover practices (Litzinger & Boehler, 1997; Schlienger et al., 1999; Zwarenstein & Bryant, 2002) to facilitate decision-making. These strict roles and practices might make sure people would know whom to handoff to and what to handoff.

Handover research has also stressed the importance of prior knowledge and common ground besides communication. Patterson and Wood's (Patterson & Woods, 2001) field studies of NASA shuttle missions highlight the influence of prior knowledge and building a common ground between practitioners in having an effective and efficient update. Harper and Hughes (Harper & Hughes, 1993) observed that flight controllers chose prior agreements over active communication to minimize errors.

> *"Flight controllers try to minimize the amount of communication between sectors, since it can take up valuable time, by using 'silent handovers', that is, using procedurally agreed flight levels for the transition between sectors"*.

While this observation by Harper and Hughes sounds contrary to the push for more communication, there are several possible explanations for the limited verbal communication. Firstly, the flight controllers have shared visual data and high common ground and their problem is mainly of allocating attention. Secondly flight control handovers seemed to involve lots of routines and are thus somewhat different from typical sensemaking situations. Prior agreements and procedures might not work in

sensemaking situations that are novel and therefore more communication may be needed. Also, because communication was costly, special routines had to be established to achieve the coordination.

The existing literature on handovers provides insights into the factors in handoffs like the need for additional communication and reiterates the need for common ground but the literature is lacking in some aspects. First, while the research on handover has concentrated on shift changes, other handoff situations have not been studied. Second, since the handover literature was focusing on transfer of task responsibility in a variety of situations, not all scenarios covered in the literature are sensemaking scenarios. Some, like flight control, involve more procedural work instead. As we learned through the examination of sensemaking theories and development of essential attributes, sensemaking presents additional problems like structure creation which are absent in routine problems, even complex routines like flight control.

2.4 Sensemaking handoffs factors

This section compiles the findings from the literature review of sensemaking and collaboration with the suggested attributes of sensemaking to list the important factors in sensemaking handoffs.

The comparison of the three sensemaking theories (Russell et al, 1993; Weick, 1995; Dervin, 1998) suggested that there are individual as well as contextual factors in sensemaking. The individual factors include the relevant prior knowledge and experience of the sensemaker. A prominent contextual factor is the task itself. The sensemaking attributes tell us that a task that requires novel representations, is difficult to encode, has a large representation search space and has high subtask interdependence involves more

sensemaking and the created representation will have broader applicability. These individual and contextual factors affect how difficult a sensemaking situation is and what handoff artifacts will be available after externalization of the representation.

The literature on collaboration and handover highlighted additional contextual factors. These factors included: intent to collaborate, common ground, shared physical space, awareness and the available communication channels. These factors affect how the artifacts handed off to the recipient might be utilized. Figure 2.2 illustrates the above factors in a sensemaking handoff situation.

Looking at the figure we can make some additional observations about sensemaking handoff. Common ground, awareness information, the handoff material and the additional communication together form an ecology to support the handoff. Common ground forms the base of this ecology. What common ground cannot cover needs to be conveyed through awareness information, additional handoff materials and additional communication since sensemaking has close-coupled activities that may require frequent call backs to the handoff provider. It must also be reiterated that the handoff material can include the sense that was made before the time of the handoff (sensegiving) as well as other resources.

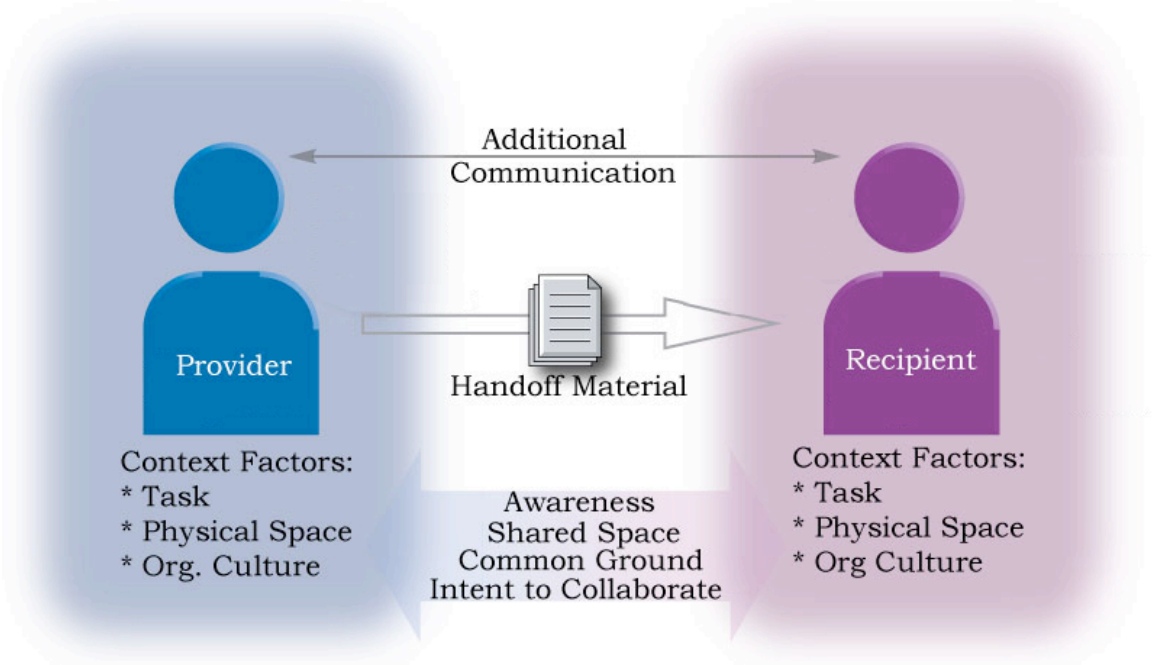


Figure 2.2: Sensemaking Handoff Factors

	Intent to collaborate	**Common -ground**	**Awareness & Shared space**	**Additional Communication**	**Handoff Material**
Shift change	Yes	Yes	Yes	Little	Yes
Referrals	Yes	Some	Not usually	Sometimes	Yes
Non-directed	No	Varying	No	No	Some

Table 2.3: Crucial elements in sensemaking collaboration

The crucial collaboration attributes: intent to collaborate, common-ground, awareness, shared physical space, additional communication and handoff materials can also highlight the similarities and differences between different handoff situations. In many shift change situations the intent, common ground, awareness & shared space and handoff materials may be present but only additional communication may be lacking. Most referral handoffs by comparison have lower common-ground and no awareness and shared space

but have some opportunities for additional communication. The most challenging handoff situations have little or no presence of the above. For example, in non-directed sensemaking handoff, someone may be trying to utilize the work of a previous sensemaker. Table 2.3 presents the summary of collaboration characteristics in different handoff situations.

2.5 Summary

The handoff of sensemaking is difficult and challenging. Essential attributes of sensemaking highlight its high complexity and interdependence. The collaboration literature suggests that such activities should require rich support, such as common ground, awareness, shared-space and additional communication. These factors are further explored in studies presented in the next chapter.

Chapter 3

A Qualitative Study of Sensemaking Handoffs

In some real life sensemaking situations handoffs are mandatory (e.g. shift changes) but other handoffs can occur voluntarily, where people choose if and when to handoff. A qualitative study of handoff practices in this situation can help to inform us about the obstacles that people encounter in sensemaking and how they use handoffs to resolve these obstacles. This chapter describes a qualitative study of non-shift change sensemaking handoffs in two computer support helpdesk groups where handoffs were in the form of referrals, directed towards an individual or a group.

3.1 Study Setting

Semi-structured interviews were conducted with ten computer helpdesk personnel at two different groups at the 4-Help phone consulting and CAEN hotline at the University of Michigan. Computer support helpdesks at the university were expected to be the site of sensemaking and sensemaking handoffs after preliminary interviews with the groups' supervisors. The existence of sensemaking in the helpdesks is examined in detail within the findings. While the number of participants was low the interviews conducted were in-depth and lasting from 1.5 to 2 hours.

3.1.1 4-HELP university wide phone based helpline group (G1)

The first group (G1) works on the phone-based helpline for anyone affiliated with the university. The group has around 20 full time employees. Out of the 8 participants interviewed from the group, 3 were female. According to the supervisor of one of the groups, the university helpdesk groups were unlike most industry helpdesk groups in many ways. Firstly the age of the personnel was much higher (30 to 66 years). Secondly the turnover rate of the group was very low. All group members had been around for 6 years or more. Thirdly there was no one in the group with a computer science degree. When asked, the supervisor of the group said that this was a conscious decision. She felt that non-CS employees were more committed to users, had better communication skills and had lower turnover rates than CS graduates. A conscious decision was also taken in the group a few years ago to not hire students as temporary workers. The supervisor and other employees reported that although students were useful in the group, their turnover was high and they had little common ground with the long-term permanent staff. These decisions in turn resulted in high-common ground and a high intent-to-collaborate within the group.

Most group members thought their group was performing well. In a survey done by the group about five years ago, 99% of respondents said they were satisfied by the service provided by the helpdesk. The group members interviewed said they were very happy with the institutional support from the university. One interviewee said that they liked that even the Director of User Services and the Director of Computing Resources spent a day answering questions with the team:

> *"(The director of user services) came down.... They got phone calls and they got to deal with the front line of these irate customers, customers upset, tried to walk them through this. It was a real eye opener to them. They said you know what....maybe we need to keep (ourselves) more in the loop when we make*

changes and when we do things because they are going to tell us what the general feel of the customers is going to be like."

The physical layout of the workspace of G1 involved a large room with workstations for each of the members. Calls to the helpline were channeled to available helpdesk members in the room. Members were not able to select or screen calls; they were expected to answer any calls in the order the calls were received based on their availability in the room. The working hours for the helpline were 8am to 7pm on weekdays and the members came in at different times of the day.

3.1.2 CAEN: Engineering College Support Hotline and Helpdesk (G2)

The second group G2 provides support to engineering school members through phone in, walk in and email. G2 was much smaller, with only 3 full time employees, all male, and up to 5 temporary part-time student employees of both genders. Two members of the group, including the supervisor of the group, were interviewed for the study. G2 members were much younger (20 to 33 years) than G1 members. This group also had a low turnover rate for the fulltime employees; the most recent member had been in the group for 5 years. The part time employees were students, whose turnover rate was high with several new students hired every semester.

The physical layout of the G2 workspace was a large office area shared with other computing staff groups. The office was divided into three subspaces. Walk-in users entered the first subspace which contained the student cubicles. The second subspace was a large cubicle for the junior most fulltime employee. The other two senior fulltime members shared an office about 15 feet away. One of these senior members, served as the supervisor for the group.

Incoming calls and walk-ins were first handled by the students and escalated to fulltime employees as needed. All three fulltime employees shared the burden of the escalations (when students could not solve the problem) as well as requests for help through email. Walk-in and phone in hours were 8am to 10pm on most days.

3.2 Data Collection and Findings

Semi-structured interviews (1-2 hours) were conducted with the individual participants at their workplace. The questions were focused on learning the work habits and work culture of the participants and the sensemaking situations they faced. Questions also asked if there were handoffs during the course of their work, and if so, what were the reasons for the handoffs, what were their handoff strategies, how they decided when to handoff and systems and tools they used for handoffs. The interview protocol can be seen in Appendix D.

3.2.1 Sensemaking in the helpdesks

The helpdesk members reported that they receive calls for troubleshooting on a variety of computer related problems. There were problems that did not involve active thinking like routine problems with known solutions like ‘password resets’ and problems which were solved without the involvement of any deep understanding (“Try rebooting, that fixes things often”). There were problems that required belabored thinking (“I cannot read my email”) and rarely, there were problems where a string of related events needed response (“We’re getting many calls regarding problems with the mail server”).

While the routine problems and problems solved without involving understanding seem to involve no sensemaking, the problems involving belabored thinking can require some

degree of sensemaking. The sensemaking attributes suggested earlier in chapter 2 can be used to examine the extent to which various types of problems involved sensemaking.

Representation novelty requirement

A possible sensemaking representation for a particular problem can be a model of the problem the user is facing. This model can be internal or can be externalized and derived from various troubleshooting algorithms, diagnostic process flowcharts etc.

Most helpdesk personnel were supposed to have knowledge relevant to most common problems. The personnel also worked in groups where questions are thrown out to others when needed and experts from sub-fields of helpdesk work were available for advice. The helpdesk personnel are also well versed with web searches and have access to other resources like web forums. This suggests that for most problems people had easy access to representations from others. Thus the representation novelty requirement in most helpdesk problems was *low*. Only when people called in with completely new problems about which a new representation needed to be created and none of the other experts in the room had ideas, can the novelty be considered *high*. Such occasions though not very frequent did occur, for example:

> *"Sometimes we end up in situations where a system has failed here at the University – a server, the email system is actually a whole farm of servers and maybe one of those servers has failed and we'll start getting calls and then you'll start hearing around the room that other people are asking the same questions you're asking your caller. And then we have to kind of put people on hold and then we have to start diagnosis ourselves what we think the issue is".*

Encoding difficulty

As mentioned before, some helpdesk problems were instantly recognizable to the helpdesk personnel ("I forgot my account password") and since these problems were

instantly interpreted they had *no* encoding difficulty. On the other hand there were many problems where the helpdesk personnel had to collect a lot of information about the problem from the user and interpret it using their current representations. Since the information was often provided by users who do not know much about computers, the degree of relevance of the information provided needs to be established. The relation of the information provided to the representation is also not known because users were not aware of the representation used by the helpers and their language and vocabulary was not consistent with the representations used by the helpdesk members. The questions put forward by the helpers needed to be in the language of the users and the answers to the questions needed to be reinterpreted to fit the representation. The user was probed again and again in order to match each piece of information to various parts of the representation. In the words of a helpdesk worker:

> *"I have to **interpret** what the caller is telling me. They don't know the terminology. In a lot of cases you ask a question: How do you get to your email? [caller say] I don't know. Well what software do you use to read your email? [caller says:] I don't know. What do you click on? [caller says:] The icon that sends email. What happens when you do that? [caller says:] My email comes up."*

The encoding difficulty of problems other than those instantly recognized was thus *very high.*

Broader applicability

Instantly recognized problems like password resets did not involve creating any additional understanding and consequently did not have broader applicability. On the other hand solving a difficult helpdesk problem that involved representation novelty or belabored encoding enabled the helpdesk personnel to have a broader understanding of the problem. For example a helpdesk member reported a case where the problem with

accessing email was due to the moisture in the telephone lines. After arriving at the answer, the helper could also make other assertions like: the user could get their emails in school where they have wireless connection, that they would not have this problem again unless it rained the day before and so on. The helpdesk problems that were not instantly recognized can be deemed to have *high* broader applicability.

Representation search space

In helpdesk problems, the problem search space was large whenever the users were not able to define the problem because of their lack of technical knowledge. This was typical in cases other than the few straightforward cases where the users knew what problems they had. For example one helpdesk member reported that often the users thought the problem was with email while the problem would be at the network level. Besides the lack of definition from the user, the involvement of complex systems (like networks) made the search space even larger. The evaluation of progress was also difficult for the same reason; the telephone helpdesk providers cannot look at the results of interventions directly and must rely on feedback from the user. While the search space was large and difficult to evaluate for most questions, the situations were not dynamic since there was typically little change in situations during the course of the troubleshooting.

The search can be considered *medium to high* difficulty for most problems. By contrast, the problems that were instantly recognized had a *very easy* search space.

Subtask interdependence

The computer troubleshooting included subtasks like defining the problem, probing the user, making interventions, evaluating intervention results, and making further recommendations. Defining the problem and probing the user needed to be done

simultaneously and can be regarded as closely-coupled. As the problems were being understood the helper needed to ask questions. Other subtasks like making and evaluating interventions followed each other. Since some and not all subtasks were simultaneous and closely coupled and others were dependent on other subtasks, the subtask interdependence for most tasks in helpdesks can be considered *medium*. It should be pointed out that routine problems had preset specific responses that usually involved a sequence of steps with little back and forth between the steps. The interdependence between subtasks in these cases was comparatively *low.*

	Attributes	**Routine/ Recognized**	**Interpretation**	**Multiple-events**
Structure Creation	**Representation Novelty**	None	Low	High
	Encoding Difficulty	None	High	High
	Broader Applicability	None	High	High
Complexity	**Representation Search Space**	Very Easy	Med-High	Med-High
	Subtask Interdependence	Low	Medium	Medium

Table 3.1 Summary of attributes for different types of helpdesk problems.

Overall

Helpdesk troubleshooting work involved a wide range of questions. Routine and easily recognizable problems did not involve any sensemaking other than that there were many problems that required active interpretation. This second kind of problem involved sensemaking due to the presence of both structure creation and complexity. The structure creation aspect came from the encoding difficulty rather than the novel representation creation. Besides these two types of cases there were also the rare cases where even novel

representation creation was needed. These cases often involved reports of multiple events/users.

Table 3.1 summarizes the attributes of the three different types of problems. While a sizable number of routine problems can be excluded from being considered sensemaking, many other problems involved sensemaking. The pattern of many routine problems interspersed with sensemaking cases in the helpdesk offers a good opportunity to study sensemaking. This pattern is consistent with what both Weick and Dervin have observed, that sensemaking is often situated in a breakdown or a gap in routine work. If sensemaking and its handoffs are to be supported, it is important to study the sensemaking as it occurs in the context of routine work.

3.2.2 Handoffs and communication

Most problems that were routine and recognizable were resolved quickly by the person who received the call. Even problems involving sensemaking were not handed off very often. The norm was to attempt solving without referral. In those cases where the helpdesk person got stuck, usually their first option was to recruit help from other experts in the helpdesk while the user was put on a brief hold.

The manner and medium of asking was different in both groups (see below) due to their different spatial layouts and workplace hierarchy. If help was easily available it was sought from others in the group. Otherwise, the participants said they proceeded to conduct internet searches on the topic. One example of using expertise in the room can be seen here:

> *"Sometimes you just need a sounding board. You know okay I am stuck. I am not seeing something here and boom nine times out of ten it is resolved in the room right there."*

The participants in both groups prided themselves as "problem solvers" and liked dealing with challenging sensemaking problems. In this role as problem solvers they seemingly took ownership of the questions presented and often wanted to know what they missed in case they referred a question.

> "*We're **problem solvers** and if you can't solve a problem then you're kind of like oh darn. When you have to make a referral almost everybody wants to know what the answer was."*

If no answer was available the problem was prepared for a 'referral', the term for a handoff. Tough sensemaking problems and consequently referrals were more common when a new technology was rolled out or when new batches of students arrived at the university. New students and new technology both led to the lack of familiarity between the users and the university systems. As discussed above, the problems were also compounded when help was sought over the phone rather than as a walk-in as the employees could not see the users' computer and were unable to interact with it directly and thus interpretation of the problem was difficult.

> *"Sometimes people call and say my email is not working. Well you go to them well let's open up a web browser well then they can't load any web pages. And you're like well this isn't an email problem."*

Whenever a handoff was done, a 'referral ticket' was prepared and forwarded to a subgroup of experts appropriate for the problem. Members of the groups formed subgroups according to their expertise on topics like email clients, Mac/apple OS, windows OS, networking and hardware. A member of the appropriate expert subgroup would claim the ticket and start working on the problem. G1 members had different ways of communicating than G2 members. Since G1 shared a single space, it was easy to ask

around for help. Help was often sought and received in this manner. Most participants in G1 said they liked this culture of open admission of a knowledge gap and asking for help.

> *"We're all real comfortable with each other. I mean we have our ups and downs as a family would. But we rely heavily on each other. There's no such thing as knowing everything there is to know about everything so we rely very heavily on each other where I might have an expertise in one field.....so we rely on each other very heavily."*

Yet all group members in G1 were not present in the room at all times. The members split their work time in the phone room and working from home on referrals or on other developmental work like testing and training. A conscious decision was taken to limit work hours in the phone room to 20 per week. This was one reason for the low turnover and high job satisfaction in the group. In order to support communication with 'away' members of the group, all group members were provided cellular phones with 2-way radio support. The members not in the room were supposed to be on call during working hours, from 8am to 7pm. If those in the room did not answer a request for help, members would request help from the 'away' members through a wireless phone.

> *"Like if I'm not in the room and somebody has an email question they can two way to me and I can give them suggestions on what to do or I can say to them I don't know let's refer it and we'll work on it later."*

G2 members were not able to throw out a question to others as easily because of their space configuration. Students were easily able to escalate or ask for help from the adjacent fulltime employee, but not from the other two senior fulltime members who were in their personal offices detached from the rest of the group. G2 relied more on instant messaging (IM) to compensate for the difficulties of the space configuration. If the problem needed a significant amount of communication, the members were forced to walkover to the other member's workspace.

The free sharing of knowledge and advice in both G1 & G2 seems to be in accordance with prior research on information sharing attitudes. Constant et al (1994) studied information sharing attitudes and found that exchanges situated in social and organizational context are different from pure individual-to-individual (i2i) interactions. In pure i2i, self interest and reciprocity is prevalent but in social situations negative behavior and self-interest is reduced. Sharing was also found to be dependent on the type of information in question. Tangible information like documents was treated more as a commodity than intangible information like tips and advice. Tangible information was shared depending on prosocial attitudes and organizational norms while intangible information was shared anyway. Constant et al attribute sharing of intangible information like advice and tips to the need to be self-expressive and to boost self-worth. The helpdesk members interviewed often talked about sharing stories about interesting problems and solutions:

> *"Everybody wants to know and sometimes if you get a really odd one and you find kind of an odd solution then we'll send a message out to the whole group and say hey I was working on this and I found this answer just so you know in the future."*

3.2.3 Handoff Reasons

Participants from both groups reported that handoffs ('referrals') were rare in their work. There were many reasons to not refer or handoff. Many problems were routine and could be solved right away. The high level of experience of most full-time members meant that as a collective the people in the group knew a lot. Computing support at this and other universities have been striving to lessen the number of referrals, as low number referrals are considered an indicator of better customer services. One interviewee said the following about referrals:

> *"Ones (cases) that get referred are **the trickier ones** that somebody (else) really does need to work one-on-one with the customer. Somebody who is an expert at whatever that problem is has to work one-on-one with the customers."*

The supervisor of G1 reported that the norms in university helpdesks considered it poor service to have the user wait for hours while the referred problem was picked up by another expert. Also, as mentioned before, the employees prided themselves as problem solvers and were loath to refer the problems to the next level.

"I think part of it is a matter of pride. None of us just wants to pass off a problem before we've given it the best shot we can."

As is the case in many domains, one cause for handoffs in the groups was shift end. Often in these situations the helpdesk employee would write a ticket, but would often go back and claim it back whenever possible. These handoffs to self were also common when the caller was pressed for time and wanted to continue the problem solving at a later time. Handoffs were also made when it was realized that someone else in the team had the appropriate skill to answer the question or if a senior member was needed because access to a restricted resource was required.

> *"Once in a while a consultant will be at the **end of their shift**, it will be like 7:00 and we're closing at 7:00 and this person called at 3 minutes to with an impossible problem and they'll just say you know I'm out of time, I'm out of patience and I've got to refer this. And then sometimes a consultant will refer it and then take it themselves."*

One of the biggest causes of handoffs was personal conflict with users. Rude and irate callers were a frequent cause for stress for many participants. Many participants remarked that surgeons, law school students and business students were particularly rude. Participants often said that they would ask around for help in dealing with a rude or irate caller just like they did with a tough question and transferred the call if anyone else was willing to take it.

> *"Some of them can be the most awful people on the face of the earth and there's really no reason for it. They just kind of have an attitude when they call. So yeah it can be very stressful, very stressful sometimes."*

> *"I guess it has happened where I just can't work with that customer, we're not communicating, someone else just needs to take over the call. That's happened in the room, not just with me but with others."*

Referrals due to personal conflicts were usually handled like other referrals. Usually the helpdesk expert who took the call asked other people in the room if anyone else was willing to take the call and relieve the stress. Sometimes the problem was referred to a particular expert since the expert was considered adept at handling a certain type of user. For example one of the helpdesk personnel was an ex-marine and was often referred cases with very angry and aggressive callers.

Finally a handoff or referral was the only option when a helpdesk worker had exhausted all of his/her options and was unable to proceed. In many such situations, a different perspective rather than a different skill set was sought when the handoff was made. The employees reported that another team member would take up the case and ask slightly different questions, which helped with troubleshooting in many cases.

> *"Sometimes you get too focused on the problem and you miss obvious things and then a fresh pair of eyes will figure it out. That always happens."*

3.2.4 Handoff Time

The participants reported two distinct kinds of handoffs.

- *Transfer: very early handoff.* The first was called a 'transfer'. Here the helpdesk employee would get the initial details of the problem, ask around for help from others in the room if stumped and if another employee would offer to take the call, it would be transferred. This kind of handoff was common when the employees had a user they had

personality problems with or when it was clear that another employee had the requisite skill or knowledge to solve the problem.

> "*It's quick in the sense that the customer spends very little time with the person who answers the call. When you transfer it to another consultant, generally I would give them as much information as I have."*

- *Referral: very late handoff.* The other kind of handoff was the referral. If the employee had exhausted all their options, they would write a ticket and refer the problem to the appropriate group of experts. There was considerable institutional as well as peer pressure to not 'refer' unless absolutely necessary. The employees were rather encouraged to transfer the problem early on if they thought another member was more appropriate and available. Both groups took pride in the low number of referrals. Usually a lot of work had been done on the problem before it was referred.

> *"I think part of it is a matter of pride. None of us just wants to pass off a problem before we've given it the best shot we can."*

> *"Normally before it gets to a referral point or go for referral most of our calls have been better than 30 or 45 minutes before someone will even think about referring"*

3.2.5 External representations handed off

Both groups informed that they used the Footprints[1] ticketing system for tracking problems as well as sharing information amongst members. Footprints is a call tracking system used by many helpdesks. The footprints system allowed employees to record communications with the user and other employees; at the same time it also allowed them to add notes. The employees could also add information about actions taken; they could also categorize and label a problem. It was typical to start a new ticket as soon as a new

[1] http://www.numarasoftware.com/FootPrints.asp

call was received, while some employees updated the ticket during a call, others typed up a ticket after the call was over. This allowed the helpdesk employees to allocate more attention to the user. In case of walk-ins for G2, the tickets were written after the walk-in is over.

Once a ticket had been written and the problem was still unresolved it was categorized, by picking a label from a list or adding a new label, and assigned to a group. Most participants said that they attempted to be exhaustive when writing a referral ticket. They tried to put in two kinds of information. The first was user related, for example the operating system used and client affiliations. The other information was about questions asked by the helpdesk, actions taken as well as other notes and memos.

There were also individual variations reported in the length and detail of the tickets. While there was peer pressure to be exhaustive yet precise, there were some reports of team members writing incomprehensible tickets. These were either too short and shoddy or too long and rambling. One helpdesk member expressed his dislike of very lengthy tickets.

> *"He's (the ticket writer) the head of the virus busters' team. He prefers not to talk to people on the phone but he sends a novel to everybody. It's like trying to get a drink of water from a fire hose."*

In both these cases, the participants said they would call the writer to clarify details in the ticket and also occasionally complained to the supervisor about poorly written tickets.

> *"If somebody doesn't put in the platform or the client or the version or something immediately somebody's going to zing back and say hey, well what kind of computer were they using because everybody knows that's a pretty basic question.... so we keep an eye on each other."*

Often if the ticket was too long, the expert would skim it and then call the person rather than wade through the text. Most participants said that they read a ticket to get a general idea of the problem so far and would often supplement the information in the ticket with other information they could collect themselves. If possible they would call the user again to verify the problem and to gather any other missed information. They would also call or talk in person to the ticket author; this was a low cost operation because the team members were very accessible.

> *"I will glance at it or read through just to get an idea of what's going on.... The person is having address book issues with Mulberry or Mulberry (inaudible) issues. So I'll get the general idea but I will typically start as if it was a fresh call. Say okay let's try this or take a look at this."*

3.3 Discussion

There were three main findings in the study. First, many helpdesk cases were sensemaking cases interspersed with routine cases and the practices of the helpdesk members can offer us insights into sensemaking handoffs. Second, easy additional communication meant that other experts were the first resource whenever sensemaking arose; this precluded the need for most handoffs and handoffs were discouraged whenever possible. Third, the employees put in considerable effort in preparing material when handoffs actually took place. Still the handoff recipients chose to skim the information and start over in many cases.

We start the discussion by looking at handoff practices of the helpdesks with respect to the crucial collaboration elements suggested in the literature. Then the avoidance of handoffs and reasons for handoffs are discussed.

3.3.1 Collaboration elements in the helpdesks

The collaboration elements crucial for sensemaking were: intent to collaborate, common ground, shared space/awareness, handoff material and additional communication. These elements form an ecology to support sensemaking handoffs and in the helpdesks all of the elements were present. Intent and common ground together were a group characteristic that formed the basis for collaboration and handoffs. Shared space/awareness and additional communication together complemented the handoff material in the groups.

Group characteristics- Intent to collaborate & Common ground

The intent to collaborate and common ground was closely linked in the helpdesk groups. The members had spent considerable time working together and they were comfortable collaborating with each other well. Consequently they also knew what expertise other members' possessed and used the expertise in others as their primary resource. In their years of experience they had not only built up personal computing skills common to everyone but also transactive knowledge (Argote, 1999). They were aware what expertise other people had.

> *"We're all real comfortable with each other. I mean we have our ups and downs as a family would. But we rely heavily on each other. There's no such thing as knowing everything there is to know about everything so we rely very heavily on each other where I might have an expertise in one field, XXX has different, YYY has different...so we rely on each other very heavily."*

Besides the transactive knowledge the members also shared knowledge of computers and also the shared identity of a 'problem solver'. It can be argued that the intent to collaborate and common ground was high in the group.

> *"And we have…not me…there are some of the smartest people computer wise in that room....we're problem solvers."*

Shared space/awareness & additional communication

Both helpdesk groups had a shared physical space for their operations and in the case of G1 the space was one big room with no partitions. This meant that the helpdesk members had good awareness of other members. It was clear when other members were available for help or when they were busy with work or unavailable. The shared space awareness was supplemented by additional communications. In G2 it was instant messaging and in G1 it was 'push to talk wireless phones' which enabled quick communication. The shared space and additional communication even obviated the need to handoff sensemaking by recruiting additional help and making the collaboration synchronous.

> *"The fact that we've had these two ways and we can easily communicate with people that aren't in the room at that time have cut the referrals way, way down. I mean I probably haven't put in two referrals in the last month."*

Besides the communication with other members the norm to contact users again in the referral meant that communication could be established with the user again which helped sensemaking.

> *"Now 9 times out of 10 that customer will give you another piece of information they did not give that consultant will then change everything and then you end up going down a different path and redoing the trouble shooting."*

The shared physical space and resulting awareness as well as the ability to communicate easily meant that collaborative sensemaking and consequently handoffs in the helpdesk groups were smooth.

Handoff material

The results showed that team members tried to prepare high quality tickets, to obviate the need for later clarifications. Tickets that were missing information, or were too verbose to read through required the recipient to call and clarify. Thus the emergent norm was to write a ticket that required minimum clarification from the writer. Even though G1 team

members had two way radios and cellular phones, additional communication is always disruptive to answer, thus most writers said they strove to write precise tickets.

The tickets usually had details regarding the user (the operating system used and client affiliations) and the questions asked by the helpdesk, actions taken as well as other notes and memos. Thus besides conveying the important information in the case (operating system etc) that can be used for encoding by the recipient of the referral, the provider also gave their representation (hypotheses and related actions) to the recipient. Together these two kinds of details meant the recipient had the pieces of information to build their own alternate representations besides the representation of the problem provided.

Though a great deal of effort was expected to be put in writing tickets another finding was that referral recipients often still skimmed the information in the tickets and started with their own data collection.

> *"I'll read through the entire thing, see where they went and think okay I'm going to call the customer and I'm going to start in a completely new direction because I don't think this is the right way to go on this."*

This finding suggests that even though the tickets had information and representation ideas, the information was skimmed and often the sensemakers chose to create their own representations and collect additional data. This finding reinforces the suggestion from Russell et al. (1993) and Dervin (1998) that sensemaking representations are very personal and idiosyncratic and people are reluctant to accept others' representation. As mentioned in chapter 2, handoff material can include 'sense' made till now and other resources. It seems the handoff material in the helpdesk case did not offer good representations to the recipients. Though it is clear that helpdesk members read through the handoff material, it is not clear how much of the handoff material was useful. This

question of usefulness of handoff material is the subject of a lab study detailed in the next chapter.

We find that in the case of referral handoffs in the helpdesks all the crucial elements of collaboration needed for sensemaking were available. While handoffs helped in resolving problems, the handoff material was not the main driver of sensemaking. The usefulness of the materials in conditions where some of the above elements are missing is explored in the two studies described in the next chapter.

3.3.6 Handoff avoidance

The supervisors of both groups reiterated that they took special effort to minimize the number of referrals. For both groups, a referral was considered somewhat equivalent to a failure and both groups strove to keep referral numbers low. The supervisor for G1 remarked that they had been successful in reducing the number of referrals from a few-a-day to two-a-month in the last few years since adoption of new communication channels like two-way radios. This feeling was also present in the helpdesk workers and they considered the low number of referrals a good thing so they always sought to reduce referrals to a minimum.

There were many reasons given for the avoidance of handoffs like attempting to provide speedy service and a feeling of failure at referring. There seemed to be a tacit acceptance that handoffs result in wasted time for the user if not a waste of time for the helpdesk group. Whether handoffs impose a cost on the group engaging in handoffs needs to be explored further and is also one focus of a lab study described in the next chapter.

Though handoffs were avoided, their advantage in overcoming inertia of representations was acknowledged and considered one of the main reasons for handoff. This finding

points to one of the values of handoffs mentioned in chapter 2. In shift change situations people have no choice on whether to handoff or not but in non-shift-change situations they have the choice and overcoming inertia seems to be a valid reason for a sensemaking handoff.

3.3.7 Handoff time & handoff material use

Interviewed participants reported that they engaged in handoff at two distinct times. The first, a 'transfer' occurred at the very beginning of the sensemaking and the second, a 'referral' occurred very late into sensemaking. The 'transfer' handoffs were done because another expert was deemed a better choice for the problem. Since the members did not want to handoff at all and did so only when they hit a dead-end the referral handoffs ended up being later.

While the helpdesk members tried to make good handoff material and avoid handing off too early it is interesting to ask why the recipients had to start over many times. One possible reason is that even though the helpdesk members tried to handoff after they had spent significant time and effort on a problem, this effort was many times not close to completion and the ticket did not offer a reasonable representation of the problem. This suggests that sensemaking representation that is far from complete may be unstable and hard to externalize since the sense at this stage can only include information and rudimentary representations. The last study in this dissertation (chapter 5) explores the benefits and costs of handoffs at early and late stages of sensemaking

3.4 Conclusion and Summary

Analysis of interviews of helpdesk workers found evidence of sensemaking in the context of routine work. It was also found that members shared important collaboration elements like intent, common ground, shared space, awareness, additional communication and handoff material. The presence of these elements meant the group could obviate many handoffs, which was desirable. After a handoff many participants reported that they started over again which could have happened because the handoff happened when the provider was unable to provide a good representation to the recipient.

The study suggests that collaboration elements can complement handoff materials since most referred problems were successfully solved. Yet the study raises many questions. What would happen in situations when collaboration elements are lacking but handoff materials are available from later stages of sensemaking? Would it help people choose to draw representation ideas from others' representations? Is early sensemaking less useful to a recipient of a handoff compared to sensemaking that is close to complete? The studies described in the following chapters attempt to answer these questions by focusing on the creation and the use of handoff materials.

Chapter 4

Exploratory Lab-studies of Handoff Artifacts

In order for a provider and a recipient to share sensemaking, it seems that crucial collaboration elements are important such as intent to collaborate, common ground, awareness and additional communication. It is an open question if only artifacts can be relied on because they may be too specific to the provider. In the helpdesk study, where crucial collaboration elements were present, handoff material was still only skimmed and people often started their own sensemaking from scratch.

This chapter describes two studies of sensemaking handoff where the focus was on the handoff-material. The first study examines if sensemaking material can have any benefit at all when crucial collaboration elements are missing. For most sensemaking problems, there may be partial work by other people that is relevant and can be helpful. If more is known about this non-directed low-intent sensemaking handoff, it may be helpful for utilizing past work by others. The second study explores how high and low quality sensemaking handoff materials are used differently by recipients. The helpdesk study in chapter 3 also suggested that material from incomplete sensemaking was used sparingly. The second study focuses on the use of handoff support material, noting differences in usage depending on the quality of the material.

The material presented to 'handoff recipients' was from completed sensemaking. Other crucial collaboration elements were kept as low: common ground was low, no shared physical space or awareness information was made available and there was no option of additional communication. The intent to collaborate was present but was much lower than in the helpdesk case. The crucial collaboration elements were kept low to investigate if sensemaking material can be helpful. This condition resembles the one mentioned in chapter 1 where sensemakers can use information systems and the internet to find and utilize the sensemaking work from others who have been working on similar sensemaking problems. In such situations other collaboration elements are lacking and there is minimal if any intent to collaborate. The study will thus have implications for the design of information systems that help find and utilize existing sensemaking work.

4.1 Study task and its sensemaking aspects

The two studies were conducted in the laboratory to allow for more control in examining a few aspects of sensemaking handoff. The studies reported here tested the performance of students sharing information in an online searching and sensemaking task. Choosing amongst a complex set of products has been considered sensemaking before (Russell et al, 1993). The following task was presented to the participants of both studies:

> *Your friend's father is an avid traveler who goes on vacations frequently. That's why your friend thinks a digital camcorder would be the perfect gift for him. He is also a serious photography enthusiast and he would make movies not just for memories but also to create travel movies that provide a medium for his artistic expression. The product's typical use will be on vacations, but it will sometimes be used for making home videos. Your friend needs help in buying the gift. Use the provided resources to search for the most appropriate camcorder for him and recommend a place to buy it at the best price. Your friend is willing to spend up to $500 for the camcorder but will go slightly over budget for a good camcorder.*

The subjects were also told that they would need to fill in a post-experiment questionnaire that would include questions about the justification of their choice. The questionnaire can be seen in Appendices E and F. The essential attributes of sensemaking introduced earlier in chapter 2 can be used to examine the extent to which this task involves sensemaking.

4.1.1. Representation novelty requirement

A sensemaking representation in this task would involve at least two major components. The first would be a representation of the needs of the person in the profile with respect to the task. This representation could be in the form of a list of needs of the person in the profile. The second representation component would be a structure that would capture the available products and the relevant features of the products.

People not familiar with the required type of product will lack any substantial knowledge regarding products and features. The profile used in the task can be well known to the participants like 'a stay at home mom' or unfamiliar like 'the homeless'. Even designers of the product might lack the knowledge of the first component of the representation if the profile is new to them. Only experts whose job is to recommend products for a profile (for example a camera sales person) might have knowledge of user profiles. The relevant knowledge was low for most subjects since both the product and the profile were unfamiliar to them.

The access to representations created by others depends on the choice of the product and user-profile pair. Certain products and profiles have web pages dedicated to them (e.g., digital camera for vacationers) while other products (or profiles) may be esoteric. In a laboratory version of the task, access can also be limited in a controlled setting by

blocking content or providing limited information resources if desired. At the time of the study (2002) digital camcorders were a new and unfamiliar product.

For the intended experimental subjects, then, the representation novelty requirement of the task is *high* since the product-profile pair was completely unfamiliar to the subjects and limited external resources existed that allowed easy decisions.

4.1.2. Encoding difficulty

Examples of the information to be encoded in the camcorder choice task would be the various available products and their many relevant attributes. With a plausible representation the sensemaker should know which features of the product are important. There may be many sources providing information about features like manufacturers, sellers, reviewers and other shoppers. Establishing usefulness of information may be problematic where there is conflict in these sources. Product reviews in particular can be difficult to interpret and their relevance can be difficult to establish since they involve conflicting opinions from unknown users. When there are only a few reviews their usefulness is questionable and when there are too many reviews it may be too time consuming to read and encode them.

Once a representation is available the sensemakers will know what features are relevant to the user profile. Most sources of information, like seller sites, present information about many features explicitly. Thus establishing the relationship of information with the representation should be easy and intensive matching with representation might not be needed. For example if it has been established that good zoom, long battery life and light weight are the most important features, this information for various camcorders in the market can be gleaned and parsed in order to compare them.

The encoding difficulty of the task is *low to medium* since most information except for customer reviews is available in a form that supports encoding.

4.1.3. Broader applicability

Once a product choice task has been accomplished, the sensemaker should be equipped with knowledge that can be used to answer many other questions. What are the latest features in the product? Which brands have high reliability? What are the best sellers to buy from? What are some of the other user profiles? This happens because the information gathered and organized in the recommendation task includes information related to the above questions. The broader applicability of the task can be assessed by asking the sensemakers such questions.

4.1.4. Representation search space

A product like camcorders has many features and attributes that can have many values. This can result in a big representation search space in the task since the participants must decide what camcorder brands to look for, which features to pay attention to, which features are related, which camcorders have which features and which sellers are reliable. The evaluation of the representation is also not straightforward. The sensemakers need to ascertain how much relative weight should be placed on the individual features depending on the user needs. The representation search difficulty is not exacerbated since the situation in the task is not very dynamic. Since product models and specifications only change every few months, someone working on the task for a few hours will not experience considerable flux in models, features and selling prices. The representation search space is *medium difficult* due to the large size of the representation space and the difficulty in evaluation of representations.

4.1.5. Subtask interdependence

There are many possible strategies or steps that can be used to accomplish the task. One series of subtasks could be:

- Learn about important product features
- Find out which features are relevant for the profile
- Find out which brands are reliable
- Find out which camcorders have the needed features
- Read reviews of the product at seller sites
- Find the place that has the best deal on the product and
- Establish if the seller is reliable.

These tasks need to be accomplished in a loose order and a few of them need to be worked on simultaneously. For example learning about features and learning about what features are appropriate for the profile need to be done simultaneously. Most of these steps might not need very close coupling but still cannot be accomplished in isolation. For example finding the best deal needs to be followed by a check regarding seller reliability for each product and a sensemaker may need to go back and forth between these two tasks. With just a few subtasks being simultaneous and closely coupled, the subtask interdependence of this task can be considered *low to medium.*

In summary, the task has both significant structure creation and complexity which imply that sensemaking needs to be accomplished. The structure creation aspect comes from the high representation novelty requirement even though encoding is easy and the created representations also have broader applicability. The complexity comes from the difficulty

of the representation search space even though the subtask interdependence is not very high (table 4.1). The unfamiliarity with the product in question is the biggest driver of sensemaking here. In contrast the helpdesks discussed in the last chapter had a lower representation novelty requirement but higher encoding difficulty which was the main driver of sensemaking in most helpdesk cases.

Representation Novelty Required	Encoding Difficulty	Broader Applicability	Representation Search	Subtask Interdependence
High	Low to medium	High	Medium	Low to medium

Table 4.1 Summary of attributes for camcorder task

4.2 Experiment Details

4.2.1 Task Details

As mentioned before, the participants were presented a scenario where they had to search online and recommend a camcorder to be used by a friend's father. This indirect task, recommending for a friend's father, was used in part to standardize the task scenario, but also, importantly, to encourage the participants to externalize both their work and the rationale for their final choice. Time allowed for the task was one hour, after which participants had to make their final decision.

At the end, the participants individually answered a questionnaire about their search process and their acquired knowledge of camcorders. The questionnaire had three main sections. The first section dealt with demographic and background information. The second section was composed of questions related to camcorders. The purpose of these questions was to gauge the increase in the participants' understanding of camcorders and the subsequent broader applicability of their understanding. For every question they

indicated whether they knew the answer before the online-search. The last section was related to participants' self-evaluation of their effort, the process of collaboration and feedback regarding their partners or sensemaking material that they received.

In order to enable their friend to understand their choice, the participants were told to document their search. The information they collected about camcorders was to be saved in a way that would be usable by their friend later. They were told to bookmark all of the important pages that they visited. They were also asked to organize their bookmarks into appropriate categories or folders. They were provided paper/pen and a word processor (MSWord) so that they could make additional notes during the task to supplement the bookmarks.

4.2.2 Equipment

Subjects used two identical Dell D800 1.6GHz notebook-computers running Windows XP, with attached mice. The computers had 15.4 inch diagonal displays (1900x1200 pixels) and 11Mb wireless internet connections. Subjects had access to a word processor (MSWord), an internet browser (Internet Explorer) and scratch paper to make notes.

4.3 Experiment 1 on Handoff Effectiveness

The first experiment used a between-subject manipulation to evaluate if sensemaking handoff material can be useful even when common ground, awareness information and additional communication are absent.

4.3.1 Participants

A total of 30 participants were recruited through email sent to students at the University of Michigan. Sixty eight percent of the participants had technical educational

backgrounds (engineering, cognitive science, information, economics and management) and thirty-two percent had non-technical educational backgrounds (education, arts, planning, languages and humanities). Only people who had never bought a camcorder and had never searched online for one were asked to participate. Of the 30 total participants, 16 were male and 14 were female. The average age was 26 years with a range from 19 to 39. All but two participants had completed their bachelor's degrees and all participants had shopped online at one time or another.

4.3.2 Experimental Conditions and Groups

There were three experimental conditions, all of which involved the same camcorder task. Thirty participants were randomly assigned to the three conditions:

Control group. In this condition, participants (N=10) completed the camcorder recommendation task alone.

Hand-Off Collaboration. In this condition, the participants (N=10) were provided a set of bookmarks, in the form of an "exported webpage," and accompanying notes made by a randomly chosen previous participant from the control group. They were informed that they could use the provided bookmarks and notes to aid themselves in the task if they wanted to, but they still had to create their own, separate collection of notes and bookmarks.

Synchronous Collaboration. In this condition, two people completed the task side by side on separate computers. Thus the participants (N=10) worked in 5 pairs. During the task they could collaborate by exchanging notes and links verbally or via chat. They were informed that they could help each other in any way they wished, but had to create their

own, separate collections of notes and bookmarks. They were also told that they were not required to agree on their final choices.

It was expected that synchronous collaboration would perform the best since the collaboration mode allowed double the 'work hours'. It was expected that the handoff condition would perform better than the control group but not better than the synchronous group because handoff participants had no access to additional communication with the providers. It was expected that the handoff group would do better than the control group because they had access to representations created by earlier sensemakers to guide their sensemaking.

4.3.3 Results

Performance

The basic dependent measure used here was the quality of the final recommendation chosen by the participants. Two independent experts made a list of camcorder criteria reflecting the profile of the hypothetical user and budget. The experts generated 22 and 29 important features respectively, out of which 20 were common. Every camcorder could either score low (1 point), medium (2 points) or high (3 points) on each of these features. Experts also gave the features an importance weight from 1 to 10. The correlation of the weights between the experts was 0.6. Of the 29 total features generated, 2 were not found in any of the camcorders selected by participants. Since they would be irrelevant to scoring, they were dropped. All 27 remaining features were used, and given either the average weight if mentioned by both experts or the corresponding individual weight if mentioned by only one. These weighted components were added up to create an

overall Choice Quality score (CQscore). The 18 different camcorders chosen by the 30 participants in the study ranged in CQscore from 188 to 255.

The subjects' final camcorder choices were analyzed to see if collaboration had an impact on quality, as indicated by the CQscore. Mean CQscores were calculated for all three groups and t-tests were performed to determine if differences in means were significant. The data are displayed in Table 4.2 below.

Group/ Condition	Mean (Std.Err)
Group I (Control)	214.9 (5.82)
Group II (Hand-Off)	235.1* (5.65)
Group III (Synchronous)	232.8* (4.55)

* differs from Group I (Control) at the $p<.02$ level of confidence

Table 4.2 Mean Choice Quality Scores in the three conditions.

The mean CQscores in collaboration groups II (Handoff) and III (synchronous) were significantly higher than the control group, with $p<0.011$ and $p<0.013$ (one tailed t), respectively. There was no statistically significant difference in CQscores between the handoff and synchronous groups ($p>0.75$).

Group/Condition	Mean (Std.Err)
Group I (Control)	5.9 (1.63)
Group II (Asynchronous)	4.3 (1.02)
Group III (Synchronous)	5.7 (1.45)

(No pair-wise differences statistically significant.)

Table 4.3 Mean Learning Scores in three conditions.

The other basic dependent measure was the participant's score on the post-session knowledge questionnaire, interpreted with subjects' self-report. The participants were given a point for each correct answer, provided they indicated that they did not know the answer from prior knowledge. Overall, the learning scores ranged from 0 to 17 with a mean of 5.3 (S.D. = 4.3). Mean learning scores were calculated for all three groups and t-tests were performed to determine if differences in means were significant. The data are displayed in Table 4.3. Although in the post-experiment questionnaire all groups asserted learning various facts from the exercise, there was no differential effect of condition: the mean scores in groups I, II and III were not significantly different at the 0.05 level.

Other findings

The subjects' behavior and attitudes showed that the predecessor's bookmarks actually helped the recipients. In the Hand-Off collaboration condition, 80% of the participants indeed used the stranger's bookmarks, visiting 32% of them on average (SE=10%). The subjects generally rated the bookmarks as quite understandable (average 4.25 on a scale of 5, SE=0.31), and those who considered the bookmarks more useful, visited a higher percent of them ($r=0.93$, $p<0.002$) and expressed a lower need for more time ($r=-0.9$, $p<0.014$). Although the Handoff Collaboration helped, the specifics of the performance of the two collaborators (the subject creating the bookmarks and the subject receiving the hand-off) were not strongly linked: The final CQscores between the two were not significantly correlated ($r=0.33$, $p>0.35$), and none of the subjects made the same choice of camcorder as their predecessor. In Synchronous collaboration condition, there was a stronger linking of performance: there was a significant correlation ($r=0.66$, $p<0.038$) between the CQscores of the participant and their partners.

4.3.4 Discussion

The results showed that performance was better in an information gathering and sensemaking task when collaboration was involved. In contrast with the helpdesk referral cases, the non-directed handoffs here were lacking many of the crucial collaboration elements. Since the providers did not know the recipients and were just told a subsequent person might use their bookmarks, the intent to collaborate could not have been high and certainly much lower than the helpdesk cases. Many of the participants were graduate students in the university and thus may have some common ground. However they were strangers and with varying backgrounds which suggests that common ground was much lower when compared to the helpdesk scenario. There was no option of additional communication and spatial or other awareness in the laboratory setup of the handoff condition. The only element present was the handoff material.

Despite these collaboration handicaps, the outcome of handoff sensemaking as measured by the choice task was significantly better than the individual effort. In fact, at least for this task, it was comparable to the synchronous sensemaking. One possible reason why the handoff material was useful for the recipients was because the material was the outcome of a nearly complete sensemaking effort by the provider. Most recipients also rated the provided bookmarks as good quality. Thus the result of the recipients' work was due to two person-hours, something that can also explain why synchronous collaboration was better. Note that this is non-trivial – if handoff were worthless, the first person's effort would have been wasted, and the two person-hours would have been only as good as one. This finding is encouraging for handoffs since it suggests that a handoff at least

from a nearly completed sensemaking work can be nearly as helpful as having another collaborator.

Another interesting observation was that participants in the hand-off condition sometimes did not seem to start with the provided bookmarks, rather they started on their own and came back to the bookmarks they were handed after a few searches. There could be several reasons for this. One of the more intriguing reasons is that perhaps they were not "ready" to use them. Perhaps they needed to explore a bit themselves before they could know how to interpret the provided material or assess its value. This possible reluctance to start with and completely depend on the handoff material might also have contributed to the fact that participant pairs in the handoff condition had different recommendations. This finding reinforces the earlier suggestion in chapter 2 and 3 that handoffs can be helpful in overcoming representational inertia and confirmation biases in sensemaking. However since the above finding regarding the pattern of usage of handoff materials was just an informal observation by the experimenter, another study was conducted to allow close observation of material usage pattern.

4.4 Experiment 2 on Handoff Material Quality and Use

In the helpdesk study (chapter 3) many participants reported that they started over again rather than relying on the handoff material. This could have happened because the handoff material was from incomplete sensemaking and did not provide good representations to the recipient. In the last study it was also observed that many participants started with their own work. These findings raise interesting and important questions about the patterns of usage of handoff material. Does the quality affect when

and how a material is used? While the first lab study shows that handoff material can be useful, does the quality affect what the material is useful for?

The issue of the effect of quality on the use of handoff material by recipients was further explored in the lab in the second study described here. In many ways, the second study was an open-ended exploration to see what was going on in detail with handoffs in sensemaking and the focus was not on collecting and comparing performances of many subjects as in the first study. To see how the Russell et al. model fit in the second participants' use of the bookmarks, detailed minute-by-minute observational data on users' behavior was collected. The second study also tried to find how the pattern of handoff material use might differ as a function of the quality of the material.

As mentioned before, one of the goals of this research is to investigate the use of information systems to share sensemaking work. The sensemaking work shared by people might also vary in quality and it is useful to investigate how differently the work with varying quality will be used by subsequent sensemakers.

4.4.1 Participants

A total of eight participants were recruited through email sent to students at the University of Michigan. Five participants had technical (Information, human computer interaction) and 3 had non-technical educational backgrounds (languages, political science). Of the 8 total participants, there were equal numbers of males and females. The average age was 27 years with a range from 22 to 51. All but 3 participants had completed their bachelor's degrees and all participants had shopped online at one time or another.

The low number of participants cannot give statistical power for between subject comparisons but it allowed for detailed and minute by minute activity of the sensemakers post handoff, the study can suggest rich insights into handoff material usage and can guide further large-scale studies.

4.4.2 Experimental conditions

The participants performed the same camcorder recommendation task used in the first study (handoff condition) with two exceptions. First, while some of the subjects in the previous study had gotten notes as well as bookmarks (depending on whether their randomly chosen "provider" generated notes); in this study we used material from people in the first study who had in fact not generated notes – only bookmarks. That is, only bookmarks were handed-off to the current subjects. Second, to simplify the task and focus on the role of the bookmarks in their sensemaking, the current subjects were not required to make bookmarks or notes of their own; they just had to come up with a recommendation for a camcorder for the profile (friend's father).

Each minute while performing the task, the subject's behavior was assigned two codes by the experimenter sitting with the subject, one for their activity (G=looking at general information, M=looking at specific models, S=selecting a model), and one for the type of website they were looking at (Handed-off Bookmark, Buying Guide, Seller Website, Review site).

Participants were randomly assigned to two conditions, each performing the same camcorder task, but differing in the quality of the bookmarks provided.

1. *High Quality Bookmarks*. A single set of bookmarks was chosen from those generated in the previous study that had been given very high ratings by earlier

users. (Understandable=5/5, Useful=4/4, Better than own=4/4. An independent domain expert also gave this set of bookmarks a 5/5 rating for overall helpfulness). On inspection, these bookmarks appeared systematically organized (two levels), both the links and their groupings were well labeled, there were several general links, and the groupings appeared in a coherent order.

2. *Low Quality Bookmarks*. A set of bookmarks was selected that had a comparable number of links to the High Quality set, but had low ratings from subjects in the first study, was not organized into groups, and was not carefully labeled. (The independent judge gave these a 3 rating on overall helpfulness.)

After completing the task the participants were asked a series of questions about their usage of the provided bookmarks.

4.4.3 Analysis and Results

The time stamps of various webpage visits were normalized to a [0, 1] range, by dividing by the subject's overall time. These normalized timestamps tell what proportion of the way through each subject's session the sample of activity occurred. The mean timestamps for the two groups were then compared using 't-tests'. It must be noted that the small number of participants means that any statistical significance of differences between the two conditions are suggestive at best. This is because the study utilized a between subjects design which inherently confounds treatment effects with subject effects that can only be untangled with a larger number of participants. Thus any statistical differences noted between the high and low quality groups could be a result of individual differences not related to the treatment variable in the study (quality). The original purpose of the

study was to get a qualitative feel for the minute-to-minute details of the sensemaking activities, and look for any suggestive indications of treatment effects that would be encouraging for further large-scale experiments to examine more sensitively the impact of quality on artifact usage.

The mean timestamps of these three categories of activity are in Table 4.4. Subjects overall spent about 10% of their time using the provided bookmarks. This did not vary significantly between groups or between individual subjects. The overall use of the bookmarks was sporadic, spread throughout much of the session, though on average they tended to be consulted a bit earlier than other websites: the mean normalized timestamp for consulting bookmarked sites was 0.404 compared to 0.522 for other sites (significantly different, $p<0.027$).

There was no significant difference in the Choice Quality score as a function of the quality of the bookmarks handed-off, but there was a significant difference in the way the High and Low Quality bookmarks were used. Links in the high quality bookmarks were followed early and those in the low quality ones followed late.

	High Quality BMs	**Low Quality BMs**	**Signif.**
Mean Norm. Timestamp	0.277	0.567	p = 0.0055
Time to First Look	1.25 min	2.5 min	n.s.
Time from First Look to First Use	0 min	8 min	trend: p = 0.07
Time After Last Use	34 min	10 min	trend: p = 0.07

Table 4.4 Bookmark Quality and Use

This can be seen in several ways. For example, the mean normalized timestamp for bookmark use was considerably earlier for High Quality bookmarks (Table 4.4, row 1). Also, two trends in the data were relevant in an intriguing way. As one would hope, there was no significant difference (Table 4.4, row 2) between groups as to when they took their first look at the provided bookmarks. Only after that point could the bookmark quality make a difference. However, people who were handed-off high-quality bookmarks tended to use them right away (Table 4.4, row 3). Moreover, people with the good bookmarks used them and were done with it, whereas people with bad bookmarks still consulted them increasingly, up to the end. (Table 4.4, row 4). This is also illustrated in Figure 4.1 below, showing bookmark use in successive thirds of the subjects' session time. Use of High Quality bookmarks was all in the first two thirds, while Low Quality bookmarks were used more and more towards the end.

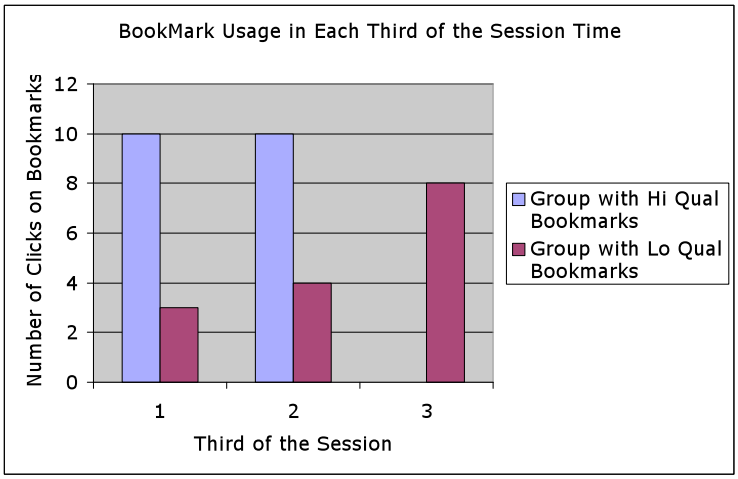


Figure 4.1 Bookmark usage in each third of the session time for the high and low quality bookmark groups. ($\chi^2(2)=13.91$, $p<.001$).

4.4.4 Discussion

Examination of the data led to an interesting pattern of bookmark use which can be summarized thus: everyone looked early, then those with High Quality bookmarks used and finished with them, but those with Low Quality bookmarks, while ultimately using them just as much, waited until nearer the end of their time.

According to the Russell et al model, sensemaking involves two major subtasks: (1) coming up with a good representation or framework for the information to be used in a task, and (2) encoding instances of that representation based on particular data in the world. If a person is working entirely alone, they must produce their own representation, by deducing from their own background knowledge and inducing from instances in the context of the task. If the person has access to the results of professionals who have made sense of things and authored guides, the person can get some help coming up with a good representation from them. Presumably this is why in the data analysis it was found that the sites consulted early tended to be general overview sites as well. If there is output from some relevant amateur efforts that can be handed off, these too can provide guidance for finding a good representation if they are of sufficient representational quality. The High Quality bookmarks in this study were presumably valuable in this way: they clustered the bookmarks sensibly for the task, named both the bookmarks and the clusters well and even presented the clusters in an order that made sense for the task (General, Models and Sellers). Furthermore, having the links clustered accordingly, those links could be used systematically in gathering information to be encoded. For these reasons, the good bookmarks were immediately useful, were followed quickly, and used fully. Later work just carried on where these left off.

In contrast, the low quality bookmarks had no such valuable structure. Subjects in that condition were left much more on their own to come up with a representation by a combination of induction from instances and any hints the subjects might find on the web for general issues to consider. Only after they had done so were the Low Quality bookmarks helpful. Even then, after the subjects had a representation of their own, without clustering and good labeling in the provided bookmarks, it was not clear which links would be useful for providing information relevant to what topics in the subjects' personally created representations. Thus it was likely that the links were of most use in providing a check on their own work, regarding the adequacy of their representation, and completeness of coverage for encoding. In fact, two of the subjects finished in exactly this way, spending their final 5-10 minutes taking their most extensive look at the provided bookmarks just before making their decision. Apparently the quality of even the poorer bookmark set was adequate for this.

This study also points to the usefulness of detailed analysis of handoff material usage. The larger-scale study proposed in the next chapter will include this detailed analysis and will present an opportunity to substantiate the results of this study which were only suggestive due to the small number of participants.

4.5 Conclusion and Summary

The first study evaluating the usefulness of handoff materials showed that well made understandable handoff material by amateurs can be helpful in handoffs even in the absence of elements like common ground and additional communication. The second study is suggestive of the link between the usage of handoff material and the quality of materials. While low quality material is either ignored or only useful for some later

information gathering, and information gathering verification, the high quality material can be of help for both the representation and encoding/information-gathering parts of sensemaking.

Since the handoff was non-directed and between complete strangers the common ground and the communication was not as high as the helpdesk cases. But the other factors seem to have made up for this lack of common ground. Firstly, the task overlap was complete as people were working on the exact same task as their handoff provider. Secondly, the chance for setbacks due to premature handoffs where latent representations and progress is involved was lower since the handoff material was from nearly completed sensemaking. The providers had nearly worked the whole task through before handing off their material. This meant that the handed representations were quite complete and often a useful plug-in for the recipient.

It is interesting to question if these results would have been different if the handoff materials came from an early stage of provider's sensemaking but if the recipient had overall more time to make up for the early handoff. This question is explored in the next chapter.

Chapter 5

Laboratory Study of Sensemaking Progress and Use of Handoff Artifacts

The goal of the research presented in this chapter is to study how people utilize handoff artifacts of varying maturity as they progress through their own sensemaking. As mentioned in chapter 2, Russell et al's model of sensemaking (1997) usefully lists the various subprocesses involved in sensemaking like: processing the task requirements, searching for organizing schemes for information, collecting and organizing information into this scheme, modifying organization schemes when needed and using organized information to accomplish the task. While people have studied how people use various tools/support systems during sensemaking (for example Nelson et al, 2009; Qu, 2006; Pirolli and Card, 2005), empirical data on when people move between these various processes is lacking. How much has been accomplished in each of these stages can impact handoff of the task. For example, searching for an appropriate organizing scheme for information is a demanding task (Russell et al, 1997); if it is known that sufficient progress has been made by a sensemaker in this sub-process, it is more likely that a recipient will find the materials handed off by this sensemaker useful. To address this gap in our understanding of sensemaking and handoff artifact usage, the study presented in this chapter has the following two objectives:

1. *To study in detail how people engaged in sensemaking progress through various stages in their sensemaking (e.g. collecting information, organizing information) and how artifacts mature through various sensemaking stages.*
2. *To study how this progress affects subsequent handoffs and use of hand off artifacts by recipients in their own tasks*.

These objectives if fulfilled can help further our understanding of sensemaking handoffs in many ways. First, a better understanding of the relationship between sensemaking progress and the sensemaking artifact production can help in tracking progress in sensemaking and provide a means of measuring that progress. Second, the tracking of sensemaking progress over time can help validate and refine Russell et al's sensemaking model (1997) by informing us when various sub-processes take place. Third, how artifact maturity impacts its subsequent usage can help develop guidelines about when to handoff and what artifacts of varying maturity are useful for.

In this chapter the possible difference in early and late sensemaking stages are highlighted with special emphasis on artifact creation. This discussion also includes the relationship of sensemaking to sources of structure and handoff artifacts. In the second part of the chapter, a laboratory study of sensemaking progress and artifact usage is presented along with findings and conclusions from the study.

5.1 Sensemaking stages and artifact creation

We start by examining possible events in the early stage of sensemaking. In the Russell et al model, sensemaking starts with the search for a good representation. Depending on whether good representations are easily available or not, people may be engaged in different activities at various stages of their sensemaking. In case good representations

are available from prior knowledge or through other sources like the worldwide web (hereafter structure available from past experience and from websites online is referred to as "easily available structure"), the sensemaker may start by finding a good representation, appropriating it and start encoding. If a good representation is not readily available externally for adoption, representation must be created either from existing knowledge or built from the bottom up from the information collected (Qu & Furnas, 2005). The sensemaker may start with a rudimentary representation from past experience and modify it depending on the information found early on. In this case while some encoding may be attempted early on (using information found while searching for a representation), steady encoding and modification of the representation is expected to happen later.

The later stages as per the Russell et al model should involve encoding and representation modification. However, in a particularly novel situation where structure is not available online and there is not much past experience to draw on- it is possible that search for a representation may be ongoing. Thus after a fixed amount of time sensemaking activities may differ depending on the availability of structure (including handoff structure and external structure) as well as prior knowledge of the sensemakers.

These differences in sensemaking activities have an impact on and can be studied through the sensemaking artifact being created. Representation construction can be observed when existing information is grouped or when organization categories are created. When structure is appropriated early on, the artifact should exhibit the addition of considerable organizing elements over a short period. When a representation is being created from past experience the artifact should exhibit the addition of a few organizing element or themes

early on and then other elements would be added over a prolonged period. A bottom up construction of representation should show up in the artifact as additions of disjointed pieces of information. The encoding process should also be visible in the artifact with information elements being placed within the existing organizing themes. During representation modifications we should notice renaming or reordering of organization elements as well as reallocation of information elements to a different organizational element.

Thus we can make some simple and basic predictions regarding artifacts in various stages, depending on the availability of structure elsewhere. When structure is easily available elsewhere even early versions of the artifact may have organizational elements and some encoded information while later version may have even more organizational elements and considerable information elements encoded. When external structure is unavailable, at early stages the artifact may have a few organizational elements accompanied by some information elements while materials from later stage are expected to have well-established organizational elements as well as some information encoded. These differences may impact subsequent use of the artifact by a handoff recipient and this aspect of handoff artifact usage is discussed next.

5.2 Sensemaking stages and handoff artifact use

If the handoff artifact has different elements depending on when and under what conditions it was made, it is expected that the handoff recipients will use the artifact differently. Artifacts that have well articulated structure as well as encoded information are expected to be most useful to the recipient especially when other structure is hard to

come by. In contrast, artifacts lacking organizational themes will require the recipients to develop their own themes and these handoff-artifacts might be less useful.

5.3 Laboratory Study on Artifact Usage

This study focused on the nature of handoff artifacts and their subsequent use by recipients. Using a sensemaking task, an in-laboratory experiment was conducted to track sensemaking progress and artifact creation in two conditions: one where structure was readily available (on the web, or from prior knowledge) and the second when a good representation was not readily available. Then either early or late versions of the artifacts created by the participants were presented as handoff materials to another set of participants working on the same task. The study then tracked the progress of the recipients and their use of the handoff artifact.

Unlike the lab study presented earlier in section 4.3 where the focus was on measuring performance in a sensemaking task, here the focus was on tracking sensemaking behavior with particular attention to behavior related to external artifact creation and use. The focus on sensemaking behavior rather than the final outcome allowed the microanalysis of sensemaking activities. Even though activities relating to external artifacts creation and usage are just a small part of overall sensemaking activities, external artifacts offered a way to track sensemaking behavior over the period of the task.

5.3.1 Research Questions

The goal of the study was to answer the following questions:

1. **When do the various sensemaking sub-processes occur?** The Russell et al model predicts representation adoption followed by encoding and representation modification. The study aims to validate the sequence empirically. The study also

has the goal to assess the differences in structural and information content of the artifacts in early and late stages.

2. **How does the presence of easily available structure affect sensemaking sub-processes?** Qu & Furnas (2005) examined how the availability of external sources of structure affects representation construction. This study will validate the results of that research while extending the findings to the relationship between structure and all sub-processes of sensemaking.

3. **How do handoff recipients use early and late versions of artifacts?** The study aims to compare differences between the use of artifacts from early and late stages of sensemaking throughout the sensemaking session of the recipient. If it is found that early and late stage artifacts have different degrees of structure and information (see 1 above), then the study can help to illuminate how both structured and unstructured information from the provider is used by a receiver.

4. **How does handoff artifact use differ based on the availability of structure in other places?** Sources of structure can be used to appropriate a good representation for sensemaking. This study will also examine how and to what extent artifacts are used when structure is easily available (through past-experience or online) and when structure is not easily available elsewhere.

5.3.2 Sensemaking Task

The sensemaking task used in the study was the task of preparing to give a talk on an unfamiliar topic. This kind of "topic-comprehension" task can involve considerable sensemaking and has been used by others in the past to study sensemaking [Qu & Furnas, 2005]. The participants will be asked to prepare a talk using online resources on one of

the two topics that have been identified for use in the study. The first is "tea" and the second is "drinks for the elderly". These topics were used by Qu & Furnas (2005) to study representation construction in sensemaking. Details of the task including instructions can be seen in Appendices F and G.

The talk topics have been chosen because while the topics are somewhat similar (both relate to drinks) they are different in a useful way. "Tea" is a well-established topic so participants might have prior knowledge as well as good structured information available online. "Drinks for the elderly" is a topic that has very little structured information available online. This difference in availability of "structure" allows us to study it as a variable. The distinctions between the two tasks have been discussed by Qu & Furnas (2005). For a detailed analysis of the performance of the tasks with regards to sensemaking attributes presented in chapter 2, see Appendix I. The analysis also highlights that the "drinks for the elderly" task (hereafter referred to as the no-structure or 'drinks' task) task has a higher novelty requirement than the "tea" task (hereafter also referred to as the structure task).

As the participants worked on their task they were asked to prepare an outline for the task and bookmark useful information. The outline and notes were created in MS word while bookmarks were created in the web-browser (Firefox 3.0). The participants had 50 minutes (t) to complete this task. During this time their activities and 'think aloud' (Ericsson & Simon, 1980) comments were recorded using a screen capture program (MORAE). MORAE[2] allowed keystrokes and mouse events to be recorded along with synchronized screen images and microphone input with a resolution of 10 milliseconds.

[2] http://www.techsmith.com/morae.asp

5.3.3 Participants and Equipment

The participants (n=60) were recruited from the students of the University of Michigan. All participants had knowledge regarding the use of online resources. The participants were between 19 and 44 years of age (median= 23 years). They came from a variety of education backgrounds ranging from chemical engineering to English literature. In order to secure participation, a subject-fee of $20 was provided. In order to motivate participants to do well in the task a bonus of $10 was promised to the top 10 percent of the subjects as judged by the quality of their outline by a subject expert. People with professional background or training in reference library work were excluded from the study. This was done because the study wanted to focus on amateurs who have search experience but are not search experts. All the participants had high or native English fluency.

Equipment consisted of desktop PCs with 2.66 GHz Intel Core2 Duo CPU and 3 GB RAM. The configuration included a monitor with 17-inch LCD flat screen and a keyboard and mouse. The participants used a web-browser (Firefox 3.0) to research the topic and create bookmarks and a single MS Word 2008 document to create the outline and notes. MORAE screen capture ran in the background and was also used to conduct a post-task questionnaire that requested feedback on artifact material quality and requested biographical information (see details in Appendix J).

5.3.4 Experiment Conditions

The experiment was conducted in two parts, the ‘provider’ part and the ‘recipient’ part. Participants in both parts of the experiment were assigned either the ‘tea’ or the ‘elderly drink’ task. So half the participants worked on the ‘tea’ talk task and half worked on the

'drinks for elderly' task. The details of participant counts can be seen in table 5.1.

Progress in sensemaking and the accompanying artifacts were examined at two stages during the Provider part of the experiment. The Early Stage was after 10 minutes of work (t/5) and the Later Stage was after 50 minutes (t).

Participants in the recipient part (part two) were provided handoff artifacts including a talk outline, notes and bookmarks from a participant in part one of the experiment who had worked on the same task. The outline and notes document was made available and the accompanying bookmarks were imported into the browser. The part two participants were assigned to either early or late version groups. Half the participants got the early version (at 10 minutes or t/5) of artifacts from a random participant in part one and other half got a later version of artifacts (from 50 minutes or t).

Task	**Part 1: No-handoff (Providers)**	**Part 2: Handoff (Recipients)**	
		Early Artifacts	**Late Artifacts**
Structure (Tea)	10	10	10
No- structure (Drinks for elderly)	10	10	10

Table 5.1 Conditions and Participant Counts (Total = 60)

The early and late version artifacts were used as an approximate measure of the maturity of the sensemaking and the resulting artifacts. This was based on the assumption that the longer that someone worked on it, the more mature his or her representation would be. Time was a straightforward variable that was easy to operationalize.

The early time (10 minutes or t/5) was chosen after an examination of the progress of participants in Part 1 of the experiment. In Part 1, most participants (84%) had added

their first set of outline elements (sections, encodings, information elements) in quick succession (with less than two minutes between them). Since we are interested in how early externalizations of structure affect subsequent sensemaking as compared to late externalizations the time was picked after some externalization was accomplished. These elements were possibly based either on prior knowledge or easily found structure and information from external sources. However, since prior knowledge regarding the topics varied between the participants the number of elements varied as well.

Individual progress did vary with some outliers who added either too little or too many sections at the above times. In both early and late version, those artifacts with number of sections more than two standard deviations away from the respective mean were excluded (n=2) from the pool of artifacts to be handed off in the second part of the study.

5.3.5 Data Collection and Coding

Information gathering as well as artifact creation/use activities of the participants were tracked to enable a microanalysis of sensemaking behavior. The MORAE recordings were used to track and code for counts of various activities of the sensemakers for each minute of the session. These tracked activities were a subset of overall sensemaking activities. Other activities like creation and manipulation of internal-representations were not tracked. The sub-processes listed in the Russell et al model (1993) were used to decide which activities to track and code for. To operationalize various sub-processes of sensemaking, including those delineated in the Russell et al model, the following *sensemaking activities* were coded for all the subjects:

- **Representation Generation:** In this activity delineated by Russell et al (1993), the sensemaker creates a representation. In the current task this activity was

operationalized in two ways:

- **Creating folders in bookmarks ('folder'):** The time of adding a folder in the bookmarks was captured and counts were created for the number of folders created for each minute of the session. Here sensemakers are adding structure to their collected information and thus building a representation.
- **Adding sections in their outline ('section'):** The time of adding a new section or a subsection in the outline was captured and counts were created for the number of sections created for each minute of the session. Here also the sensemakers are adding structure to their collected information and thus building a representation. Section creation was coded when text was added to create a talk organization theme rather than the addition of a fact in support of an existing section. An example was 'history of tea'.

☐ **Data Coverage:** This activity involves identifying information and organizing it into a representation (Russell et al, 1993). There were two parts to this activity: finding/identifying relevant information (operationalized as querying below) and adding the information. If the information found cannot be organized into an existing representation it may be just added (operationalized below as adding bookmarks and adding information into outline). If the information found can be organized into the current representation we can consider it "encoded".

- **Querying ('Q'):** Query counts were done for all queries in search engines as well as queries in websites and databases. Queries within pages were not counted. Queries meant to reach a determined destination website were also not counted (e.g. Google search for 'wikipedia'). Counts were used to code the

number of queries for each minute of the session. Search can occur in at least two places in the Russell et al model. First, when people 'search for a good representation' and second when people 'instantiate the representation' by encoding data into the representation. Since it is difficult to ascertain whether participants were searching for structure or just information all queries were coded and hence include both kind of queries.

- **Adding bookmarks ('BM-add'):** The time of bookmarking a webpage was captured and counts were created for the number of bookmarks created for each minute of the session. Here sensemakers are collecting information that is intended for encoding into the representation.
- **Adding information ('info-add'):** Counts of when people added facts to the outline or notes, putting them at the top-level of the outline without organizing them into existing sections were used to code for count totals for every minute of the section. An example of this activity was someone copying and pasting a fact into the notes (rather than in an outline section).
- **Encoding ('enc'):** The time of adding a piece of information or a fact to an existing section or a sub-section in the outline was captured and counts were created for each minute of the section. Encoding additions were different from section additions as the encoding additions were facts in support of a section or a sub-section. Encoding was also different from 'adding information' since encoding was an addition into an existing section rather than adding freestanding facts.

☐ **Representation Shifting:** To reduce the costs of various operations in

sensemaking, the sensemaker may need to "shift representations" (Russell et al, 1993). This process was operationalized for both bookmarks and the outlines:

- **Reorganizing bookmarks ('folder-mod'):** The time of moving bookmarks to an existing folder was captured and counts were created for the modifications to structure for each minute of the session. Renaming a folder was also considered a modification event. Here sensemakers are modifying structure that composes their representation.
- **Reorganizing outline ('section-mod'):** The times of moving pieces of information or sub-sections in the outline to another section were captured and counts were created for the modifications to structure for each minute of the session. Renaming a section was also considered a modification event. Here also the sensemakers are modifying structure that composes their representation.

Besides the above coding categories that were used in both parts of the experiment, some additional categories were coded for part two of the experiment (handoff recipient part) and were primarily concerned with the handoff artifact use. We wanted to track not just usage but various levels of engagement with the artifact: when recipients showed interest in the artifacts (bookmarks and outlines) as well as when the recipients used or incorporated the provided artifacts into their own artifacts. The following **artifact-use activities** were coded:

- **Bookmark perusal ('BM-look'):** Bookmarks were imported and kept in a folder labeled 'provided bookmarks'. The first time when a recipient looked at the contents of the folder was noted.

- **Bookmark click ('BM-use'):** The time of clicking any one of the provided bookmarks were also noted and counts created for each minute of the session.
- **Outline perusal ('OL-look'):** The outline was provided to recipients as a word document using the outliner tool. The provided outline was collapsed and the initial time of expanding the provided outline for perusal was noted.
- **Outline appropriation ('OL-use'):** The time when either parts of the provided outline were incorporated into their own outline was also noted. Incorporation was done either by copying/moving parts of the provided outline to merge with their new outline or by making the provided outline the primary outline and making changes to it.

Coding was done during the sessions as well as later looking at created outlines and data captured by MORAE that included screen-capture, web-history and audio comments from the user. It should be noted that coding criteria for some categories are objective and can be done from user logs. These categories included logged events and their times like: creating bookmark folders, querying, adding bookmarks, modifying bookmark folder, bookmarks, adding of outline elements (sections, encodings, information), modifying outline and using outlines. These categories were coded by the experimenter alone using browser event data. The criteria for whether an outline element was 'information', 'encoding' or a 'section' was subjective and relied on the coders understanding of the coding scheme. The experimenter coded these categories during the session, going to the session recording if needed. An additional person looked at the outlines later also coded for whether an outline element was 'information', 'encoding' or 'section'. The second

coder was trained using pilot data and then coded all the outlines. The inter-coder agreement for the coders was found to be Kappa = 0.79 ($p<0.001$), 95% CI (0.77, 0.81).

Additionally, information collected from post-experiment questionnaire (see Appendix J) was also analyzed. This information included demographic information as well as **artifact ratings** on a seven-point scale for the usefulness of the provided outline and the provided bookmarks as well as open-ended comments regarding these ratings.

- **Outline usefulness ('OL-rate'):** The participants rated the usefulness of the provided outline.
- **Bookmarks usefulness ('BM-rate'):** The participants rated the usefulness of the provided bookmarks.

5.3.6 Data manipulation and analysis

Figure 5.1 presents a snapshot of the data that was collected. For the part 1 group (no-handoff/providers), only *sensemaking activities* were coded. These activities included querying as well as *artifact creation activities* (bm-add, folder, folder-mod, info-add, enc, section, section-mod). *Artifact use activities* (bm-look, bm-use, ol-look, ol-use) were also coded for the part 2 group (handoff/recipients) in addition to sensemaking activities. Thus the activities were grouped into the following dependent variable groups:

- ☐ *Artifact Creation Activities*: bm-add, folder, folder-mod, info-add, enc, section, section-mod
- ☐ *Sensemaking Activities:* querying, artifact creation activities
- ☐ *Artifact use activities (part 2 participants only):* bm-look, bm-use, ol-look, ol-use

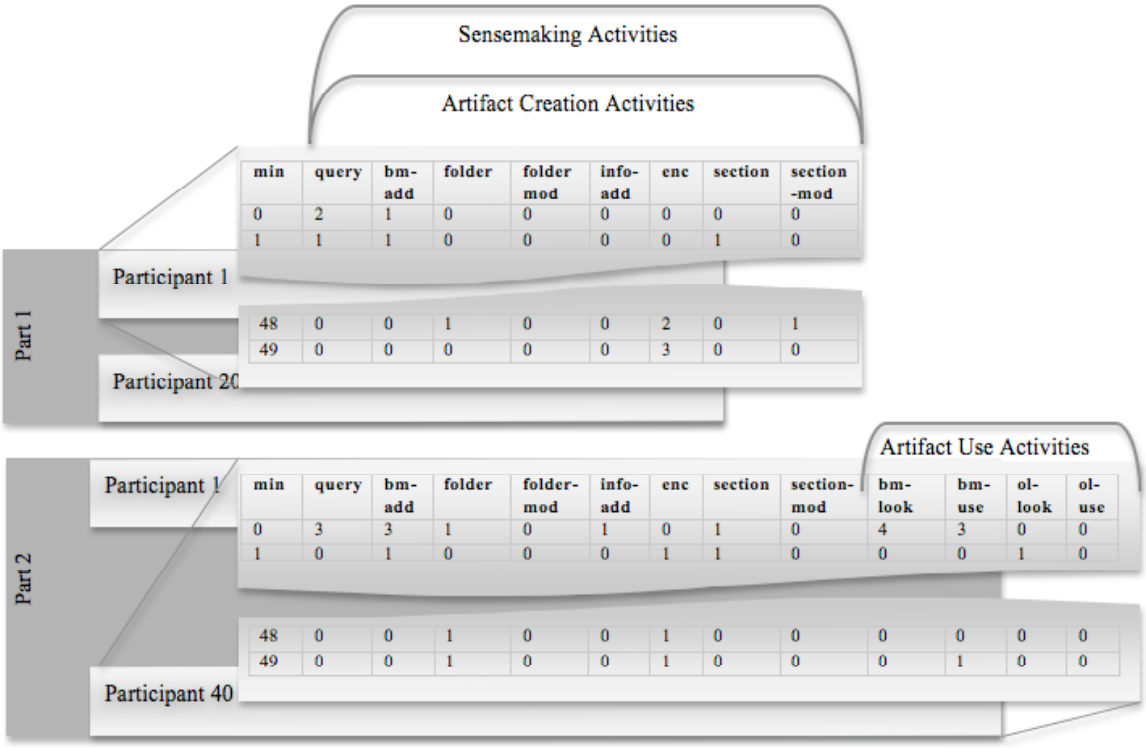


Figure 5.1 Snapshot of data with groups of dependent variables

The collected data was analyzed in two ways:

1. Counts, mean activity-times and ratings by participants: Total counts for each activity including artifact use as well as average time when a participant engaged in each activity was calculated. Means from the activity counts and times as well as artifact ratings were calculated for various conditions.
2. MANOVA analysis of minute-by-minute activities: MANOVA (Krzanowski, 1988) is a form of analysis used to identify if variation in an independent variable has significant effects on a set (more than one) of dependent variables. Three independent variables used in the MANOVA analysis corresponded to the conditions in the study (structure/no-structure, handoff/no-handoff, late-handoff/early-handoff). The two sets of dependent variables were: the various sensemaking activities of all the participants

engaged in (query, bookmark, folder, folder-modify, information, encode, section, section-modify) and the artifact use activities which participants in Part 2 of the study engaged in (bookmark-look, bookmark-use, outline-look, outline-use). Artifact use activities and sensemaking activities were analyzed separately because part 1 participants did not engage in artifact use activities (see Figure 5.1).

Independent variable	*Dependent variable(s)*	*Hypothesis*
Structure (Tea vs. Drink task)	Activities	1.1 Overall effect of task (MANOVA)
		1.2 More structure created in tea task (folders & sections)
		1.3 Structure (folders & sections) created earlier in tea task
		1.4 Encoding done earlier in tea task
		1.5 Modal activity in drink task is querying
	Artifact Use	1.6 Overall effect of task (MANOVA)
		1.7 More artifact use in drink task
		1.8 Artifacts used sooner in drink task
		1.9 Rated better in drink task
Handoff (Yes vs. No)	Activities	2.1 Overall effect of handoff (MANOVA)
		2.2 Encoding earlier when handoff artifacts received
Artifact maturity (Early vs. Late)	Artifact Creation Activities	3.1 More structure in later versions (folders & sections)
		3.2 More encoding in later versions
		3.3 Overall effect of handoff time (MANOVA)
		3.4 Encoding done earlier in late handoffs
	Artifact Use	3.5 Overall effect of handoff time (MANOVA)
		3.6 More artifact use in late handoffs
		3.7 Late versions are used earlier
		3.8 Rated higher in late handoffs

Table 5.2 Hypotheses.

5.3.7 Hypotheses

Three groups of hypotheses relating to the three independent variables were tested using the data collected in the study. The first group is about the effects of the amount of available structure (structure), the second group is about the effects of availability of

handoff artifacts (handoff) and the third group is about the effects of artifact maturity (artifact maturity). A snapshot of the hypotheses can be seen in Table 5.2. The hypotheses are further grouped (see Table 5.2 column 2) by the dependent variables (sensemaking activities and artifact use activities explained in section 5.3.6 above). It is worth noting that for the effect of availability of handoff artifacts, only sensemaking activities were evaluated because no handoff artifact usage occurred in the no-handoff condition. For the effect of artifact maturity, differences in content of early and late versions of artifacts created by the no-handoff participants were also analyzed (see hypotheses 3.1 and 3.2 in Table 5.2).

The hypotheses are based on the Russell et al model (1997), Qu and Furnas' (2005) work on sources of structure and studies presented earlier in this dissertation (chapters 3, 4). It should be noted that when a particular hypothesis mentions a coding category (e.g. 'artifact-use activity') all coding categories under it (e.g. BM-look, BM-use, Outline-look, Outline-read) would be applicable.

1. Effect of easily available structure

a. Sensemaking activities differ based on the presence of easily available structure. This hypothesis intends to replicate results from Qu & Furnas (2005). It is expected that sensemaking activities will differ based on the task (H2.1).

H1.1 Variance in Sensemaking activities can be accounted for by task. (MANOVA model should show significance).

Utilizing the same tasks as the ones used here, Qu & Furnas found external sources of structure like websites provided participants with representation ideas.

To be more specific, it is expected that when structure is readily available (tea) the participants would add more structure elements (sections, folders) to their artifacts (H2.2) and would do so sooner (H2.3).

H1.2 Structure-count $_{tea}$ > Structure-count $_{drinks}$

H1.3 Structure-mean time $_{tea}$ < Structure-mean time $_{drinks}$

This would also allow encoding to begin earlier when structure is easily available (H2.4).

H1.4 Encoding-mean time $_{tea}$ < Encoding-mean time $_{drinks}$

When structure is not easily available (drinks) the participants may add some representations from past experience and then construct representations from bottom up using querying. Querying is expected to be the predominant activity in drink task early on (H2.5).

H1.5 Modal activity-early $_{drink}$ = Q

b. **Post-handoff, artifact use activities differ based on the presence of easily available structure.** Handoff artifacts can be an additional source of representation as well as an information source for the recipients. However, their artifact use (BM-look, BM-use, Outline-look, Outline-use) is expected to differ based on how much structure is available from other sources like websites (H2.6). When structure is hard to find (drinks), handoff artifacts will serve as the predominant source of structure and information besides the participants' past experiences. Thus in more specific versions of H2.6: handoff-artifacts are expected to be used more (H2.7) and sooner (H2.8) during the generation loop

when easily available structure is missing. I expect artifacts to be rated (Outline-usefulness, BM-usefulness) more useful (H2.9) by recipients when other sources of structure are not easily available (drinks task).

H1.6 Variance in artifact-use activities can be accounted for by task. (MANOVA model should show significance).

H1.7 Artifact use-count $_{tea}$ < Artifact use-count $_{drinks}$

H1.8 Artifact mean use-time $_{tea}$ > Artifact mean use-time $_{drinks}$

H1.9 Artifact-ratings $_{tea}$ < Artifact-ratings $_{drinks}$

2. **Handoff artifact effects**

   a. **Handoff artifacts support structure creation and do not just provide information.** As mentioned before, handoff artifacts are expected to include both structure and information elements and the structure elements can help the representation generation loop of the recipient. It is expected that overall sensemaking activities of recipients will be different from providers (H3.1).

   H2.1 Sensemaking activities vary when handoff artifacts were provided (MANOVA model should show significance).

   More specifically, since artifacts are expected to boost representation generation, it is expected that encoding which follows generation will occur early in recipients on average (H3.2).

   H2.2 Encoding-time $_{recipients}$ < Encoding-time $_{providers}$

3. **Effect of handoff time (early and later artifacts)**

a. **Early versions have lesser structure.** According to the Russell et al model, sensemaking begins with the search for a good representation (generation loop). Qu and Furnas (2005) found that the generation loop can involve any of the following: Adopting an existing representation, building a representation from existing knowledge or building a representation bottom up from the information collected. We can assume that sensemakers use a combination of the above approaches. They may start with a few elements from past experience as well as some found ready-made elsewhere and then build the rest up. In most cases this would mean that sensemakers add some structure early on (from external sources and past experience) and the rest is added and refined later. The first hypothesis was trivial and a needed check for other hypotheses: that later versions of the artifacts would have more structure. This can be measured by comparing the number of structure elements (folders & sections):

   H3.1 Structure-count $_{early}$ < Structure-count $_{late}$

b. **Early versions have less encoded information. The** Russell et al model suggests once a representation has been generated sensemakers also begins 'data coverage' which includes collecting information and encoding it. It can be argued that data coverage and representation generation are intertwined since data coverage affects generation through representation shifts. However, since data coverage is usually guided by and followed by some rudimentary representation, it is expected to occur later than representation generation. Consequently it is expected that while early artifact versions will have some un-encoded information (info-add) that has been added but not organized, later versions of the artifact will have higher

quantity of encoded information (enc) that has been organized:

H3.2 Enc-count $_{\text{early version}}$ < Enc-count $_{\text{late version}}$

c. **Post-handoff, sensemaking activities differ whether artifacts were from early or late stage.** As per H1.1 mature/later versions of artifacts are expected to contain more structure and representation ideas than early versions. More representation ideas would imply an overall impact on sensemaking activities (H3.3).

   H3.3 Variance in Sensemaking activities can be accounted for by handoff-time (early vs late) (MANOVA model should show significance).

   More specifically, later versions of artifacts would be more helpful in the generation loop and enable quicker move to encoding (H3.4).

   H3.4 Encoding-time $_{\text{late-handoff}}$ < Encoding-time $_{\text{early-handoff}}$

d. **Post-handoff, artifact use activities differ based on artifact maturity.** Since handoff artifacts are expected to differ in their content (H1.1 and H1.2), they are also expected to be used differently (H3.5).

   H3.5 Artifact-use activities will differ depending on handoff time (early vs late) (MANOVA model should show significance).

   More specifically, later versions of the handoff-artifacts are expected to be used more (H3.6) and sooner (H3.7) during the generation loop since they are expected to have better representation ideas.

   H3.6 Artifact use-count $_{\text{early-handoff}}$ < Artifact use-count $_{\text{late-handoff}}$

   H3.7 Artifact use-time $_{\text{early-handoff}}$ > Artifact use-time $_{\text{late-handoff}}$

Later handoff artifacts are also expected to be rated more useful (H3.8) by recipients because of their presumed better structure and content.

H3.8 Artifact-ratings $_{\text{early-handoff}}$ < Artifact-ratings $_{\text{late-handoff}}$

Indep Variable	Dep Variables	Data Set	Call in R fit <-manova ()	Df	Pillai	approx F	num Df	den Df	Pr(>F)
Structure	Activities	All	yact~b$str	1	0.009	3.548	8	2991	0.000
	Artifact Use	Part 2	y2use~b.part2$str	1	0.005	2.315	4	1995	0.055
Handoff	Activities	All	yact~b$ho	1	0.035	13.405	8	2991	0.000
Artifact maturity	Activities	Part 2	y2act~b.part2$late	1	0.012	3.005	8	1991	0.002
	Artifact Use	Part 2	y2use~b.part2$late	1	0.007	3.601	4	1995	0.006

Table 5.3 MANOVA results.

5.3.8 Results

The collected data were analyzed to calculate mean activity counts and to calculate mean occurrence times for events. MANOVA analysis was done to analyze the effect of available structure, handoffs and artifact maturity on various activities. The details of the MANOVA analysis can be seen in table 5.3. The first column in table 5.3 lists the three independent variables. The second column lists the type of dependent variable that was used in the analysis. It is useful to note that for the effect of handoff, only sensemaking activities (see Figure 5.1) were analyzed. The third column lists the data set used for the analysis. It can be noted that for artifact use activities only part 2 data were used. The table also lists degrees of freedom and p-values for the analyses.

1. Effect of easily available structure

a. Sensemaking activities differ based on easy availability of structure.

Data from both Part 1 and Part 2 of the study were analyzed for the effect of task on activities. The results on this hypothesis were mixed.

H1.1 Variance in Sensemaking activities can be accounted for by task. – Confirmed

The most general hypothesis that sensemaking activities will differ based on the task confirmed the findings of Qu & Furnas (2005). MANOVA analysis showed that the task (tea vs. drink) significantly accounted for the variance in sensemaking activities ($p < 0.001$).

H1.2 Structure-count $_{tea}$ > Structure-count $_{drinks}$---Confirmed

The hypothesis regarding people in the tea task adding more structure elements was also confirmed. In the tea task 2.1 folders were created on average (SE=0.6), while in the drinks task 1 folder was created on average (SE=0.3) (differ at $p= 0.047$). More sections were also created in the tea task (mean=16.9, SE=1.7, $p< 0.004$) compared to the drinks task (mean=11.5, SE=1.5).

H1.3 Structure-mean occurrence $_{tea}$ < Structure-mean occurrence $_{drinks}$---Not Confirmed

This hypothesis was not confirmed. While folders were created earlier (trend, $p=0.1$) in the tea task (mean= 18.6 minute, SE=3.0) than in the drinks task (mean= 26.1 minutes, SE=5.2), there was no difference in the time of creation of sections.

H1.4 Encoding-mean time $_{tea}$ < Encoding-mean time $_{drinks}$—Not confirmed

This hypothesis was also not confirmed. No significant difference was observed in the tea (mean time=28.3 minutes, SE=1.6) and the drink task (mean time=26.5

minutes, SE=1.1).

H1.5 Modal activity-early $_{drink}$ = Q ---Somewhat Confirmed

The modal activity early (up to 10 minutes or t/5) in the drinks task was not querying, however the modal activity in the drinks task was web browsing and bookmarking (followed by adding sections). These activities often occurred as a result of querying. In contrast, the modal activity for the tea task was adding sections (followed by encoding).

b. Post-handoff, artifact use activities differ based on the presence of easily available structure.

Data from Part 2 of the study was used to evaluate the hypotheses in this group. The results regarding the effect of task on artifact use were mixed.

H1.6 Variance in artifact-use activities can be accounted for by task.--Confirmed

MANOVA analysis showed that the task (drinks vs. tea) accounted for the variance in artifact use activities. The result showed a strong trend ($p = 0.055$).

H1.7 Artifact use-count $_{tea}$ < Artifact use-count $_{drinks}$---Partly Confirmed

This hypothesis showed some positive evidence. People used more provided bookmarks in the drinks task (mean=6.1 bookmarks used, SE=1.2) as compared to the tea task (mean=2.8 bookmarks used (SE=1). The differences was significant at $p<0.001$. There was however no difference in the usage in outlines in the two different tasks, Eighty percent of participants in each task used the outline provided to them.

H1.8 Artifact use- time $_{tea}$ > Artifact use- time $_{drinks}$---Partly Confirmed

This hypothesis also had mixed evidence. While outlines in the drinks task were used earlier (mean usage time=6.7 minutes, SE=1.5) than in the tea task (mean usage time=11.6 minutes, SE=3.0), the results only showed a trend (p=0.076). There was no difference in the time of bookmark use.

H1.9 Artifact-ratings $_{tea}$ < Artifact-ratings $_{drinks}$—Not Confirmed

This hypothesis was not confirmed. There was no significant difference between ratings give to artifact received by people in the tea and drinks task.

2. Artifact effects

a. Handoff artifacts support structure creation and do not just provide information.

Sensemaking activities of Part 1 and Part 2 participants were compared to evaluate the hypotheses in this group. The results were mixed.

H2.1 Sensemaking activities vary when handoff artifacts were provided—Confirmed

MANOVA analysis showed that the presence of handoff accounted for the variance in sensemaking activities. The result was significant at $p < 0.001$.

H2.2 Encoding-time $_{recipients}$ < Encoding-time $_{providers}$—Not confirmed

This hypothesis was not confirmed. There was no difference in the encoding time between Part 1 and Part 2. Mean encoding time for Part 2-recipients was 26.7 minutes (SE=1.2) Mean encoding time for Part 1-providers was 28.9 minutes (SE=1.7) ns

3. Early and later artifacts

Data from participants in part 1 of the study was used to compare the late and early versions of their artifacts to check for differences in counts of elements in the bookmarks and the outline. Both the trivial hypothesis about early and later versions were confirmed.

a. Early versions have lesser structure.

H3.1 Structure-count $_{early}$ < Structure-count $_{late}$---Confirmed

Both folder counts and section counts were significantly higher at 10 minutes (t/5) than at finish time (t). Mean Folders count at t/5 was 0 (SE=0.22) while it was 2 (SE=0.76) at 50 minutes (differ at $p= 0.035$). Mean section count early was 6 (SE=0.82), while it was 19 (SE=2.3) at the end (differ at $p< 0.001$).

b. Early versions have less encoded information.

H3.2 Enc-count $_{early\ version}$ < Enc-count $_{late\ version}$---Confirmed

Mean number of encoding elements early was 3 (SE=0.7), late was 25 (SE=2.5) (differ at $p< 0.001$).

c. Post-handoff, sensemaking activities differ whether artifacts were from early or late stage. Data from only Part 2 was analyzed to ascertain the effect of maturity on activities.

H3.3 Variance in Sensemaking activities can be accounted for by handoff-time (early vs late)—Confirmed

MANOVA analysis showed that the time of handoff accounted for the variance in sensemaking activities. The result was significant at $p =0.002$.

H3.4 Encoding-occurrence $_{\text{late-handoff}}$ < Encoding-occurrence $_{\text{early-handoff}}$ —Not confirmed

This hypothesis was not confirmed, as there was no significant difference in the mean encoding time between early and late version recipients. Mean encoding time for the late condition was 26.2 minutes (SE=1.5). Mean encoding time for the early condition was 27.1 minutes (SE=1.9).

d. Post-handoff, artifact use activities differ based on artifact maturity. Data from Part 2 was also analyzed to see how artifact use differed between the late and early conditions.

H3.5 Artifact-use activities will differ depending on handoff time (early vs. late) --Confirmed

MANOVA analysis showed that the time of handoff accounted for the variance in artifact use. The result was significant at p =0.006.

H3.6 Artifact use-count $_{\text{early-handoff}}$ < Artifact use-count $_{\text{late-handoff}}$—Partially confirmed

This hypothesis had some positive evidence. Outlines were used significantly (p=0.015) more in the late condition (19 out of 20) than in the early condition (14 out of 20). Bookmark use was also significantly higher (p=0.01) in the late handoff condition (mean= 6.2 bookmarks used, SE=1.4) than in the early condition (mean= 2.7 bookmarks used, SE=0.6). However this was possibly because the late condition people received more bookmarks. There was no difference in the percent of bookmarks used for the two conditions.

H3.7 Artifact use- time $_{\text{early-handoff}}$ > Artifact use- time $_{\text{late-handoff}}$

There was no difference in the two conditions regarding the time of use of bookmarks or outlines, so there was no evidence for this hypothesis.

H3.8 Artifact-ratings $_{\text{early-handoff}}$ < Artifact-ratings $_{\text{late-handoff}}$

The results regarding this hypothesis were mixed. The outlines from the late handoff were given an average rating of 6.85/10 (SE=0.54), which was significantly (p=0.015) higher than the outlines from the early handoff which were rated 5/10 on average (SE=0.6). There was no difference in the ratings given to bookmarks.

5.4 Discussion

5.4.1 Salient Findings

The results of the MANOVA analysis show that external-structure on the web as well as provided structure in the form of handoff artifacts both have an effect on sensemaking activities. The effect of structure is in accordance with Qu & Furnas's (2005) finding that people use different strategies based on availability of structure. The study presented here additionally found that the differences included what people did early on, how much structure they added and how they used handoff artifacts. The presence of easily available structure in the tea task resulted in people adding more structure elements than the drinks task where easily available structure was lacking. The analysis of modal activity in the early part of sensemaking showed that when easily available structure is lacking people spend time early on querying and bookmarking. In contrast, when structure is available people start by adding structure and encoding.

The MANOVA analysis showed that presence of structure also had an effect on artifact

use. Analysis of activity counts showed that people used more of the provided bookmarks when external structure was hard to find. In the absence of easy-to-find external structure or prior knowledge people relied more on the handed off sources of information. In the words of a participant working on the drinks task:

> *"It (bookmarks) gave me a basic place to start to get an idea on some of concerns around the topic"*

When external structure was hard to find (drink task) people also appropriated from the provided outlines sooner as compared to when structure was easily available. In the tea task the first search query often lead people to the Wikipedia entry on 'Tea' (en.wikipedia.org/wiki/Tea). The webpage had a sizeable article with a structured outline that was instantly observed by a lot of people engaged in this task. In contrast there was no such easy to find structure for the drinks task. This might have prompted earlier reliance on the provided outline. In the words of a participant in the drinks task:

> *"The outline gave me an idea of where to start searching, as well as what information needed to be expanded upon and researched more thoroughly."*

MANOVA analysis also shows that the time of the handoff also has an effect on the sensemaking activities of the recipient. Comparing early and late versions of provided artifacts, it was confirmed that material from late stage had more structure and more encoded information. The later versions of outlines in particular were used more often and rated higher by the participants as compared to the early versions. This was expected because later versions would have content that was more well thought out and better organized. In the words of a participant in the late handoff condition:

> *"[the outline] Was very comprehensive in terms of topics and supporting facts. Very detailed for an outline."*

5.4.2 Exceptions and discrepancies

While the findings confirmed some hypotheses there were some exceptions. The exceptions seemed to relate to two aspects. Firstly, hypotheses relating to encoding time were not confirmed. Secondly, some hypotheses regarding artifact-use were partially confirmed which might be related to the discrepancies between the two types of artifacts involved (outlines and bookmarks). These two aspects (encoding time and differences between two types of artifacts) seem to account for most of the exceptions and are explored below.

It was expected that when a good structure would be available to sensemakers in the form of handoff artifacts or through available structure from prior knowledge and external sources (tea task) they would start encoding sooner. The average encoding time did not differ based on easily available-structure or the handoff-artifact. One possible reason is that encoding really does take place all along during sensemaking rather than a separate, subsequent stage, but is an active driving process all along.. A look at all encodings binned by minutes (1 to 50) by all participants in the study (see Figure 5.2) shows that encoding started quite early and occurred all through the sessions. This might have resulted in there being no difference in average time of encoding between the various conditions. A possible manipulation might be to look at average time of *first instance of encoding* for the various conditions rather than average time of encoding.

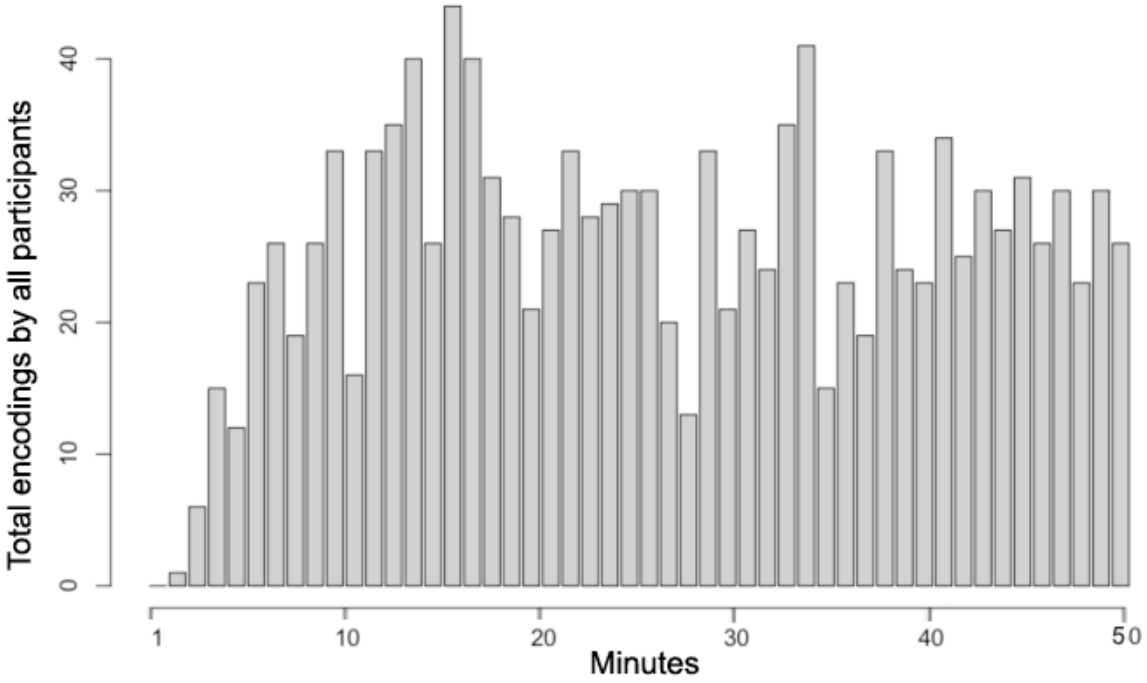


Figure 5.2 Encodings by all participants binned by minutes.

A second set of unexpected exceptions is related to the discrepancies between when the two types of handoff artifacts (outlines and bookmarks) were used and how they were rated. For example bookmarks were not used earlier or rated higher in the drinks task even though outlines were. One possible reason for this discrepancy is that the two kinds of artifacts served different purposes in the sensemaking activities of the recipients. While the outlines were the primary placeholder for structure and ideas, the bookmarks seemed to be a supplementary place to get more information regarding the ideas in the outline. In the words of a handoff recipient:

"It (bookmarks) gave me an idea where the content of outlines come from."

The bookmarks being considered supplemental and used after going through the outline might have led to their being used later in the process. Also that the bookmarks were considered as merely elaborating the outline rather than provide important structure might have contributed to their receiving a lower rating.

This observation about the difference between bookmarks and outlines closely echo the finding by Qu & Furnas (2005) about the two different artifacts:

> *"The bookmarks provided storage and easy access to anything that might be useful later. By contrast, a talk outline served as a hierarchical framework for a sequential presentation, requiring logical continuity between sub-topics, and certain conventional parts, such as opening, closing, etc."* (p.1990)

The bookmarks were also easier to miss because they were on a sidebar in the browser. In contrast the provided outline had its own window. In the words of a recipient:

> *"I forgot about the existing bookmarks and therefore did not use them."*

It also seemed that most participants were adept at searching for information online and felt they could get to better sources on their own. According to a recipient:

> *"(Bookmarks were) Not very helpful because I could easily find the information on my own once I know what to search for as provided by the given outline."*

Another unexpected finding with respect to the outline was that there was no difference in the percentage use of the outline between tea and drink tasks. In both tasks subjects appropriated from the provided outline 80% of the time. This could have been because even early versions had some content that was too good to pass up on. Someone who used parts of an early-handoff outline commented:

> *"It had a couple pieces of information that I placed in areas of my outline. Seeing Turkey mentioned was helpful to think of other countries/areas."*

It was also unexpected to see no difference in time of usage of the artifacts between the early and late handoffs. One possible reason for the delay in using late versions could be because they were longer and more substantial so took recipients longer to read and process. There was more to read in the outlines and more bookmarks to click and consequently more to read on the bookmarked websites.

5.4.3 Future directions

While the study focused on the effects of easily available structure and time of handoff on sensemaking activities, it raises questions about how easily available structure and time of handoff interact. For example are late-handoffs more important when external structure is missing? Is early material ignored or used less when a lot of easily available structure is present. The data collected in this study will be analyzed to answer these questions.

Another issue to explore is the effect of late and early stage material on how comfortable people feel modifying artifacts. Ideas in early artifacts might not be well developed so people may be more inclined to modify them. Later versions may seem more concrete so people may not be likely to pursue their own approaches.

5.5 Summary & Conclusions

The study found that structure available in handoff artifacts as well as externally available in websites can affect the sensemaking activities during an online topic comprehension task. When structure is easily available from prior experience or external websites, people adapt and use it early on. When there are no sources of structure people start by querying and browsing. If structure is also available in the form of handoff artifacts people use it differently based on how much structure is easily available. When structure is not easily available people appropriate from it sooner from the handoff artifacts as compared to when it is easily available. How mature the artifacts are also has an effect on recipients' activities. The primary placeholder for structure (outlines in this case) from late stages was used more often and was rated higher by the recipients. The theoretical and practical implications of this and other work in the dissertation are discussed in the next chapter.

Chapter 6

Conclusions and Implications

Sensemaking and its handoff are challenging. The goal of this dissertation was to understand sensemaking handoffs in order to deal with its challenges and provide implications for the design of support systems as sensemaking practice. This chapter presents conclusions from the literature review, the findings from the four empirical studies, the implications that can be drawn from the findings and the possible directions for future research. The last section summarizes the contributions of this dissertation.

6.1 Conclusions from literature

In order to understand and support sensemaking handoffs, it was important first to understand the attributes of sensemaking and how handoffs in sensemaking differ from other handoff situations.

- *Sensemaking involves structure creation and complexity.* The review of the sensemaking literature and examination of prototypical sensemaking scenarios led to the development of a set of attributes of sensemaking concerned with knowledge structure creation and complexity. When the sensemaking scenario calls for a new representation or when encoding is difficult, new structures must be created. The structure thus created has the attribute of broader applicability going beyond the task

itself because the structure is based on a wide range of information organized in a new way. The complexity of the sensemaking task is indicated by the difficulty of the representation search and the interdependent nature of the subtasks. By using these attributes to evaluate sensemaking tasks, we can begin to fine-tune our understanding of the search and representation requirements of sensemaking, and we can also be more selective in choosing tasks study sensemaking.

- *Collaboration in sensemaking has additional demands compared to collaboration in other activities*. The literature review in section 2.6 suggested that due to the close coupled nature of sensemaking; collaboration will likely be more successful when certain elements are present. Studies by Olson & Olson (date?) showed that these elements are: a strong intent to collaborate (also suggested by Klein, 2006) and high common ground. An analysis based on the works of others adds the following elements to this list: good awareness information of collaborators (Dourish & Bellotti, 1992) additional communication channels (Handover literature discussed in section 2.7) and a shared physical space (Suchman, 1988). Common ground, awareness information, the handoff material and the additional communication together form an ecology to support the handoff. Common ground forms the base of this ecology. What common ground cannot cover needs to be conveyed through awareness information, additional handoff materials and additional communication since sensemaking has close-coupled activities that may require frequent call backs to the handoff provider.

6.2 Findings from empirical studies

- *Presence of collaboration elements can lead to successful resolution of sensemaking-handoffs.* The helpdesk study presented in chapter 3 suggested that handoffs were reported to be mostly successful possibly because of the favorable existence of all the collaboration elements. The participants formed a coherent group that was motivated to have the intent to collaborate. They also had been working as a team for more than 6 years and shared high common ground. The group worked in a shared physical space where they had awareness of others' actions. The group members had access to low cost additional communication channels as they could shout out questions to each other or contact absent members through two-way radio. Finally there was a norm in the group that encouraged most people to create high quality handoff material for recipients.

- *Handoffs can be costly and may need to be avoided.* While most handoffs were reported as successful, participants in the helpdesk study also reported that they followed a norm that directed them to handoff sensemaking work only if they reached a dead-end in their sensemaking. It was recognized that unnecessary handoffs were detrimental to the group and were therefore avoided.

- *Situations lacking some vital elements needed for sensemaking collaboration can still have successful handoffs.* Sharing and reuse of sensemaking artifacts offers an opportunity to get low-cost support in the difficult process of sensemaking. The first lab study evaluating the usefulness of handoff materials when the intent to collaborate, common ground, awareness and additional communication are absent found that well made high quality handoff material made by amateurs can be helpful to recipients. This could have happened because firstly, the recipients were working

on the exact same task as their handoff providers. Secondly, the providers had nearly worked the whole task through before making their handoff material available. This meant that the handed-off representations were quite complete and often useful for the recipient's sensemaking.

- *Quality of handoff material affects its usage by the recipient*. The second lab study suggests that the usage of handoff material differs depending on the quality. While low quality material was either ignored or only useful for some later information gathering, and information gathering verification, the high quality material was used for both the representation construction and encoding/information-gathering parts of sensemaking.

- *Sensemaking activities vary based on available structure.* The study presented in chapter 5 additionally the presence of easily available structure affected what people did early on, how much structure they added overall. The presence of easily available structure results in people starting by adding structure and may help people add more structure to their sensemaking artifacts. This confirms as well as adds to the findings of Qu & Furnas (2005).

- *Easily available structure affects use of handoff-artifacts.* The study presented in chapter 5 shows that people use handoff artifacts differently based on how much structure is easily available for the task. When structure is not easily available people are more likely to appropriate handoff artifacts for their task. They are also likely to use handoff artifacts sooner when external structure is not available as compared to when structure is easily available.

- *Handoff-artifact maturity affects the sensemaking process and handoff-artifact use*. The lab study presented in chapter 5 found that people are more likely to incorporate later versions of artifacts into their sensemaking as compared to early versions that might not have well-developed structure. Later versions of artifacts are also likely to be rated as being more useful by recipients as compared to the early versions.

6.3 Implications

In this section, I present possible implications for the design of handoff sensemaking support systems and handoff sensemaking practices, drawn from the findings from the literature and the studies in the dissertation.

- *Sensemaking attributes can guide system design and handoff practices.* Besides their intended purpose of guiding the selection of sensemaking tasks, some of the essential sensemaking attributes presented in this work can also provide pointers for sensemaking support systems, both general purpose ones, and those specifically for handoff sensemaking. A couple of these design ideas for handoff-sensemaking support systems and practices are presented here.

  Representation novelty can be the result of the lack of relevant existing knowledge and the lack of access to representations created by others. One goal of a handoff support system is to enable the transfer of a usable representation to a recipient. To that end it might be useful to highlight structure aspects within a handoff artifact so that the recipient can extract structure more readily after the handoff. For example outlines handed-off in a topic comprehension task were helpful because they made structure and organization themes evident and easy to grasp.

Encoding difficulty is high when intensive matching with all parts of the representation is needed. A provider or a handoff support system can help a recipient by highlighting parts of the representation that need encoding and suggest sources of information to consider as well as avoid.

- *Collaboration elements can guide system design and practice*. The intent to collaborate, the degree of common ground and shared physical space all depend on the task environment. A handoff sensemaking support system can have little effect on some of these elements. It can however strive to boost what it can. For example incentives may be designed to encourage sharing of prior sensemaking work. A support system can also help by boosting awareness, providing low cost communication channels and helping the sharing of handoff materials where possible. Most participants in the helpdesk study, for example, said asynchronous communication was too slow for troubleshooting. Synchronous communication with people involved in handoff can help clarify details quickly and save time. Awareness can be helpful especially in dealing with dynamic situations discussed above.
- *Handoff artifacts from later stages of sensemaking are useful for recipients.* The helpdesk study participants in chapter 3, the first lab experiment in chapter 4 as well as the lab-study in chapter 5 all suggested that later stages of sensemaking are more useful. The first lab experiment showed that even when the handoff was from unknown providers, (no intent to collaborate, low common ground, no awareness and additional communication) the material from their completed sensemaking was useful for the recipients. The second exploratory lab study suggests that good quality material might provide representation ideas to recipients and can reduce the

representational novelty of the task while poor quality material is only used for encoding. The third lab-study presented in chapter 5 also suggested that late stage material is considered useful and is more likely to be utilized than early stage material. For support systems and practice this means sharing and reusing of sensemaking artifacts from later stages should be encouraged. Artifacts should also have clear indications of their maturity (for example how much time was spent on them). Once such indicators are present, recipients should be encouraged to use high quality material early and reserve the low quality material for later information gathering and verification.

- *Handoff artifacts can help in representation construction when structure is not easily available.* The lab study presented in chapter 5 found that information sources provided in handoff (bookmarks) were used more and the primary externalizations of structure (outlines) were used sooner when external structure was hard to find. This implies that artifacts are especially useful early on when external structure is hard to find. Providers and support systems should include information sources and external representations to a recipient if the recipient is starting off fresh on the task.

6.4 Future Directions

The work presented in this dissertation also establishes possible directions for future research. These directions include analyzing the interaction between external and provided structure. Another direction is to explore the differences between different types of sensemaking situations (for example trouble-shooting, product-choice and topic comprehension) as well as different domains (for example health-care, software development and design).

6.5 Summary of contributions

Five attributes were derived and proposed as a suite of ideas and corresponding tests for identifying and exploring sensemaking tasks. These five attributes including their nomenclature and elaboration on their usage is one contribution of this work. In this process crosscutting themes from three sensemaking theories of Russell et al (1993), Weick (1995) and Dervin (1998) were identified and the attributes were tested against cases including a prototypical sensemaking scenario and two kinds of problem-solving (well-defined and ill-defined) scenarios. The attributes capture what makes sensemaking difficult and also help in choosing tasks to study sensemaking as well as modifying laboratory tasks so that they involve more sensemaking. These attributes are related to knowledge structure creation (representation novelty required, encoding difficulty, broader applicability) and complexity (representation search space and subtask interdependence).

Synthesizing existing literature on collaboration, the dissertation identified important elements in a sensemaking handoff. These elements (intent to collaborate, common ground, shared space, awareness, additional communication and handoff artifacts) make up an ecology that helps deal with challenges of sensemaking expressed by the attributes of sensemaking tasks. These collaboration elements suggest ways of leveraging collaboration in sensemaking and help frame future research.

The dissertation included a study of sensemaking handoffs in the real world (a university computer support helpdesk). Sensemaking was found to emerge in the context of routine tasks. The study identified reasons for handoff other than shift-changes: personal conflict with the customer and the need for a new perspective. The study found that the crucial

collaboration elements identified earlier in the dissertation were not just used to support sensemaking handoffs but were also employed to obviate them whenever possible. The study also highlighted costs associated with handoff as it was observed that handoffs were avoided whenever feasible. The study identified amount of time on task to be an important factor in handoffs. Handoffs were done either very early to transfer work to an appropriate recipient, or very late after the providers had exhausted their options. Middle -period handoffs were avoided. It was suggested that middle handoffs were avoided because until late, the representations created by the provider were immature and not appropriate for handoffs. The study also raised questions about the quality and utility of handoff material from incomplete sensemaking, and about the timing of handoffs. Artifacts from unsuccessful sensemaking were not very helpful and required frequent restarts of sensemaking.

To answer these questions that the lab-study raised, three lab-studies conducted in the dissertation provided insights regarding the role of artifacts in sensemaking handoffs. The first study involving a product choice task confirmed that handoff can be as effective as simultaneous collaboration. This finding is encouraging for the sharing and reuse of sensemaking artifacts. The second lab-study also involving the same product choice task suggested that the quality of the handed-off material was an important factor. Poor quality material seemed to be used at different times and in different ways from good quality material.

The third lab-study involving microanalysis of a topic comprehension task, found that available structure in the form of websites as well as handoff artifacts can have an effect on sensemaking. The study also found evidence of greater usefulness and usage of more

mature handoff artifacts. When structure is easily available people adapt and use it early on. When there are no sources of structure people start with their own exploration. If structure is also available in the form of handoff artifacts people use it differently based on how much structure is available externally. When structure is not easily available people appropriate from it sooner from the handoff artifacts as compared to when it is easily available externally. How mature the artifacts are also has an effect on recipients' activities. Artifacts from late stages that are placeholders for structures in a task were used more often and were rated higher by the recipients.

The dissertation also suggests implications for handoff support systems and practice. The most important implication was that artifacts from other people have the potential to be quite useful to subsequent sensemakers working on a similar task. Usefulness is also greater when people do not have other easy sources of structure and when the handoff material is from later more complete stages. Early material might be useful as well, for information gathering and verification.

These contributions can guide future research, provide directions for support system design and provide guidelines to people engaged in sensemaking handoffs.

Appendix A

Prototypical Sensemaking Scenario & Sensemaking Attributes

In this section we look at a prototypical sensemaking scenario to see how the attributes can be used to analyze a task using the attributes.

Consider the case of the response by various agencies to the West Nile Virus (WNV) outbreak and its consequences in Queens, NY in the fall of 1999. The chief of infectious diseases at the Flushing Hospital alerted the Department of Health (DOH) about some patients with encephalitis, fever, GI distress, mental confusion and muscle weakness not typically seen with encephalitis. The rise of an unknown condition needed the creation of an understanding and a framework to deal with the situation. The Flushing Hospital doctors, the DOH, a pathologist at the Bronx zoo, the Center for Disease Control (CDC) and various other organizations were consequently involved in collaboration to ascertain the cause and treatment of an outbreak to be mosquito-borne West Nile virus (WNV). The case of identifying and treating a rare disease can be considered a prototypical case of sensemaking since it involves the addition of a new piece of knowledge structure, because the people did not know how to act faced by an unknown condition and because there were no simple and straightforward plans of action.

Representation novelty requirement

In the WNV example, the doctors first tried to diagnose the cases drawing on their knowledge of common ailments, like encephalitis that approximately matched the symptoms. The muscle weakness in the patients was baffling in particular because it did not match any known the symptom of common encephalitis. The various scientists did not consider WNV because the condition had never been seen in this part of the world, thus the addition of WNV disease identification and its properties like its vectors, its classification, its origin, its infectiousness and its prevention/treatment was novel in this social-system of health agencies and administration.

Encoding Difficulty

In the WNV case the various people had pieces of information but their relevance and interpretation was difficult. For example there had been articles in the newspapers about dead birds but no one considered it relevant to the hospitalized humans. The WNV case highlights the difficulty of encoding in sensemaking. The relevance of the dead birds in the WNV case was unclear and realizing its relevance was a significant part of sensemaking. In the WNV case it seemed relevant that cases had muscle weakness but this symptom did not fit with the known and typical types of encephalitis. The definitive identification of the virus was much belabored. Members of the virus family in question could be extremely difficult to distinguish and layers of testing were needed to pinpoint the true disease agent. The properties of the virus also needed to be screened against hundreds of known viruses.

Broader Applicability

In the WNV case the primary task was to identify the condition and treat it, but the understanding created during sensemaking had much broader applicability. For example,

once it was established that the condition was indeed WNV and that it could spread through birds, it was also known that birds could be used as sentinels to monitor the spread of WNV.

Representation Search Space

The large size of the search space was also observed in the WNV case. Encephalitis seen in the patients can happen due to a number of pathogens including bacteria and viruses. Even when it was known the encephalitis was viral there were many thousands of potential viruses that could cause the condition. The large search space contributed to the complexity.

Subtask Interdependence

In the WNV case, the naming of the culprit virus and further detection of cases was not very tightly coupled. Though it took time and effort, the various agencies working separately with limited communication were able to solve the mystery of WNV.

Overall

The WNV case lists as high on all attributes except one. This shows that the five attributes capture the essence of sensemaking quite well. It also shows that tasks do not need to be high on all attributes to be good candidates for sensemaking studies. Those high on most attributes still involve serious amount of sensemaking.

Appendix B

Well-defined Problem Solving & Sensemaking Attributes

Evaluating a well-defined problem solving (PS) scenario using the sensemaking attributes can help us identify the important similarities and differences between PS and sensemaking. The 'hobbits and orcs' problem has been used to study problem solving (Jeffries, Polson, Razran and Atwood, 1997)

Three Hobbits and three Orcs arrive at a river bank, and they all wish to cross onto the other side. Fortunately, there is a boat, but unfortunately, the boat can only hold two creatures at one time. Also, there is another problem. Orcs are vicious creatures, and whenever there are more Orcs than Hobbits on one side of the river, the Orcs will immediately attack the Hobbits and eat them up. Consequently, you should be certain that you never leave more Orcs than Hobbits on any river bank. (Note that the Orcs, though vicious, can be trusted to bring the boat back from across the river!).

The essential attributes of sensemaking discussed in the last section are employed to see how well defined PS compares to sensemaking.

Representational novelty

Well-defined PS can be considered the process of reaching the goal state from the initial state using the allowable operations. The whole space of problem states, the operators

and the heuristics used to evaluate moves make up the representation of the problem. The representation of the state can also be externalized using simple symbols (Anderson, 1993), for example symbols of the hobbits, orcs, the boat and the two banks in the problem above.

One of the relevant types of knowledge required is the knowledge of logical thinking. The problem solvers could also benefit if they would have solved this problem or other problems of the same type before. A useful stratagem which can be attained by solving many such problems involves the knowledge that moves that seemingly go back towards the initial state rather than towards the goal state are sometimes needed, for example bringing back to the starting bank of the river an item that has already been taken across. Most users will have most of the knowledge needed to draw a simple representation using symbols and a few 'experts' will have all the strategies as well. Still people who face a well defined problem for the first time will lack strategies for that particular problem and may need to try multiple moves to develop a representation for the problem.

By definition the well-developed problems have a unique solution and the solution to most problems is widely available if people search online. Under most lab conditions subjects can be denied this access.

Since most people have little to no strategies needed in a particular task and access to others' representations can be controlled, the representation novelty requirement of the task is medium to high.

Encoding Difficulty

By definition, all the information needed to solve the problem (the initial state, the goal state and the allowable operations) is provided in the problem. This means that the

information relevance is known. The information to be encoded includes the current state of variables, for example the location of three hobbits, three orcs, the boat and the two banks. The other rules and conditions can be used with a simple graphical representation without much effort. This implies that the relationship to representation is easily known for most information. The number of variables is low and there is no matching involved.

In this problem people have the relevant information at hand. They also know the relationship of the information to the ultimate representation used and don't have to intensively match with representation parts. The task can thus be deemed to be low-to-medium on the encoding difficulty dimension.

Broader Applicability

Solving the problem a few times and grasping the counter-intuitive heuristic that the boat needs to bring back the entities to the starting bank will enable people to solve other river crossing problems with ease. Yet a one shot solving of the problem will result in the creation of little understanding unless the helpful heuristic can be grasped and thus may not help considerably with other river crossing problems. People can also stumble upon the solution by trial and error. Thus there is *low* broad applicability of the task.

Representation search space

Problem solving has also been conceived as a search through a state space (Newell & Simon, 1972). The size of the space is determined by number of choices or operators at various states. Most well defined problems have a few variables (number of tower pieces, water jugs etc.). In the hobbits and orcs problem, the problem solver has a maximum of 5 choices at a time (an orc, a hobbit, two orcs, two hobbits or a hobbit and an orc) and only the ones next to a boat can move. Thus the size of the representation space is not very

large in well-defined problems. Most moves can be discovered and mapped through trial and error. The evaluation of various changes is seemingly straightforward as the progress can be evaluated by the number of entities transported. However, in many well-defined problems like hobbits and orcs, seemingly counter productive moves are needed. This means that evaluation is slightly difficult. There are no changes in the situation as all the information needed to solve the task is provided and is static. The representation search is between *easy and difficult* in most well defined PS due to the slight difficulty in evaluation of representations.

Subtask interdependence

The major subtasks in the problem are: creating an external representation with the problem information, using the representation to try various moves and assessing progress. Trying moves and assessing progress are steps that may need to be done simultaneously and are coupled as well. Yet there are not so many different tasks to coordinate, no information gathering/assessment and hypothesis formation to be done in an interwoven manner. The interdependence of the subtasks can be considered low to medium.

Overall

We find that well-defined problems score low on most of the sensemaking attributes. This suggests that well-defined PS does not involve considerable sensemaking. The hobbits and Orcs example of PS still has high representation novelty requirement as well as slightly difficult representation search. The novelty of the situation, the difficulty of evaluation and the somewhat high subtask interdependence could be a few of the reasons why even well defined PS can be difficult. The representation search space is still smaller

compared to sensemaking and the solution can ultimately be stumbled upon by trial error. The smaller representation space seems to be one reason why well-defined problem solving requires some sensemaking but not intense and prolonged sensemaking. Next we employ the attributes to analyze ill-defined problem solving.

Appendix C

Ill-defined Problem Solving & Sensemaking Attributes

Ill-defined problems are quite different from well-defined problems but seem similar to sensemaking in many ways. This section uses the sensemaking attributes to compare and contrast sensemaking and ill-defined problem solving. Planning a vacation to an unknown destination has been studied as ill-defined problem solving (Carroll, 2002). An example scenario is evaluated here:

You and three other friends decide that it is time you fulfilled a life long dream of hiking the Himalayas. Your project is to present a detailed plan of your hike.

Representational novelty

An ultimate encoded representation in the vacation-planning problem would include a detailed itinerary. The plan will also require issues like what equipment to bring, what inoculations to get, budgeting, etc. The representation would also allow the participant to argue why the itinerary is a "good itinerary".

People's relevant existing knowledge: Solving an ill-defined problem usually requires generating a creative or novel representation and procedure (Qin, Johnson and Johnson, 1995). In the above case the lack of familiarity with the destination means that people will not have extensive information. They may still have knowledge of some aspects of the task: they may have gone on hikes before, or traveled abroad, for example. If people

have access to someone who has hiked the region before they may benefit a lot. There may also be information available online. Such access can be somewhat restricted in a lab task if desired. Since people have some aspects of the knowledge needed in the task and the access to others' representations can be restricted, the representation novelty requirement of the task in the lab is medium to high and should be medium to high.

Encoding Difficulty

Examples of the information to be encoded would be places to visit, prices and equipment. Every place has attributes like travel connectivity, lodging and food availability, weather conditions, distances from other places, appropriateness for hiking, reviews from other hikers and safety considerations. The relevant information in the task needs to be gathered. People who are not familiar with vacation planning need to establish which sources are trustworthy and which information is relevant. All this means that for people with no experience with the task, the information relevance is not known. Once a place seems relevant, it still might not be clear how its inclusion affects the rest of the plan. Other important issues in the task like equipment, budgeting and schedules still need to be sorted out. This implies that the relationship to representation is not easily known in the task. There may be a number of possible places to visit on the itinerary. Deciding what they offer, which ones to include, which order to include them requires assimilation with all the other points in the itinerary. The problem requires choosing from a complex set and then optimizing based on the choices. Thus the task goes beyond simple optimization of variables and there seems to be the need for an intensive matching of every variable with the itinerary.

In this problem the people do not have the relevant information at hand and the relationship of much of the gathered information to the ultimate representation is also not known. Intensive matching of information collected with many parts of the representation is also needed. The task can thus be placed close to high on the encoding difficulty dimension.

Broader Applicability

The principle task is to prepare an itinerary for the trip but once people complete the task they will be able to use the understanding created to complete many other related tasks. For example they can answer questions like: What are the most difficult and easiest trekking routes? What is the best time to visit the region? What safety precautions should be taken while trekking in any mountains? Solving the problem once will enable people to solve planning problems involving aspects like hiking or Himalayan regions.

Representation search space

The search space in this problem can be considered quite large as just the geographical considerations can result in a large search space. The Himalayas are a vast region spanning many countries which means that there are many possible combinations of places that can be included in an itinerary. Besides geography other aspects of the problem like logistics, travel, lodging, safety and budgeting make the representation search space even larger. Evaluations of a candidate plan can be done by considering all aspects of the problem; this makes evaluation possible but difficult and slightly delayed. Real time changes in weather and political conditions in the sensitive regions means that the situation is dynamic. The large search space, some difficulty in evaluation and dynamic situation means that the representation search space is *very difficult.*

Subtask interdependence

The major subtasks in the problem include[3] working out the details of budget, supplies, lodging, travel, safety precautions and weather. Most of these tasks are closely coupled. Budgeting for example requires deciding on the list of supplies needed, lodging and travel decisions and vice versa. Safety precautions are affected by weather conditions and help decide the need for supplies and equipment. Most of the tasks listed above need to be done simultaneously as well and affect each others' outcomes. We can conclude that the subtask interdependence is *high.*

Overall

This example suggests that ill-defined problems score high on all of the sensemaking attributes which further suggests that ill-defined PS involves considerable sensemaking. Both kinds of PS involve novelty, but ill-defined problems due to their lack of structure demand more novelty from the sensemaker. Ill-defined problems also have more difficulty in encoding and have broader applicability. The structure creation aspect of ill-defined problems is thus considerably stronger than well-defined problems where the problems are tightly structured already. The lack of definition in ill-defined problems is one reason the search space becomes considerably larger than in well-defined PS. In some ill-defined problems the existence of a dynamic situation may further add to the difficulty of the search space of representations. The large size of the search space in ill-defined problems can result in the need for much more sensemaking than the sensemaking required in well-defined problems. The analysis also informs us that ill-

[3] Source: Wisconsin Center for Education Research Project Based Learning Site (accessed 3/15/2008): http://college.hmco.com/education/pbl/project/project2.html#problem

defined problem solving is very similar to sensemaking and ill-defined problems can be suitably used to study sensemaking.

Appendix D

Interview Protocol for Helpdesk Study

- Biographical *(to see if sensemaking handoff practices are different)*
  - Age
  - Qualification and Background
  - How much experience do you have working here?
  - What led you to this job?
- Typical Work Practices *(and how do they change during sensemaking)*
  - Can you give me a walkthrough of a typical workday?
    - When do you come, leave etc
  - Do you ever take work home?
  - When? Why?
  - Who brings work to you?
  - Describe relationships to other workers
    - Formal or informal
    - How often do you have to communicate?
  - Do you ever get lost in your work (flow instance?)
    - What kind of problems are these
  - Does your work produce stress for you?
    - How often?
    - How did these situations develop?

        - What was the outcome?
        - Is there any particular kind of work that you really like at your job?
- Sensemaking- tough problems e.g. what is going on here? *(Systems in place for dealing with sensemaking)*
    - How often do these come up?
    - Can you think of examples?
    - Trigger/What started it?
    - Actions/What did you do?
    - Challenging aspects of the problem
    - Problems you encountered
    - Workarounds
    - How did the situation make you feel?
        - Gratified
        - Tiring
- Were there any handoffs?
    - Received
    - Handed Off
- Handoff as Recipient *(Patterns and practices in handoffs)*
    - Trigger
        - Why was it handed off to you?
        - Authority Issues
        - Shift change
        - Tired

        - Expertise requirement
    - How was the handoff done?
        - What was handed off?
        - Was a system used to facilitate handoff?
        - Was the system enough?
        - Was the system supplemented with other things?
            - Additional Communication
            - Additional Artifacts
    - Was it handed of repeatedly?
        - How many people were involved (you+another or another→you→another)
        - If yes were there any issues with repeated handoffs
    - When was it handed off?
        - What percentage of the work was done before handoff?
        - Did you find the handoff useful?
    - Problems
        - Did you ever ignore the handoff (just start on your own again)
    - Workarounds or personal strategies for dealing with handoffs

- Handoff as Provider *(providing can be different)*
    - Trigger
        - What made you hand it off
        - Authority Issues

        - Shift change
        - Tired
        - Expertise requirement
    - How was the handoff done?
        - What was handed off?
        - Was a system used to facilitate handoff?
        - Was the system enough?
        - Was the system supplemented with other things?
            - Additional Communication
            - Additional Artifacts
    - When was did you hand it off?
        - How much percentage of the work was done before handoff?
        - How useful did you think your progress was?
    - Problems
        - Did the recipient get back to you with questions and clarifications?
    - Workarounds or personal strategies for handing off

Appendix E

Post-Completion Questionnaires for First Camcorder Study

Section F was only given to participants in collaboration conditions.

Based on their collaboration condition, participants got different versions of section F

A-Please provide some information about you:

1. How many hours per week do you use the Internet?
   _____
2. Education: Highest Degree received and Major?
   _____
3. Age & Gender
   _____
4. Are you a frequent online shopper? (check one)
   I never shop online ___
   Sometimes shop online ___
   (approx. once a week ____ month____ year_____)
   Do Most of the shopping online ___

B- The following questions will help us understand what you learned DURING YOUR SEARCH. Some questions ask about your knowledge before and after the search. They are not meant to test you on camcorders. Instead we want to know what information is available to shoppers.

1. In this study, what online tools (search engines, comparison sites, buying guides and other websites) did you use for your product search?

_____
_____

_____
_____
_____

2. According to you which were the top brands of camcorders?

Before your search: *After your search:*

_____ _____
_____ _____
_____ _____
_____ _____
_____ _____

3. What did you think is the difference between analog and digital camcorders?

Before your search: *After your search:*

_____ _____
_____ _____
_____ _____
_____ _____
_____ _____

4. What did you think are the main types of video formats available?

Before your search: *After your search:*

_____ _____
_____ _____
_____ _____
_____ _____
_____ _____

5. Which format did you choose and why?

_____
_____
_____
_____

6. Regarding optical zoom & digital zoom.

1. What is the difference between them?

_____
_____
_____

2. Did you know this before your search? _____

3. Which zoom was more important for you?

_____
_____
_____

7. Regarding camcorder batteries

I. What types are available?

II. Which one is better?

III. Did you know this before your search?

8. According to you, the top brands of Lens manufacturers:

Before your search:	*After your search:*
_____	_____
_____	_____
_____	_____
_____	_____
_____	_____

9. What is "Image Stabilization"?

_____
_____
_____

Did you know this before the search? _____

10. In your knowledge, what are the most common video special effects that camcorders have?

Before your search:	*After your search:*
_____	_____
_____	_____
_____	_____
_____	_____
_____	_____

11. How informative do you think your organized bookmarks will be for your friend?

Not at all informative ___
Somewhat Informative ___
Very Informative ___

12. Do you think that making book-marks helped you in deciding and learning

Not at all ___
Somewhat Helpful ___
Very Helpful ___

13. Below is a list of a few models you may have encountered in your search. Please rank these models you know about according to how suitable you think they would be for your gift recommendation. (Use 1 for the most suitable, 2 for the next most suitable, etc. Leave 'blank' any that you do not know about.)

a. Sony DCR-TRV 33 ___
b. Panasonic PV DV 52 ___
***c.* Sony DCR-TRV 310 ___**
d. Cannon Elura 50 ___
e. **JVC GR-DVF 21 ___**
f. **Cannon Optura 20 ___**
g. **Sony DCR-TRV 22 ___**

14. Did you need more time for the task? If yes, how much more time do you think you would need?

_____
_____
_____
_____

15. Is online search enough? Explain. What else would you do if you think online search is not enough?

_____
_____
_____
_____

E-Questions about your final recommendation: You may refer to your notes or bookmarks to answer, please don't access any sites you didn't bookmark.

16. What is the product you would finally recommend? (Give brand and model number only)

_____
_____
_____
_____

17. Important features that your chosen product has:

i. Optical zoom (leave blank if it has no optical zoom): ___ x or Don't know_____

ii. Resolution: _____lines of horizontal resolution or don't know_____

iii. Recording Time (Memory):_____minutes or don't know_____

iv. Size & weight: _____lbs or don't know_____

v. Night Shot: Yes _____ No_____ Don't know_____

vi. Battery type & life: _____hrs or don't know_____

vii. LCD screen size: _____inches or don't know_____

viii. Lens manufacturer: _____ don't know_____

ix. Image Stabilization: Yes _____ No_____ Don't know_____

x. Special Effect Capabilities (check all those apply, write N/A if not known):
Sepia____ B&W___ Scene Fader____ Solarize____ Mosaic____

xi. Still Images: _____ Mega Pixels _____MB storage or don't know_____

xii. Sound/Microphone System (check all those apply, write N/A if not known):
Built in Mic___ Windscreen____ Mic jack_____ Zoom Mic_____ Don't know_____

xiii. Others Features:

_____
_____
_____
_____

18. Seller Info: Where will you recommend they buy it from and what is the price (including shipping)?

_____
_____
_____
_____

19. Did you read any reviews of the product? Yes_____ No_____
    1. If yes, where:

    2. What did the reviews say

20. Did you read any reviews of the seller? Yes_____ No_____
    1. If yes, where:

    2. What did the reviews say

21. How confident are you about your choice?

Not confident at all ___
Somewhat confident ___
Very confident ___

F-Questions about collaboration:

1. Did collaboration help you? Explain briefly.

_____
_____
_____
_____
_____

2. Were you trying to come to a consensus (choose the same product)? Yes _____ No _____

3. Did you decide on the same product? Yes___ No____ (if answer is Yes, please answer 3a & 3b)

   a. Why did you choose the same product?

   _____
   _____
   _____

   b. Was consensus difficult?

   _____
   _____
   _____

4. Do you think you have performed better alone? Explain briefly,

_____
_____
_____
_____
_____

5. Did you divide the task? If so, how? Did this help you?

_____
_____
_____
_____
_____

6. Please give feedback about your partner
   1. Was he/she co-operative (Scale 1 to 5 where 5= very cooperative): ___

   Why do you think so?

_____
_____
_____
_____
_____

2. Do you think he/she knew more about camcorders than you (Scale 1 to 5 where 5= knew a lot more): ____
Why do you think so?

_____
_____
_____
_____
_____

F-Questions about organized bookmarks you were provided:

1. Did you refer to the bookmarks provided to you? Yes____ No____

Please give reasons for doing so:

_____
_____
_____
_____

2. Rate the bookmarks you were provided (also please explain your rating)
   1. Were they understandable (Scale 1 to 5 where 5= very clear): ___
   Explain:

   _____
   _____
   _____

   2. Were they useful for your task (Scale 1 to 5 where 5= very useful): ___
   Explain:

   _____
   _____
   _____

   3. Were they more helpful than your own bookmarks (Scale 1 to 5 where 5= much better): ___
   Explain:

   _____
   _____
   _____

3. Would you have performed better without them? Explain briefly.

_____
_____
_____
_____

4. Out of all the links in the bookmarks you got, how many web pages did you visit?

None ___
Some ___ (which means: ____ out of ____)
All of them ___

Appendix F

Post-Completion Questionnaire for Second Camcorder Study

Participant ID:

A-Please provide some information about you:

5. **Age**: **Gender:**

6. **Education**: Highest Degree received and Major?

7. **Education:** Current Degree & Major?

8. **Internet Use** (not including email)
   hours/ week

9. **Online shopping/product searching frequency:** (Choose the most appropriate options)
   1. *Never* ____
   2. *Rarely* ____
   3. *Sometimes* ____
   4. *Often* ____
   5. *Mostly* ____

*B-Questions regarding **the sensemaking material you received**. You may refer to the material while answering these questions.*

22. Did you use them?
    Yes ____ No ____

23. How many of them did you use?
    ____ Out of ____

24. How did you decide which ones to use?

25. How informative were the links in the material?

1. *Not at all informative* ____
2. *Very little informative* ____
3. *Somewhat informative* ____
4. *Very informative* ____
5. *Extremely informative* ____

26. How well labeled and organized were the material?

1. *Very Poorly labeled and organized* ____
2. *Poorly labeled and organized* ____
3. *Somewhat well labeled and organized* ____
4. *Very labeled and organized* ____
5. *Extremely well labeled and organized* ____

27. How useful were they overall?

1. *Of no use at all* ____
2. *Of little use* ____
3. *Somewhat useful* ____
4. *Very useful* ____
5. *Extremely useful* ____

Thank you; please inform when you have finished filling in the questionnaire.

Appendix G

Task Instructions- Tea Topic

TASK OVERVIEW

1. You will complete the Task outlined below (50 minutes)
2. You will fill out a brief Demographic Survey

PARTICIPATION CRITERIA

- ☐ You are fluent in English
- ☐ Are able to use MS-Word and able to research online
- ☐ DO NOT have experience working in reference service

INTRODUCTION

You have been invited to give an **hour-long** introductory talk on the topic of "***tea"*** in your community's public library. The audience could be anybody in your community. It's safe to assume the audience does not know much about this topic. In this talk, you want to give a survey of the topic so that the audience could have an overview. The talk is a few days later, but you want to start early and prepare for it. You want to: **learn** the topic yourself, **collect information** you might use later to prepare the talk (facts, images, videos, examples, stories) and **prepare an outline of your talk**.

DELIVERABLES

Please use the Internet-browser provided to search online resources and learn about the topic. For the purpose of the task, you need to prepare the following two things:

1. **Talk Outline-** Please create a draft outline of your 1-hour talk using what you learn about the topic from online resources. Please use the outliner tool in Microsoft-Word to create your outline.
2. **Bookmarks-** Please bookmark any useful websites you might need to revisit when you prepare for the talk later. Collect as much information as possible so that you can use it in the preparation of your talk. You need not read everything in detail now. You can also organize your bookmarks in folders.

COMPLETING HANDOFF TASK (IF APPLICABLE)

A previous participant has worked on this task for some time and has handed off their materials (outline and bookmarks) to you. I will point out the provided materials to you, please build on this existing material in whatever way that you see fit to complete the task.

THINK ALOUD

I'll be recording the screens, what you are doing, and what your comments are. In much of the study, it's very helpful if you can comment on what you are doing, for example: noting any

problems you are encountering, what are you trying to find etc. If you have questions regarding think-aloud please let me know.

SURVEY

We are using a screen-recording program. At the end of 50 minutes it will pop-up a survey and you will know you are done. We also have a clock so you can see how much time you have spent. Please stop working and fill in the survey when it pops-up.

COMPENSATION

A one-time compensation will be given to you at completion of the lab experiment. The amount will be $20 plus bonus ($10) if applicable. The additional bonus will be given to top 10 percent of participants based on the quality of the talk-outline as judged by a subject expert. Since performance cannot be graded instantly after participation, you shall be informed and the bonus disbursed later if you become eligible.

Appendix H

Task Instructions- Drinks Topic

TASK OVERVIEW

3. You will complete the Task outlined below (50 minutes)
4. You will fill out a brief Demographic Survey

PARTICIPATION CRITERIA

- ☐ You are fluent in English
- ☐ Are able to use MS-Word and able to research online
- ☐ DO NOT have experience working in reference service

INTRODUCTION

You have been invited to give an **hour-long** introductory talk on the topic of "***Drinks for the elderly"*** in your community's public library. The audience could be anybody in your community. It's safe to assume the audience does not know much about this topic. In this talk, you want to give a survey of the topic so that the audience could have an overview. The talk is a few days later, but you want to start early and prepare for it. You want to: **learn** the topic yourself, **collect information** you might use later to prepare the talk (facts, images, videos, examples, stories) and **prepare an outline of your talk**.

DELIVERABLES

Please use the Internet-browser provided to search online resources and learn about the topic. For the purpose of the task, you need to prepare the following two things:

3. **Talk Outline-** Please create a draft outline of your 1-hour talk using what you learn about the topic from online resources. Please use the outliner tool in Microsoft-Word to create your outline.
4. **Bookmarks-** Please bookmark any useful websites you might need to revisit when you prepare for the talk later. Collect as much information as possible so that you can use it in the preparation of your talk. You need not read everything in detail now. You can also organize your bookmarks in folders.

COMPLETING HANDOFF TASK

A previous participant has worked on this task for some time and has handed off their materials (outline and bookmarks) to you. I will point out the provided materials to you, please build on this existing material in whatever way that you see fit to complete the task.

THINK ALOUD

I'll be recording the screens, what you are doing, and what your comments are. In much of the study, it's very helpful if you can comment on what you are doing, for example: noting any

problems you are encountering, what are you trying to find etc. If you have questions regarding think-aloud please let me know.

SURVEY

We are using a screen-recording program. At the end of 50 minutes it will pop-up a survey and you will know you are done. We also have a clock so you can see how much time you have spent. Please stop working and fill in the survey when it pops-up.

COMPENSATION

A one-time compensation will be given to you at completion of the lab experiment. The amount will be $20 plus bonus ($10) if applicable. The additional bonus will be given to top 10 percent of participants based on the quality of the talk-outline as judged by a subject expert. Since performance cannot be graded instantly after participation, you shall be informed and the bonus disbursed later if you become eligible.

Appendix I

Attribute Analysis of Tea & Drink Task

Topic comprehension tasks require users to collect information on a topic and use it to understand a topic. An attribute analysis of the Tea & Drink tasks is presented here.

Representation novelty requirement

Preparing a talk requires people to understand how to present in an organized manner. The target in the task is to come up with the outline. People might have prior schemas regarding how to organize talks that they can draw from (e.g. introduction, outline, body, conclusions). For the tea talk many people drink tea and may be aware of topics to consider for a talk (eg history, cultivation, culture, geography). Awareness of the drinks for the elderly (drinks hereafter) is somewhat limited. If the subject population is not elderly or is not involved in the care of the elderly, they may know little about relevant topics. The tea topic also has many easy to access web pages with outlines on the topic that can be accessed. In contrast, the drinks topic does not have easy to find pages with structured information. The representation novelty for the tea task seems low but seems to be high for the drinks task

Encoding difficulty

Examples of the information to be encoded in task would be facts, images, videos and stories/anecdotes. Such information is widely available for the tea topic but not for the

drinks topic. However the existence of many pages for the tea task might make choosing sources more difficult. There may be many sources providing information like sellers, encyclopedias and enthusiasts. Establishing usefulness of information may be problematic where there is conflict in these sources. For the drinks task the information may be spread over many kinds of sources related to the elderly and to health and nutrition. The widespread information on tea makes encoding easy but the lack of it makes encoding difficult for the drinks task.

Broader applicability

Once the comprehension task has been accomplished, the sensemaker should be equipped with knowledge that can be used to answer many other questions. For example someone who prepares the talk on tea might be able to talk also on the health benefits of anti-oxidants. Similarly those working on the drinks task might be able so say useful things about not just what elderly should drink but also what they should eat. The broader applicability of both talk topics is high.

Representation search space

There are many possible ways of organizing a talk, which means the search space or representations here is not small. The number of topics to consider for the tea talk is quite high and in contrast somewhat limited for the drinks task since there are fewer topics. Prior experience can also guide search for representations here ("I know people in the library do not want a scholarly talk"). The search space can be considered medium difficult for the tea task and low for the drinks task.

Subtask interdependence

The sub-tasks here include: searching for information, creating a structured outline and encoding facts and evidence. All three are closely intertwined. What people find affects and is affected by their current understanding on the topic. Encoding requires searching and can often result in updating of the structure. However since there are just a few subtasks being simultaneous and closely coupled, the subtask interdependence of this task can be considered medium.

Overall

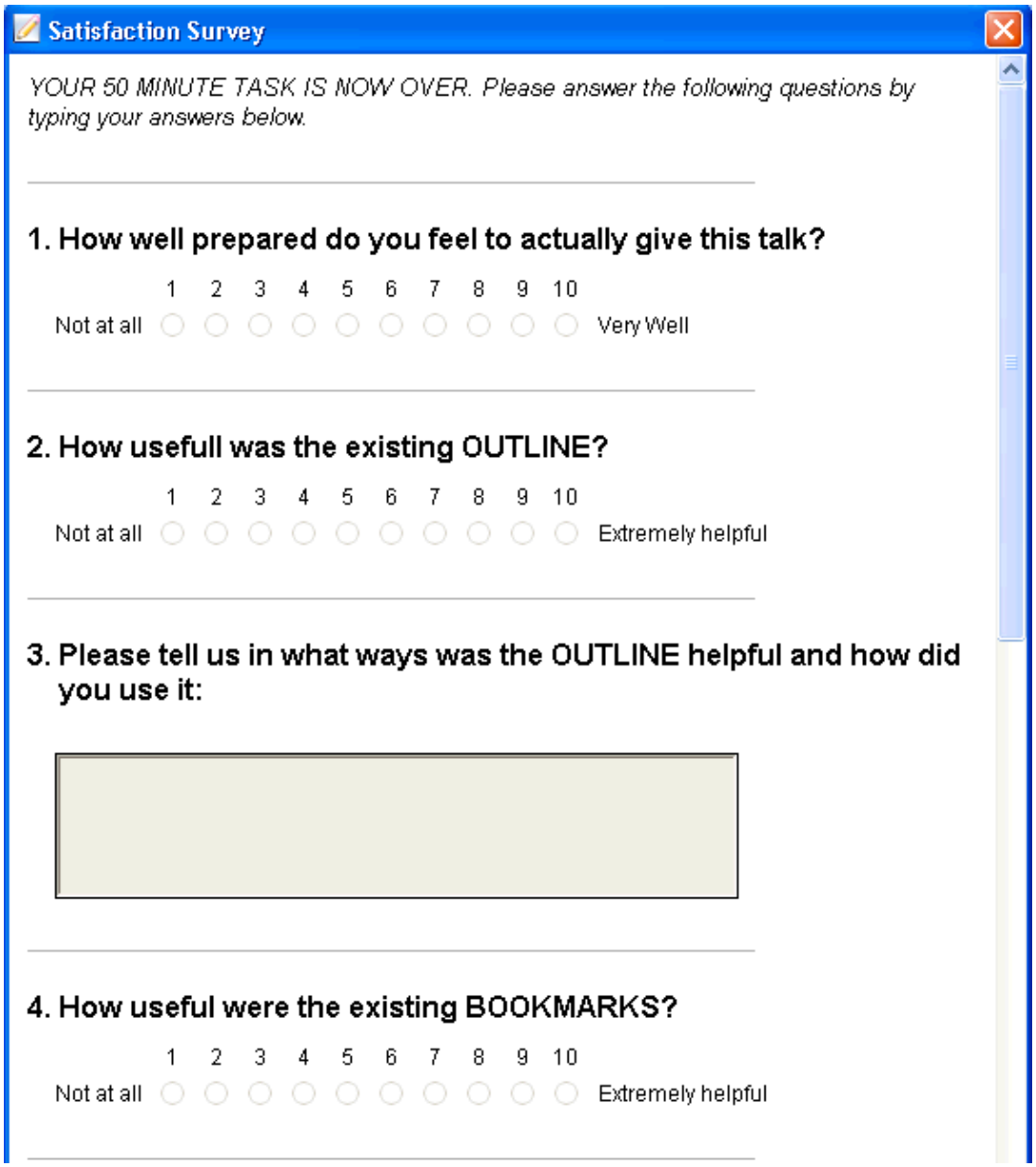
Task	**Repr novelty**	**Encoding difficulty**	**Broader applicability**	**Repr search space**	**Subtask inter-dependence**
Tea	low	medium	high	medium	medium
Drinks	high	high	high	low	medium

Summary of Attributes

The table above shows that both topics perform high on more than one attribute and low on only one of the attributes. They seem to be good candidates for studying sensemaking. The attributes also highlight important differences between the two topics. The biggest difference being how much representation novelty they involve. The drinks task has a high novelty requirement while the tea task has a low requirement.

Appendix J

Post Completion Survey for Topic Comprehension Task



5. Please tell us in what ways were the BOOKMARKS helpful and how did you use them:

6. Age

7. Gender

- Male
- Female

8. Education: Current degree major (eg MS in Library Science)

9. Education: Last Degree Major (eg BS in History)

Close

References

Anderson, J. R. (1993). Problem solving and learning. American Psychologist, 48, 35-44.

Argote, L. Organizational Learning: Creating, Retaining and Transferring Knowledge, Kluwer Academic Publishers, (1999).

Bhavnani S. K., Bichakjian C. K., Johnson, T. M., Little, R. J., Peck, F. A., Schwartz, J. L., and Strecher, V. J: Strategy hubs: Domain portals to help find comprehensive information. JASIST 57(1): 4-24 (2006).

Billman, D. O.; Bier, E. A. Medical sensemaking with entity workspace. 25th Annual ACM Conference on Human Factors in Computing Systems (CHI 2007); 2007 April 28 - May 3; San Jose; CA.

Carroll, J. (1998) Steven Pinker's Cheesecake For The Mind, Philosophy and Literature 22 (1998): 478-85.

Carroll, J.M. (2002) *Scenarios and Design Cognition*, IEEE Joint International Conference on Requirements Engineering (RE'02), E. Dubois and K. Pohl (ed.), IEEE Computer Society, Essen, Germany, 9-13 September 2002, pp. 3-5.

Chase, W. G., & Simon, H. A. (1973). Perception in chess. Cognitive Psychology, 4, 55-81.

Clark, H.H., & Brennan, S.E. (1991). "Grounding in communication." In L. Resnick, J. Levine, & S. Teasley (Eds.) Perspectives on socially shared cognition Washington, D.C.: American Psychological Association, pp. 127-149.

Clark. H. H., & Wilkes-Gibbs, D. (1986). Referring as a collaborative process. Cognition, 22. 1-39.

Constant, D., Kiesler, S. and Sproull, L. (1994) What's Mine is Ours, or Is It? A Study of Attitudes about Information Sharing, Information Systems Research, 5, 4, pp. 400-421.

Gregory B.S.C, Standardizing hand-off processes, AORN, Volume 84, Issue 6, December 2006, Pages 1059-1061, ISSN 0001-2092, DOI: 10.1016/S0001-2092(06)64003-9.

Dervin, B. Sense-Making Theory and Practice: An overview of user interests in knowledge seeking and use. (1998) *Journal of Knowledge Management*, 2(2), 36-46.

Dourish, V. Belotti, "Awareness and Coordination in Shared Workspaces", in Proceedings of CSCW `92, ACM Press, Toronto, Canada, pp.107-114, 1992.

Dunckek, K. On problem solving. Psychological Mono-graphs, 194S, 58(5, Whole No. 270).

Ericsson, K., & Simon, H. (May 1980). "Verbal reports as data". Psychological Review 87 (3): 215–251.

Funke, J. (1991). Solving complex problems: Human identification and control ofcomplex systems. In R. J. Sternberg & P. A. Frensch (Eds.), Complex problem solving: Principles and mechanisms (pp. 185-222). Hillsdale, NJ: Lawrence Erlbaum Associates.

Furnas, G. W. "Representational Change in Sensemaking,". Position Paper for Workshop on Sensemaking. CHI 2008, Florence, Italy.

Gioia, D. A. & Chittipeddi, K. (1991) Sensemaking and sensegiving in strategic change initiation *Strategic Management Journal* 12(6) pp. 433-448

Harper, R.H.R. and Hughes, J.A., "What a f-ing system! Send 'em all to the same place and then expect us to stop 'em hitting: Making Technology Work in Air Traffic Control," in Technology in Working Order, Routledge, London, 1993, 127--144.

Clinical Handover and Patient Safety Literature Review Report March 2005. Available at: http://www.safetyandquality.org/clinhovrlitrev.pdf (accessed, 12/30/2009).

Hutchins, E. (1995) "How a cockpit remembers its speeds," Cognitive Science, 19, 265-288.

Jeffries, R., Polson, P. G., Razran, L., & Atwood, M. E., (1977). A process model for Missionaries-Cannibals and other River-Crossing problems. Cognitive Psychology, 9, 412-440.

Johansen, R. (1988) "Groupware: Computer Support for Business Teams" The Free Press.

Kaplan, S. Weaver M.and French. R. M. (1990) Active symbols and internal models: Towards a cognitive connectionism. AI and Society, 4, 51-71.

Kiesler, S. & Cummings, J. What do we know about proximity and distance in work groups? A legacy of research. In P. Hinds & S. Kielser (Eds.), Distributed work (pp. 57-82). The MIT Press, Cambridge MA 2002

Kiesler CA (1971) The Psychology of Commitment: Experiments Linking Behavior to Belief. Academic Press, London, UK.

Klein, G., Moon, B.and Hoffman, R.R. "Making Sense of Sensemaking 1: Alternative Perspectives," Intelligent Systems, vol. 21, no. 4, 2006, pp. 70–73.

Krzanowski, W. J. (1988) Principles of Multivariate Analysis. A User's Perspective. Oxford.

Landrigan, P., (2007) Invited Article: The Handoff: A CriticalPoint of Vulnerability. In Special Issue "Reducing Risk During Handoffs" Forum 25(1), 8-9. http://www.rmf.harvard.edu/files/documents/Forum_V25N1.pdf. Accessed Jan 13, 2010.

Litzinger, A., Boehler R. A., Patient-oriented pharmacy on a special ward: results of a pilot project in Germany. Pharmacy World and Science., 1997. 19(2): p. 101-4.

Markus, M. L., 2001. Toward a Theory of Knowledge Reuse: Types of Knowledge Reuse Situations and Factors in Reuse Success, Journal of Management Information Systems, 18, 1 (Summer): 57-93.

Minsky, M., Steps toward artificial intelligence, Computers & thought, MIT Press, Cambridge, MA, 1995

Nelson, L., Held C, Pirolli, P., Hong, L., Schiano D, & Chi E., With a little help from my friends: examining the impact of social annotations in sensemaking tasks, Proceedings of the 27th international conference on Human factors in computing systems, April 04-09, 2009, Boston, MA, USA

Newell, A., and H. A. Simon. 1972. *Human problem solving.* Englewood Cliffs, NJ: Prentice Hall.

Olson, G. M. and Olson, J. S. (2001) Distance Matters. Human-Computer Interaction 15, 139-179.

Patterson , E.S. and Woods, D.D. Shift Changes, Updates, and the On-Call Architecture in Space Shuttle Mission Control, Computer Supported Cooperative Work, v.10 n.3-4, p.317-346, December 2001.

Pirolli, P. and Card, S. (2005). The sensemaking process and leverage points for analyst technology as identified through cognitive task analysis. In *Proceedings of International Conference on Intelligence Analysis*.

Polanyi, M. (1966): *The Tacit Dimension*, Routledge and Kegan Paul: London, UK.

Qu, Y. 2006 *Supporting Representation Construction in Sensemaking*. Doctoral Thesis. UMI Order Number: AAI3238064., University of Michigan.

Qu Y., Furnas G.W., Sources of structure in sensemaking. CHI Extended Abstracts 2005.

Reitman, W. R. (1966) Cognition and thought. An information processing approach. New York: John Wiley & Sons, Inc.

Rogers Y., Scaife M., External Cognition (February 1997). Available http://wwwv.cict.fr/cotcos/pjs/TheoreticalApproaches/ExtCogandRepr/ExtCogandReppaperRogers.htm

Rosch, E. (1975): "Cognitive Reference Points", *Cognitive Psychology* 7, 532-547.

Russell, D. M., Stefik, M. J., Pirolli, P., Card, S. K. (1993) "Cost structure of sensemaking" Proceedings of the Conference on Human Factors in Computing Systems - INTERACT '93 and CHI '93. Amsterdam, Neth. publ by ACM, New York, NY, USA: 269-276.

Schlienger, R.G., et al., Academic detailing improves identification and reporting of adverse drug events. Pharmacy World & Science., 1999. 21(3): p. 110-5.

Schein, E. (2004). *Organizational culture and leadership* (3rd ed.). San Francisco: Jossey-Bass.

Shrake, K.L., et al., Benefits associated with a respiratory care assessment-treatment program: results of a pilot study. Respiratory Care, 1994. 39(7): p. 715-24.

Suchman L., Constituting shared workspaces. In Y. Engestrom & D. Middleton (eds.) Cognition and Communication at Work. Cambridge University Press, Cambridge, MA, 1996.

Teasley, S., Covi, L., Krishnan, M. S. and Olson, J. S. (2000): How does Radical Collocation Help a Team Succeed? Proceedings of the 2000 ACM conference on Computer supported cooperative work 2000, Philadelphia, Pennsylvania, United States. pp. 339-346.

Weick, K. E. (1995) *Sensemaking in Organizations* Thousand Oaks, CA: Sage Publications.

Weick K., Sutcliffe K. and Obstfeld D., Organizing and the process of sensemaking, Organizational Science 16(4) (2005) 409–421.

Zwarenstein, M., Bryant, W., Interventions to promote collaboration between nurses and doctors (Cochrane Review). in Cochrane Database of Systematic Reviews. 2002. p. 16.