GROUP INFORMATION-SEEKING BEHAVIOR IN EMERGENCY RESPONSE

An Investigation of Expert/Novice Differences

Q. GU AND D. MENDONÇA

Information Systems Department, New Jersey Institute of Technology
Newark, NJ, USA
mendonca@njit.edu

Abstract: Emergencies—whether natural or technological, random or human-induced—may bring profound changes to organizations, the built environment, and society at large. These changes create the need for reliable information about the emergency and its impacts, and thus require responding organizations to seek and process information from an evolving range of sources. By understanding how skilled versus novice response personnel search for information in emergencies, we may begin to understand how to support and train for skillful information seeking in situations characterized by risk, time constraint, and complexity. This study develops a hypothesized model of information-seeking behavior in emergency response and evaluates it using data from expert and novice groups addressing simulated emergency situations. The results suggest that experts maintain breadth in the extent of their information seeking, despite increasing time pressure. Novices, on the other hand, decrease the extent of their search under increasing time pressure. Both expert and novice groups show a decreasing effort in information seeking; moreover, effort devoted to search for common and unique information decreases over time.

1. Introduction

Emergencies—whether natural or technological, random or human-induced—may bring profound changes to organizations, the built environment, and society at large. These changes create the need for reliable information about the emergency and its impacts, and thus require responding organizations to seek information from an evolving range of sources while tracking a possibly changing set of response goals.

I. Linkov et al. (eds.), Real-Time and Deliberative Decision Making.

In emergencies, as in many other situations, information needs drive decision makers' search for different types of information. Emergency situations differ from nonemergency situations in a number of ways, however [20, 22]. Time constraint forces decision makers to manage tradeoffs between the effort required to search and the anticipated value of information of various types. Indeed, in emergency situations, time spent on information seeking and other planning activities is time taken away from plan implementation. Emergencies also entail risks to life and property, adding to the need to make rapid but accurate decisions but also increasing the penalties associated with making the wrong decision or failing to make the right decision in a timely manner. Finally, emergencies may be complex, requiring coordination and shared responsibility across numerous organizations.

One approach to understanding how to train for and support skillful information seeking in emergencies is to examine differences in information-seeking behavior between novices and experts. This paper begins by reviewing the existing literature (Section 2) to develop a preliminary model of how conditions of risk, time constraint and emergency complexity may impact information-seeking behavior (Section 3). It then develops a set of hypotheses (Section 3) concerning how expert and novice information seeking may differ under these conditions and explores answers to these hypotheses by examining information-seeking behavior by experts and novices in a simulated emergency scenario (Section 4). The results are presented in Section 5 and discussed in Section 6, along with possibilities for future work in refining the proposed model.

2. Background and Related Research

Various factors may impact group information seeking during decision making. These include the degree of consensus of group opinion; whether the information is common, partially shared, or unique; public assignment of expert role; number of decision alternatives; decision deadline or time pressure; availability of a group support system; demonstrability of a fact's existence; and familiarity with the decision topic [7, 8, 18, 24, 25, 29, 30].

2.1. INFORMATION-SEEKING BEHAVIOR

Search may be characterized by its extent (i.e., how exhaustive is it) and nature (i.e., what is searched for) [6]. Information seeking is "the purposive seeking for information as a consequence of a need to satisfy some goal" [34]. Prior work [11, 16, 19] suggests that information seeking is a process driven by information needs for the fulfillment of particular tasks. Information seeking can be said to consist of setting goals, forming a search set, refining the search set, locating the desired information, and reviewing or evaluating found information. The information-seeking process exists within a context, and is influenced by such factors as environment, technology, individual characteristics, and task goals [26]. These influencing factors impact strategy selection, search efficiency, and search performance (i.e., the extent to which the search results satisfy the information needs and task goals).

Information seeking has also been characterized as dynamic and nonlinear [12, 32], "analogous to an artist's palette, in which activities remain available throughout the course of information seeking" [12]. Information seeking is not merely a step-by-step process: the loops of feedback and iterative activities happen anytime. Interaction between search processes, search outcomes, and the external context leads information seekers to adaptations that are reflected in their search patterns. Previous studies do not clearly explain how such changes happen over time, and how certain variables may impact these changes.

2.2. GRMOUP INFORMATION EXCHANGE AND USE

Prior work on information-seeking behavior has focused on how information seeking by individuals is influenced by environmental, technical, or personal characteristics [11, 16]. In a group context, decision makers from different professional domains can contribute their knowledge and cooperate to solve a task, and thus benefit from a larger pool of knowledge than might individual decision makers. The assumption is that group discussion will lead to the introduction of more relevant information. However, while availability of information is likely to be a prerequisite for high-quality group decisions [24], availability itself does not necessarily induce optimal decisions. This may be seen in how various types of information are used. From the perspective of group members, information may be common (if it is known to all group members before the discussion), partially shared (if it is known to part but not all group members), or unique (if it is held by one member before the group discussion) [7, 8, 25]. However, group members tend to discuss and think more about common information (i.e., information originally known to all group members) and less about unique information (i.e., information originally known to only one or a few members) [8, 29].

The relationship between information availability and group performance varies due to within-group processes. While information recall and information exchange lead to more information being used by groups, only when group members access, store, and utilize the information will it actually show its value in the decision-making process. These three activities are an integral part of every step in decision making, though their relative importance may change depending on the stage of the decision-making process.

2.3. TIME PRESSURE

In an emergency response situation, time is critical, since any time spent on decision planning is unavailable for decision execution. Time pressure may impact information-seeking behavior during decision making and problem solving in a number of ways [1, 9, 23]. Time pressure may impact decision makers' working rate and their confidence in judgments [1]. Under time pressure, decision makers may speed up their information processing and be more selective in choosing information to be processed. As time pressure increases, they may switch to simpler information search strategies and decision rules [33].

The impacts of time pressure on group information-seeking behavior may manifest in two ways. First, the information needs of the group will be more focused and the priorities of the information processed will change. Information seeking will be more directed towards task-related information in such situations [18]. Second, as with individuals, group members will use an "acceleration and filtration" strategy [18] by eliminating some options, accessing a smaller proportion of information, and accelerating their search by spending less time handling each item of information accessed. A hierarchy of these strategies exists in people's reactions to time pressure. Acceleration will be the first response to time pressure, and selection will most probably appear as the second reaction when acceleration is insufficient. If selection is still not sufficient, people switch information search strategies to meet their information needs within the time constraint [2].

Severe time constraint may lead decision makers to rely on information that is already on-hand. The group members' intention to enlarge the information pool would interact with their adoption of a filtration search strategy across the different stages of the decision-making process. The benefit of obtaining new information may not outweigh the risk of time delay under severely time-constrained conditions. The counterbalance of these two effects will determine which takes the dominant position in information seeking.

2.4. TASK DIFFICULTY

Task difficulty or complexity [10, 14, 31] can be defined in terms of the objective task characteristics contributing to the multiplicity of goals and ways to accomplish the goals [5]. Complex tasks are difficult by their nature, but difficult tasks may not always be complex. The point is that certain tasks can be difficult (i.e., require high effort) without necessarily being complex; in contrast, some tasks are difficult because they are complex.

Task difficulty is related directly to attributes that increase information load, information diversity, and/or rate of information change as follows [5]:

1. The presence of multiple potential ways to meet a desired goal
2. The presence of multiple desired goals to be attained
3. The presence of conflicting interdependence among ways to multiple goals
4. The presence of uncertain or probabilistic links among ways and goals

In emergency situations, task difficulty can be regarded as a function of time, risk, available resources, and changing sub-goals. Decreasing time and risks in the environment increases the rate of information change. Decreasing available resources requires additional information processing. As available time decreases, available resources—which are likely to be distributed over geographic space—also decrease, thus making certain solutions infeasible. Emergency responders must therefore devise alternative (possibly improvised) ways to solve the problem [25]. Third, multiple and possibly evolving goals increase information load. Given some criterion for efficiency (e.g., planning and executing within the decreasing available time), possible solutions need to be evaluated against it. In such cases, task difficulty grows according to the decreasing available resources and the decreasing feasible courses of action. Information processing requirements will increase substantially if the connection between potential decisions and desired outcomes cannot be established with sufficient certainty.

2.5. EXPERTISE

An expert could be a person with domain-specific knowledge or task-related experience, or both. Expertise can improve group performance by increasing each member's ability and judgment; task experience can improve group performance by facilitating problem recognition and utilization of relevant knowledge [13, 17].

The discovery of expert/novice differences has been instrumental in uncovering skills and knowledge that enable high performance. Such study has been found in a variety of areas, from individual physics problem solving [15, 28] to group decision making in complex tasks [1, 4]. Experts are expected to spend less time on a problem, to memorize more relevant information, and solve the problem faster than novices [6, 15, 28]. Moreover, expert/novice differences are also manifested as differences in confidence [28]. In time-constrained situations, experts may be more efficient in information filtering (i.e., separating relevant from irrelevant information) and exhibit more confidence about their choices. For example, a study on the decision making of air commanders in a dynamic environment under very limiting time constraints reveals that experienced commanders tend to make fewer decisions within a given time interval, and process additional information better than less-experienced commanders [1].

Differences are also expected in the information-seeking behaviors of experts and novices [27]. Experts' information-seeking behaviors are well organized according to sets of basic units while novices' are characterized by depth-first and breadth-first search, suggesting that experts utilize known facts more effectively than novices, since in the same circumstances novices may need more cues to solve a problem.

3. A Model of Group Information-Seeking Behavior in Emergency Response

Prior work on information seeking and the impact of risk, task complexity, and time pressure on the behavior of decision-making groups in emergencies is here integrated into a preliminary model (Figure 1). When decision makers at some time t are faced with a future deadline at time T, every minute spent on planning is one less minute available for plan execution.

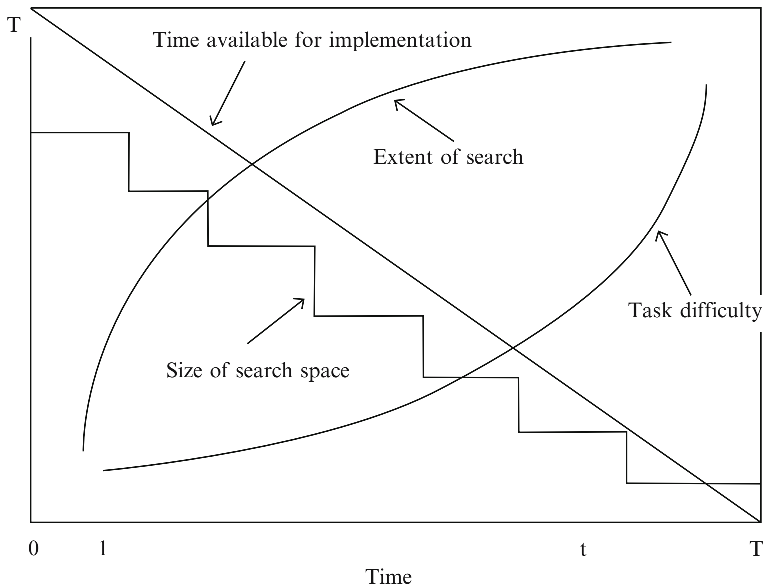

Figure 1. Model of information-seeking behavior.

Simultaneously, material and personnel resources available for responding to the event decrease, since they will typically have to be dispatched from one location to another. The number of plans (or courses of action) involving these resources decreases, thus reducing the size of the search space. As a result, a greater percentage of the resources—and therefore a greater percentage of the space—can be searched over time. In contrast, both the passage of time and the reduction in available resources contribute to increasing complexity and risk, thus making the problem of how to respond harder to solve. Consequently, response personnel are forced to "make do" with resources that are or can be made available in time. Task difficulty is inversely related to the number of available resources and the number of potential solutions.

The hypotheses that follow from this model are described below. Also included are hypotheses pertaining to the impact of expertise on information seeking, as well as hypotheses concerning the seeking of common versus unique information by groups.

3.1. H1: EXTENT OF SEARCH

The extent of search by groups could be considered from two perspectives. First, from the objective perspective, the size of the search space decreases over time because group members have fewer information sources to explore when approaching the deadline and thus are more likely to exhaust available sources. Second, from the subjective perspective, group members accelerate their search by spending less time examining each information source, leading to hypothesis H1.1:

H1.1: As time to implement decreases, the extent of search increases.

Domain knowledge and prior relevant experience can provide experts with a higher capability to deal with the emergency than novices. Under time constraint, experts are more confident in selecting the most relevant information and making decisions with a small amount of information, while novices may have to examine more information sources to enable decision making, leading to hypothesis H1.2:

H1.2: The search extent of novice groups will be greater than that for expert groups.

3.2. H2: NATURE OF SEARCH

The information-seeking process in emergency response is time critical. For two successive stages in the decision-making process (i.e., consideration set formation and final choice selection), information-seeking activities are likely to be more concentrated in the first stage than in the second one. As available time decreases, group decision makers are likely to devote more time to evaluating on-hand information and finalizing decisions, thus decreasing information-seeking activities. However, a preference for common information and the increase in time pressure may make search for common information increase but search for unique information decrease, leading to hypotheses H2.1 through H2.3:

H2.1: As time to implement decreases, search for common and unique information decreases.

H2.2: As time to implement decreases, search for common information increases.

H2.3: As time to implement decreases, search for unique information decreases.

The impact of time pressure is likely to be less for experts than for novices. Experts process additional information better than novices, and are less likely than novices to change their information-seeking strategies under time constraint, leading to hypothesis H2.4:

H2.4: As time to implement decreases, search for information (both common and unique) by groups of experts will change less than search for information by groups of novices.

4. Model Evaluation

We now turn to the design of a study used to investigate the proposed model of group information-seeking behavior in emergency response. The simulated emergency scenarios used in the study are described first, followed by the data description and the measures used in the model evaluation.

4.1. EXPERIMENT ENVIRONMENT

The data were drawn from a series of studies on group decision making in simulated emergency response scenarios [21]. Both novice and experienced groups of participants convened to work on two separate emergency response-related cases. Each group had five participants: one group coordinator (CO) acted as a facilitator and principal communicator with the decision support system and the others each represented one of four emergency services; i.e., Police Department (PD), Fire Department (FD), Medical Officer (MO), and Chemical Advisor (CA). The group's task was to allocate resources to the incident location in order to meet the goals of the emergency response. The layout of a typical experimental session is shown in Figure 2. All experimental sessions were videotaped for later transcription and analysis.

Figure 2. Layout of the experimental session.

Each group had two ways to access information during the emergency response process:

1. Track the information via the computer support system
2. Acquire information from group members via conversations

Figure 3 shows the interface of the computer support system used by the CO in Case One Phase Two. The map at the left displays the locations of resources and the incident location ("Z"). Group members obtained information for a site by clicking on its icon. A list of the equipment available at the site was displayed in the lower left. Some information was unique: each non-CO member could view only the resources at the sites controlled by that role. For example, FD could learn about sites that had firefighting equipment, but not about sites that had medical equipment. Messages were also tailored to the individual services, and could only be seen by the representatives of those services. Some information was global: all members had access to a description of the incident and all members could access information on resources (such as gymnasiums and supermarkets) that were not controlled by a particular service. Also, the CO had accessibility to information about all sites. In Figure 3, sites O, Q, L, and M are alternate resources; all other sites

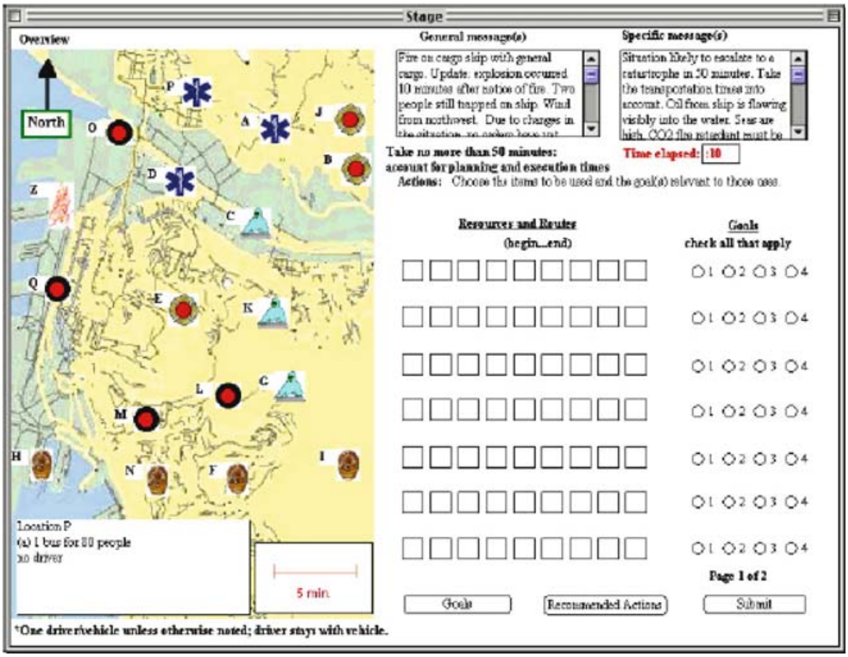

Figure 3. Computer interface for simulated emergency in Case One.

(sites A to K, N, and P) are controlled by individual services. Individuals therefore had incomplete information locally but complete information globally.

Groups were given 50 min to plan and execute courses of action to accomplish the goals of the response. In other words, every minute spent on decision planning was one less minute available for decision execution. As time passed, certain resources therefore became infeasible. Simultaneously, the situation was likely to escalate, so that problem difficulty increased due to increasing situation severity and decreased response capability. Decision support was provided to some groups when certain resources became unavailable but alternate resources could be used. The system recommended procedures that had to be assembled to form a solution. Participants elected either to accept, reject, or modify these procedures. Unsupported groups received no assistance on either case.

4.2. PARTICIPANTS

Novice participants were college students enrolled in undergraduate business or engineering programs, while expert participants were students at the U.S. National Fire Academy. Both novice and expert groups were randomly

TABLE 1. Number of observations under each condition.

		Expert	Novice
Case 1	Support	3	2
	No support	4	2
Case 2	Support	3	2
	No support	4	2

assigned to the support or no support condition in each case, with each group providing two observations via a balanced incomplete block design. The number of observations in each condition is shown in Table 1.

4.3. TASKS

Two simulated emergency cases drawn from actual accidents were used in this study. Case One concerns a cargo ship fire with an oil spill; Case Two concerns a collision between two ships with a resulting chemical emission. Each case solved by the group has two phases. In Phase One, the group is told only to plan for the activities necessary to address the emergency and is given 20 min to do so. The group then works to develop courses of action to address the emergency situation and submits these, along with the goals they wish to achieve, through the CO. Following a brief pause, Phase Two begins: the group is informed that certain resources have become unavailable but that other, nonstandard resources (specified on-screen) can be used. The time-constrained element of the experiment is also introduced: participants are told that activities have to be planned-for and completable within 50 min, at which time an event with potential for catastrophic impact is anticipated to occur. Given the nature of the Phase Two time constraint, it is essential that participants account simultaneously for planning and execution times. Phase Two (and the case) conclude once the CO has submitted the group's courses of action and corresponding goals. Each participant then fills out a questionnaire assessing their individual opinions about the course of action submitted in Phase Two. This sequence is repeated for Case Two. Participants then fill out a questionnaire assessing their professional qualifications and overall impression of the experiment. An informal debriefing session concludes the experiment, which lasts approximately 2 h.

4.4. DATA SOURCES

Data used to analyze group information-seeking behavior are stored in computer logs that contain records of which resources were examined by which group members at which time. When a group member clicked on a site to discover what resources were available, the site label and time of click were written to the log file, along with other data such as the session, group and participant role. All records are time-synchronized for analysis. Sample records from one log file are shown in Table 2. Stream indicates the category of each event in the logs. Records concerning the information-seeking process are identified with a p (for process) in the Stream column, and are here the object of analysis. (Records denoted with m mark the boundary between cases and phases; records with a d mark the point at which decisions were made.) As an example, the second record shows that participant CA in group A of session NFA1 clicked site C at 7:33:36 p.m. (148,132 ticks, where 1 tick equates to 1/60 s).

Of interest in this study is information-seeking behavior in situations requiring executing and planning at the same time. Consequently, data from Phase Two are used in the analysis.

4.5. MEASURES

Four measures are used in addressing the hypotheses, as shown in Table 3. The extent of search (M1) is measured by the proportion of search space explored (i.e., the proportion of all sites clicked by a group). The nature of search is measured by three parameters: the number of clicks on common information sites (M2), the number of clicks on unique information sites (M3), and the number of clicks on both common and unique information sites (M4). M2, M3, and M4 reflect the effort devoted to locating common, unique, and all information in the information-seeking process.

According to the measures defined above, the hypotheses proposed are summarized in Table 4.

TABLE 2. Sample records from the log file.

Session	Group	Participant	Stream	Time	Ticks	Tape_T	Event
NFA1	A	CA	m	7:33:12 p.m.	146,676	164835	“BeginC1P1”
NFA1	A	CA	p	7:33:36 p.m.	148,132	171262	“C”
NFA1	A	CA	p	7:33:44 p.m.	148,596	172035	“G”
…							
NFA1	A	CA	d	7:45:51 p.m.	192,245	292784	“Ga,1,0100”
NFA1	A	CA	m	7:45:51 p.m.	192,255	292800	“EndC1P1”

TABLE 3. Information-seeking measures.

Aspects of seeking behavior	Variable	Name	Description
Extent of search	M1	Extent	$\frac{\#of\ sites\ clicked\ within\ every\ \text{minute}}{\#of\ sites\ available\ within\ every\ \text{minute}}$ 100%
Nature of search	M2	#Common	Average number of clicks on alternative resources within every minute made by each group
	M3	#Unique	Average number of clicks on non-AR sites within every minute made by each group
	M4	#Total	Average number of clicks on all sites within every minute made by each group

TABLE 4. Summary of hypotheses.

Name	Testing hypotheses
H1.1	$M1_{t1} < M1_{t2}$, t1 < t2
H1.2	$M1_E < M1_N$*
H2.1	$M4_{t1} > M4_{t2}$, t1 < t2
H2.2	$M2_{t1} < M2_{t2}$, t1 < t2
H2.3	$M3_{t1} > M3_{t2}$, t1 < t2
H2.4	$|M4_{t1} - M4_{t2}|_E < |M4_{t1} - M4_{t2}|_N$ t1 < t2

* E – Expert groups, N – Novice groups.

5. Results

5.1. EXTENT OF SEARCH

All hypotheses are investigated for each case. The starting time of the session is 0 min and the ending time is 50 min. Data for evaluating the hypotheses are presented in Figures 4 through 9. In each figure, the horizontal axis represents time, which means the range of the time allowed for the task (i.e., 50 min). As Phase Two of each case progressed, the available time to implement decreased from 50 to 0 min. The groups had to consider the time remaining for execution since dispatching the available resources to the incident location takes some time. Dispatching time varies due to the distances between the resources' locations and the incident location. For example, in Case 1 (see map in Figure 3) the nearest sites to the incident location Z are O and Q, from which the resources can be delivered to Z within 5 min; the furthest site is I, from which the resources can be delivered within 23 min. Thus at the beginning of a phase (Time 0), all 17 sites in Case 1 were reachable for the group. As time passed, the reachable sites decreased. At Time 28, for example, resources at Site I could not be used in a feasible course of action since Site I was out of range. At Time 46, the remaining time to implement is only 4 min; even the resources at the nearest sites (O and Q) cannot be dispatched to the incident location Z. The size of the search space after Time 46 became 0. The change of the size of search space over time is shown in Figure 4. Decreased search-space size reduces the number of potential solutions, and further makes the task more difficult to complete.

All possible courses of action that can be taken using the available resources to meet the response goals are calculated and shown in Figure 5. In Case 1, the number of courses of action drops after the first 20 min of the task. At the beginning (Time Zero), there are 41,739 possible courses of action for implementation; at Time 20, the number of courses of action drops to 261. Case 2 is similar in this regard. The difference is that at the beginning

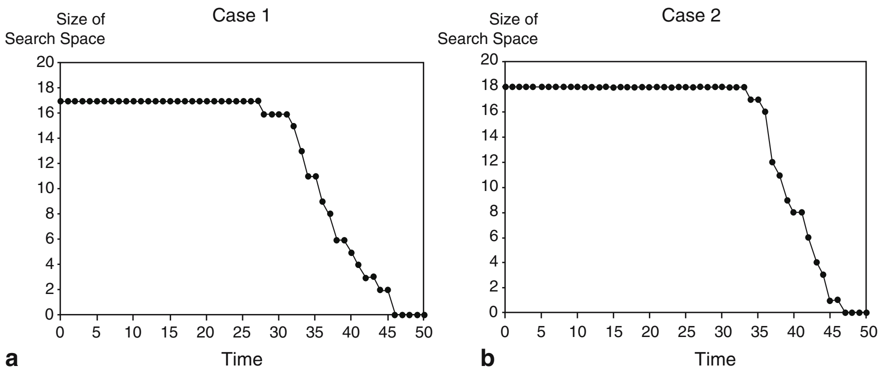

Figure 4. Size of search space over time in (a) Case 1 and (b) Case 2.

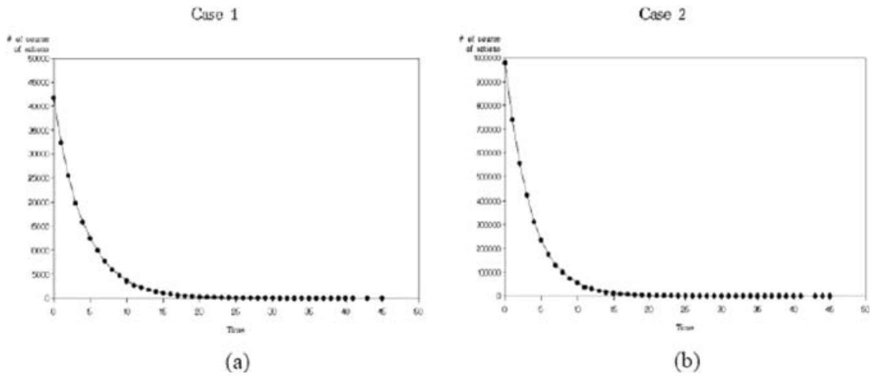

Figure 5. Number of courses of action over time in (a) Case 1 and (b) Case 2.

there are 980,128 possible courses of action, which are 23.5 times the number in Case 1, making Case 2 more complex in this sense. As discussed previously, task difficulty is inversely related to the number of potential solutions. The reductions in the number of courses of action lead to reductions of the number of potential solutions, thus increasing the task difficulty.

With the increase in task difficulty, the number of sites explored by group participants shows a decreasing trend in both Cases 1 and 2 (Figure 6). The decreasing trend is more obvious during the period when the number of courses of action drops dramatically (i.e., from Time 0 to Time 20). After that the number of sites does not vary greatly. Figure 6 also shows that novice groups explored more sites than expert groups during the first period.

The extent of search is computed according to the number of sites explored and the size of search space at every minute (Figure 7). On average

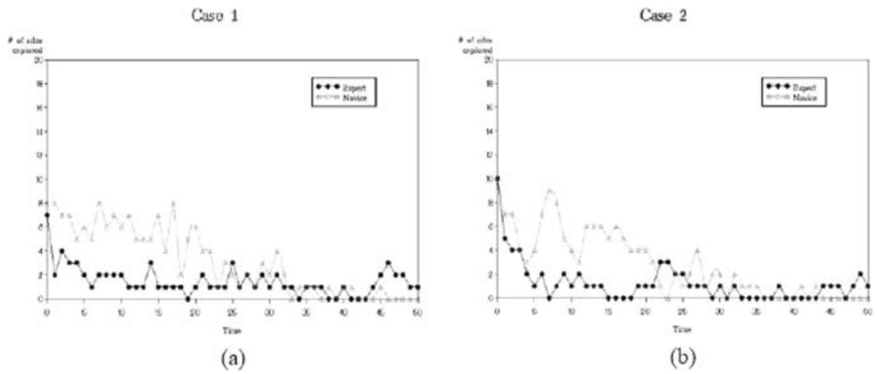

Figure 6. Number of sites explored by expert and novice groups over time in (a) Case 1 and (b) Case 2.

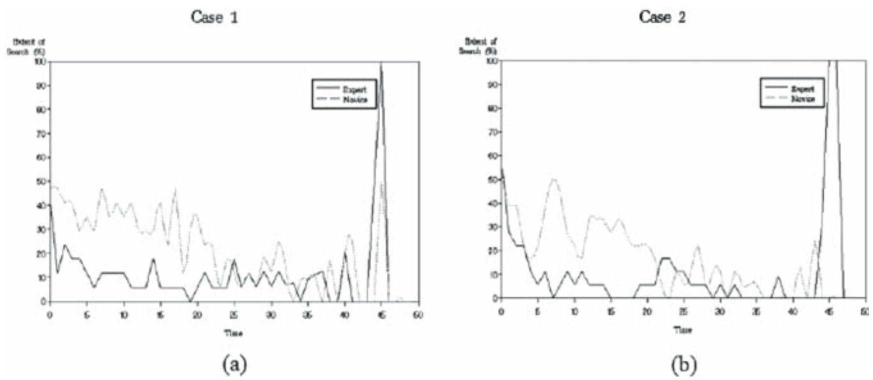

Figure 7. Extent of search between expert and novice groups over time in (a) Case 1 and (b) Case 2.

in Case 1, the extent of search by novice groups is 20.9% and the extent of search by expert groups is 11.0%. In Case 2, the extent of search by novice groups is 16% and the extent of search by expert groups is 10.7%. Novice groups have a higher extent of search than expert groups. Moreover, the higher extent is obvious in the first period of time (before Time 25). Near the end of the task expert groups show a 100% extent, which means they clicked all available sites at that time while novice groups show a 0% extent, which means they gave up the information search.

5.2. NATURE OF SEARCH

Group participants' search behavior for common, unique, and all information is shown in Figure 8.

Search for all information (both common and unique) displays an obvious decreasing pattern in both cases. Search for common information also shows a decreasing pattern in both cases. However, the search trend for unique information is not consistent: it decreases in Case 1 but persists almost at the same level in Case 2. The average number of clicks on each type of information in both cases is listed in Table 5. In Case 1, there are more

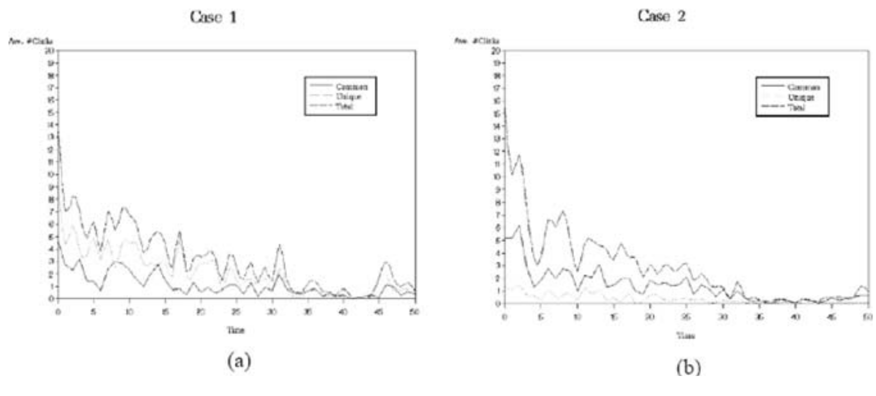

Figure 8. Clicks on common, unique, and all information sites over time in (a) Case 1 and (b) Case 2.

TABLE 5. Mean number of clicks on different types of information.

	Case 1	Case 2
Total	3.24	2.95
Common	1.11	1.37
Unique	2.13	0.36

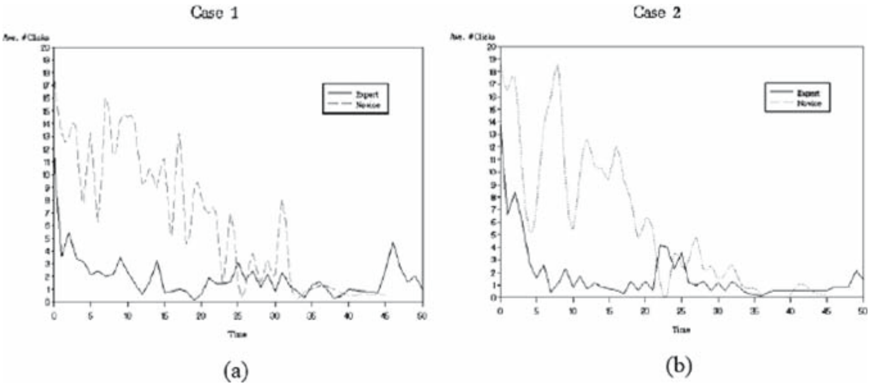

Figure 9. Clicks on information sites by expert and novice groups over time in (a) Case 1 and (b) Case 2.

clicks on unique information than on common information; the reverse is true in Case 2: there are fewer clicks on unique information than on common information.

Information search differences between expert and novice groups are shown in Figure 9. The number of clicks by novice groups is higher than for expert groups. Novice groups clicked more frequently in the first period of time and their number of clicks dropped fast as the deadline approached. Expert groups clicked quite often at the very beginning of the task, but most of the time they clicked at a relatively consistent level.

5.3. SUMMARY OF RESULTS

In summary, the extent of search displays a decreasing trend as time to implement decreases, and novice groups exhibit a higher extent of search than expert groups do. The only exception is in the last several minutes, when novice groups gave up their search and expert groups still explored all available sites, though there were only one or two sites available. As to the nature of search, the number of searches for all (both common and unique), common, and unique information decreases as time to implement decreases. Novice groups clicked much more for information acquisition than expert groups did during the first 25 min. As time passed, the number of clicks by novice groups converged with the number of clicks made by expert groups. These results are summarized in Table 6.

TABLE 6. Summary of the results.

Hypotheses		Description	Results
Extent of search	H1.1	$M1_{t1} < M1_{t2}$, t1 < t2	Rejected
	H1.2	$M1_E < M1_N$	Supported
Nature of search	H2.1	$M4_{t1} > M4_{t2}$, t1 < t2	Supported
	H2.2	$M2_{t1} < M2_{t2}$, t1 < t2	Rejected
	H2.3	$M3_{t1} > M3_{t2}$, t1 < t2	Supported
	H2.4	$\|M4_{t1} - M4_{t2}\|_E < \|M4_{t1} - M4_{t2}\|_N$ t1 < t2	Partially supported

6. Discussion

The results suggest that the extent of search does not increase over time. On the contrary, the extent decreases as time to implement decreases, though this decreasing trend is not obvious in expert groups. As discussed in Section 3, it was assumed that the decreasing size of the search space and the acceleration strategy the groups adopted in time-constrained situations would lead to an increase in search extent. However, two other factors likely may have impacted search behavior. First, task difficulty increases over time in emergency response. The number of potential courses of action decreases over time, leading to a decrease in the number of potential solutions. Because task difficulty is inversely related to the number of potential solutions and positively related to the risks involved in the emergency response, the task will become more difficult over time. This increased difficulty leads groups to spend more time processing and evaluating on-hand information. Moreover, when the task becomes harder, both expert and novice groups tend to be more purposeful [28]: that is, the scope of their search tends to shrink in order to meet response goals. Second, considered in a broader framework of information-seeking behavior, the activities of information search, processing, and use are weighted differently in the different stages of the emergency response process. Groups' efforts will be devoted to locating information more at the beginning of the decision-making process for later filtration and final choice.

Another interesting finding is that little change has been observed in the nature and extent of search behavior of expert groups over time. Experience on prior emergency cases provides experts with skills to approach a similar emergency task. Striking changes in the extent of search only happened at the very beginning and very end of the process. An explanation for the high extent of search at the beginning of the process is that risks involved in the escalating catastrophe drive experts to learn more facts to eliminate uncertainty. An explanation to the high extent of search near the end is the extremely small size of the search space (one or two sites only). Under such

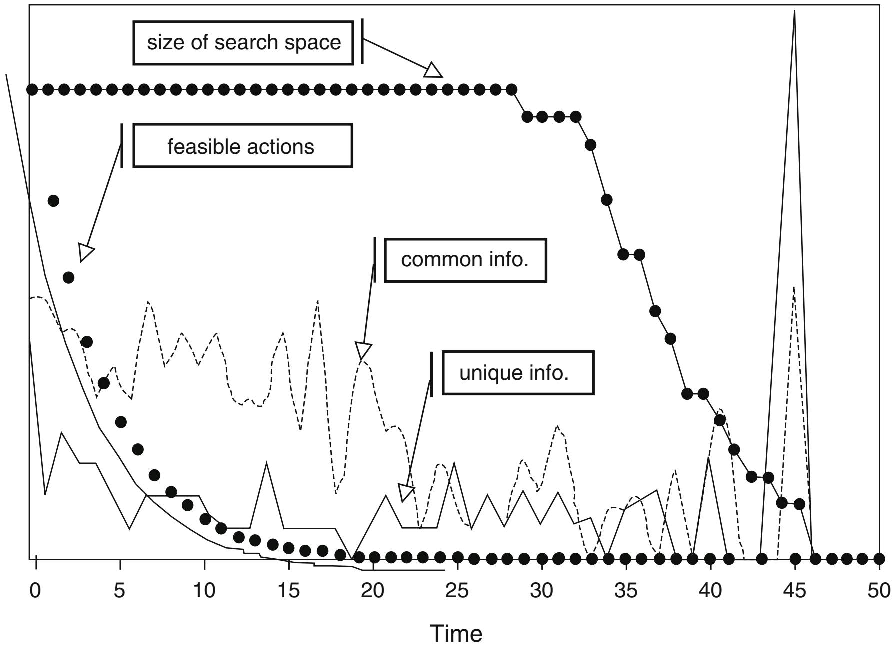

Figure 10. Revised model of information-seeking behaviors.

condition, even with severe time constraints it is easy for groups to click all sites in a very short time. Novice groups, as expected, explored a higher proportion of the available sites and sought more information than expert groups did during the emergency response process. Figure 10 shows a revised model incorporating the data from the present study.

In the simulated environment used here, the size of the search space and the number of potential courses of action decrease over time, thus increasing task difficulty. The extent of search does not show a consistent increasing trend. A number of explanations are possible. In general, the extent of search is likely to decrease in an emergency, but striking changes may be expected at the beginning and the very end, owing either to surprise at the event's sudden onset or the urgent need to complete the response before some deadline. Such changes will therefore be influenced by the risk arising from the environment and time pressure imposed on the decision groups.

7. Conclusion

Emergencies create the need for reliable information about the initiating event and its impact on society and the built environment. Response personnel may have to coordinate to seek and process information in a timely manner in order to make informed decisions about how to meet goals for the response. Understanding group information-seeking behavior is thus critical for improving group performance in emergency response situations. A computer-simulated environment was used to develop refinements to an initial model of how risk, time constraints, and expertise can influence group information-seeking behavior. The results suggest that both expert and novice groups display a decreasing trend for the extent of search as time to implement decreases, and novice groups exhibit a higher extent of search than expert groups do. Searches for both common and unique information decrease over time.

One suggestion of this research is that time pressure impacts patterns of information seeking both for expert and novice groups. Information from the same resource may not be the same as time passes; meanwhile, groups spend a decreasing amount of time and effort on information seeking. The cost of spending limited effort on unavailable information resources may be too high for emergency response groups. A second suggestion concerns the effort groups devote to seeking unique and common information. Novice groups may spend more effort locating both unique and common information than expert groups. So under the condition in which unique information is critical for decision making with time constraint, decision support systems may be of great value for decision makers in targeting search.

Future work in this area includes the consolidation of the proposed model of information-seeking behavior and the investigation of the combined impacts of time, expertise and decision support on group information-seeking behavior. It may also be advantageous to examine how learning takes place during information seeking in emergencies [30], thus contributing further to our knowledge of the factors that contribute to differences in expert/novice performance.

Acknowledgments

This material is based upon work supported by the U.S. National Science Foundation under Grant Nos. CMS-9872699 and CMS-0449582.

References

1. Ahituv, N., Igbaria, M. and Sella, A. “The effects of time pressure and completeness of information on decision making,” Journal of Management Information Systems, 15(2), 153–172, Fall 1998.
2. Ben Zur, H. and Breznitz, S. J. “The effect of time pressure on risky choice behavior,” Acta Psychologica, 47, 89–104, 1981.

3. Benbasat, I. and Taylor, R. N. "Behavioral aspects of information processing for the design of management information systems," IEEE Transactions on Systems, Man, and Cybernetics, 12(4), 439–450, July–August 1983.
4. Bonner, B. L., Baumann, M. R. and Dalal, R. S. "The effects of member expertise on group decision-making and performance," Organizational Behavior and Human Decision Processes, 88(2), 719–736, July 2002.
5. Campbell, D. J. "Task complexity: a review and analysis," Academy of Management Review, 13(1), 40–52, 1988.
6. Chase, W. G. and Simon, H. A. "Perception in chess," Cognitive Psychology, 1, 33–81, 1973.
7. Dennis, A. R., Hilmer, K. M., Taylor, N. J. and Polito, A. "Information exchange and use in GSS and verbal group decision making: effects of minority influence," 30th Hawaii International Conference on System Sciences, Maui, Hawaii, USA, 2, pp. 84–93, January 03–06, 1997.
8. Dennis, A. R. "Information exchange and use in group decision making: you can lead a group to information, but you can't make it think," MIS Quarterly, 20(4), 433–457, December 1996.
9. Durham, C. C., Locke, E. A., Poon, J. M. L. and McLeod, P. L. "Effects of group goals and time pressure on group efficacy, information-seeking strategy, and performance," Human Performance, 13(2), 115–138, 2000.
10. Earley, C. "The influence of information, choice and task complexity upon goal acceptance, performance, and personal goals," Journal of Applied Psychology, 70, 481–491, 1985.
11. Ellis, D. and Haugan, M. "Modeling the information seeking patterns of engineers and research scientists in an industrial environment," Journal of Documentation, 53(4), 384–403, 1997.
12. Foster, A. "A nonlinear model of information-seeking behavior," Journal of the American Society for Information Science & Technology, 55(3), 228–237, February 2004.
13. Grønhaug, K. and Haukedal, W. "Experts and novices in innovative unstructured tasks: the case of strategy formulation," Creativity and Innovation Management, 4(1), 4–13, March 1995.
14. Huber, V. "Effects of task difficulty, goal setting and strategy on performance of a heuristic task," Journal of Applied Psychology, 70, 492–504, 1985.
15. Larkin, J., McDermott, J., Simon, D. P. and Simon, H. A. "Expert and novice performance in solving physics problems," Science, 208, 1335–1342, 1980.
16. Leckie, G. J., Pettigrew, K. E. and Sylvain, C. "Modeling the information seeking of professionals: a general model derived from research on engineers, health care professionals, and lawyers," Library Quarterly, 66(2), 161–193, 1996.
17. Littlepage, G., Robison, W. and Reddington, K. "Effects of task experience and group experience on group performance, member ability, and recognition of expertise," Organizational Behavior and Human Decision Processes, 69(2), 133–147, February 1997.
18. Maule, A. J., Hockey, G. R. J. and Bdzola, L. "Effects of time-pressure on decision-making under uncertainty: changes in affective state and information processing strategy," Acta Psychologica, 104, 283–301, 2000.
19. Meho, L. I. and Tibbo, H. R. "Modeling the information-seeking behavior of social scientists: Ellis's study revisited," Journal of the American Society for Information Science & Technology, 54(6), 570–587, 2003.
20. Mendonça, D. "Decision support for improvisation in response to extreme events," Decision Support Systems 43(3) 952–967, 2006.
21. Mendonça, D., Beroggi, G.E.G. and Wallace, W.A. "Decision support for improvisation during emergency response operations," International Journal of Emergency Management, 1(1), 2001.
22. Mendonça, D. and Wallace, W.A. "A cognitive model of improvisation in emergency management," IEEE Systems, Man and Cybernetics: Part A, 37(4), 547–561, 2007.

23. Ordonez, L. and Lehman Benson, I. "Decisions under time pressure: how time constraint affects risky decision making," Organizational Behavior and Human Decision Processes, 71(2), 121–140, August 1997.
24. Parks, C. D. and Cowlin, R. A. "Acceptance of uncommon information into group discussion when that information is or is not demonstrable," Organizational Behavior and Human Decision Processes, 66(3), 307–315, June 1996.
25. Propp, K. M. "Information utilization in small group decision making: a study of the evaluative interaction model," Small Group Research, 28(3), 424–453, August 1997.
26. Ramirez, A. Jr., Walther, J. B., Burgoon, J. K. and Sunnafrank, M. "Information-seeking strategies, uncertainty, and computer-mediated communication: toward a conceptual model," Human Communication Research, 28(2), 213–28, April 2002.
27. Saito, H. and Miwa, K. "A cognitive study of information seeking processes in the www: the effects of searcher's knowledge and experience," Second International Conference on Web Information Systems Engineering, Kyoto, Japan, 1, pp. 0321–0330, 2002.
28. Simon, D. P. and Simon, H. A. "Individual differences in solving physics problems," In R. S. Siegler (Ed.), Children's Thinking: What Develops? Hillsdale, NJ: Erlbaum, 1978.
29. Stasser, G., Vaughan, S. I. and Stewart, D. D. "Pooling unshared information: the benefits of knowing how access to information is distributed among members," Organizational Behavior and Human Decision Processes, 82(1), 102–116, 2000.
30. Stasser, G., Taylor, La. A. and Hanna, C. "Information sampling in structured and unstructured discussions of three- and six-person groups," Journal of Personality and Social Psychology, 57, 67–78, 1989.
31. Taylor, M. S. "The motivational effects of task challenge: a laboratory investigation," Organizational Behavior and Human Performance, 27, 255–278, 1981.
32. Wai-yi, B. C. "An information seeking and using process model in the workplace: a constructivist approach," Asian Libraries, 7(12), 375–390, 1998.
33. Weenig, M. W. H. and Maarleveld, M. "The impact of time constraint on information search strategies in complex choice tasks," Journal of Economic Psychology, 23(6), 689–702, December 2002.
34. Wilson, T.D. "Human information behavior," Information Science, 3(2), 49–56, 2000.