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Cognition in the woods: Biases in probability judgments by search and rescue planners

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Abstract

A type of emergency decision-making which has not received research attention is the police search for a lost person in a rural or wilderness area. For many such incidents, decisions concerning where to search for the lost subject are made by a planning team, each member of which assigns probabilities to the various hypotheses about where the subject might be located, including the residual hypothesis that the subject is somewhere else entirely, that is, outside of the designated search area. In the current study, 32 adult males with search planning experience were asked to assign probabilities to a fictional lost person incident. It was hypothesized, according to support theory (Tversky & Koehler, 1994), that subjects who first considered the five possible scenarios accounting for how the subject could have left the search area—i.e., unpacked the residual hypothesis—would subsequently increase their probability estimate of the global hypothesis that the missing subject was *not* in the designated search area, compared to those subjects who unpacked the focal hypothesis. This hypothesis was confirmed. We also found considerable evidence for *subadditivity*, as most subjects estimated higher summed probabilities for the individual scenarios accounting for the focal and residual hypotheses, respectively. The potential negative consequences of such unpacking effects during a lost person incident were discussed, and possible means of mitigating such effects were described.

Keywords: decision making, support theory, subadditivity, emergency management.

1 Introduction

The past two decades have seen a growing interest in the manner in which emergency responders make decisions in the field. For example, Klein (1993) and his colleagues have studied the decision-making processes of various types of emergency managers, such as fire commanders, who are required to initiate an appropriate response to their respective emergencies as early in their incidents as possible. These researchers have found that the emergency managers whom they studied rarely consider alternative options simultaneously in an analytic fashion. Rather, the manager's decision making follows the pattern termed "satisficing" (Simon, 1955), in which the first satisfactory option that comes to mind is selected. The expertise of emergency managers, according to Klein (1993), is reflected in their ability to quickly categorize an emergency according to their experience, and to imagine a scenario in which a particular course of action toward resolving the emergency could be successfully implemented.

One type of emergency response not studied by Klein and his associates is the police search for a person lost in a large scale rural or wilderness area, a topic which has only recently become a focus of research by behavioral scientists (Cornell & Hill, 2006; Heth & Cornell, 1998). A variety of people become the targets of such searches, including hunters, hikers, anglers, and other outdoor enthusiasts, as well as children who wander away from camp or rural homes, and elderly people suffering from senile dementia (see Koester, 2008, for additional categories). Organized searches for lost people usually come under the authority of public safety personnel such as county sheriffs, regional or state police officers, conservation officers, or park rangers. In North America, the search management system prescribed by the National Association for Search and Rescue is nearly universally recognized as the "best practice" model for organizing a lost person incident (Hill, 1997), and is itself an application of the Incident Command System endorsed by the U. S. Federal Emergency Management Agency for managing all emergency incidents (NIMS, 2008). Below, the system will be described as it pertains to decision making processes and other cognitive variables, particularly subjective judgments of probability.

A lost person incident begins with a decision that the subject of a missing person report may be spatially disoriented in a large rural environment, such as a forested area. Such incidents are usually considered to be highly urgent, as factors related to health, age, weather, or natural hazards may threaten the subject's safety. In most U.S. states and Canadian provinces, the officer who is given authority for the incident has at his or her disposal any num-

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ber of resources for assistance, including other officers, personnel from other agencies, and civilian search and rescue volunteers, including field searchers, search dog handlers, and search coordinators. Even before searchers arrive at the location where the search will be conducted, a search management team will be appointed for the first operational period (usually 12 hours). Upon arrival at the scene, the incident commander—in consultation with other members of the search management team—will set in motion routinized efforts to quickly locate the missing subject, such as tasking searchers or canine teams to track the missing person from the "place last seen" (PLS). As well, efforts to confine the subject to the search locale will usually be implemented, such as setting up trail blocks some distance away from the PLS. After these first steps are initiated, however, the incident commander will confer with the search management team in a concerted planning session, which is strikingly unlike the "satisficing" process described by Klein. Environmental psychologists Heth and Cornell (2006), who have studied the decision-making processes of search managers, cogently described a typical planning session:

Unlike most paramilitary operations, there is a surprising amount of consensual decision making. Experienced search and rescue command teams believe that no one person can authoritatively state the best course of action. Like the naval navigation teams described by Hutchins (1995), there are fixed responsibilities and social hierarchies when operations are executed, but in contrast to an authoritarian and decisive control, experienced search managers seek consultation and develop their hypotheses and plans modestly with one to four others. During these discussions, the search and rescue planning team makes the search tractable by parsing the environment and developing scenarios of what likely happened to the lost person. Thereafter, search management consists largely of iterative task assignments in which individuals or teams are dispatched to check these possibilities. The methodology is Bayesian: the planning team will revise its priorities on the basis of field reports from the search teams, along with clues, eyewitness reports, and similar evidence uncovered during search activities (Heth & Cornell, 2006).

Specifically, the planning session involves identifying a primary search area in which search activities will be conducted, and then dividing this larger area into any number of smaller segments to which single search resources (e.g., dog teams or search crews) can be tasked. Once the segments are identified and drawn on the planning map, an attempt is made to prioritize the segments in order to ensure that those areas most likely to contain the missing subject are searched relatively early in the incident. Prioritization is accomplished by requiring the search planners to assign estimates of probability to each of the segments, termed "probability of area" (POA). As well, the methodology involves assigning some nontrivial probability to the "rest of the world" (ROW), that is, all of the area outside of the designated search area, which will likely not be searched during that operational period (Bownds, Ebersole, Lovelock, & O'Connor, 1991). The individual probability judgments are then combined and averaged, yielding a planning POA that reflects the consensual probabilities that the subject may be located within each segment as well as the ROW. As mentioned in the quote above, the methodology is Bayesian, in that the initial subjective probabilities are recomputed according to Bayes theorem as segments are searched and the lost person is not located (see Appendix A). Because the ROW, by definition, does not receive search assignments, it will necessarily grow larger in POA as the search proceeds and negative information decreases POA in various segments within the search area. Indeed, search coordinators are advised to monitor the POA of the "rest of the world", particularly with respect to decisions about expanding the search, which is accomplished by partialing out new segments formerly outside of the designated search area (Hill, 1997).

As noted by Heth and Cornell (2006), the process of developing a search plan resembles the interlocking cognitive efforts contributed by members of a navigation crew of a U.S. Navy ship as described by Hutchins (1995) in his book, *Cognition in the Wild.* Hutchins applied the term "distributed cognition" to describe such mutual and complementary efforts of individual specialists using a host of cognitive "artifacts" such as maps, charts, electronic instruments, and computers. Similarly, Fischhoff and Johnson (1997) used the term "distributed decision-making" to refer specifically to command-and-control type operations in which decisions are made by two or more individuals. Although during search operations numerous artifacts may be employed, such as maps, software, statistical data, and lost person behavior "profiles" (Hill, 1997; Koester, 2008), the emphasis in this article will be on the subjective probabilities initially assigned to the search area and which become the starting point for the subsequent Bayesian computations made as the search proceeds.

As stated earlier, the methodology for prioritizing the search area requires planners to make subjective estimates of probability for each segment in the search area, plus the ROW. It is assumed that such judgments are based on the planners' SAR experience and acquired expertise, plus reference to actuarial data tabulated from previous lost person incidents, such as how far from the PLS various types of lost people tend to travel before being located (Koester, 2008). Unfortunately, much research on decision processes would appear to cast doubt on the ability of planners to make valid probability judgments, as the ability to render unbiased assessments of probability for uncertain events has been challenged by Tversky & Koehler's (1994) support theory (see also Rottenstreich & Tversky, 1997). Briefly, support theory maintains that subjective probability judgments are based *not* on the likelihood of events themselves, but on *descriptions* of events. Thus, the same event may be seen as more or less likely depending on the manner in which it is described to those making the judgments. For example, people estimate significantly higher chances of dying from heart disease, cancer, or other natural causes, than simply from *any* natural cause (Tversky & Koehler, 1994). This *unpacking effect* is said to occur whenever people are asked to consider the disjoint components of an uncertain event (that is, various possibilities that can cause the event) rather than merely the event itself. In other words, the more explicitly an event is described, the more likely it will be judged to occur. Various explanations for unpacking have been proposed, including the tendency for an explicit inclusion of specific causes of an effect to increase confidence in that cause (Koehler, 1991), or to remind people of possibilities they might have overlooked (Rottenstreich & Tversky, 1997).

A side effect of unpacking is *subadditivity*. According to Tversky and Koehler (1994), when people are asked to make a global judgment, such as the probability of dying from an unnatural cause, they tend to base their judgments on a representative or typical case, without necessarily delineating, in this example, the possible types of unnatural causes. However, unpacking the event to be judged (e.g., homicide, fatal accident, drowning) not only leads to higher estimates of probability, but frequently in total probabilities greater than 100% (Cahan, Gilon, Manor, & Paltiel, 2003; Koehler, 2000; Tversky & Koehler, 1994). The term subadditivity therefore refers to the fact that probability judgments of the globally described event are less than the sum of that assigned to the unpacked version of the event.

Another important consideration in support theory pertains to those occasions when people judge the relative probabilities of two or more mutually exclusive hypotheses. For example, if there are three suspects in a crime, A, B, and C, the hypothesis that A is the culprit (and the associated probability that A did it) is termed the *focal* hypothesis, while the possibility that someone other than A is guilty (B, C, or some unknown X) is called the *residual* hypothesis. In this case, the set of possibilities—either A or not-A (symbolized as $\bar{A}$)—is *discrete* (that is, either hypothesis must necessarily be true). In support theory, each hypothesis under consideration will have varying degrees of support, each depending on the manner in which the hypothesis is described (for example, whether or not it is unpacked). When comparing the relative probabilities of the focal and residual hypotheses, support for the former ($s[A]$) will decrease the estimated probability for the latter ($s[\bar{A}]$), as seen in the formula:

$$P(A, \bar{A}) = \frac{s(A)}{s(A) + s(\bar{A})}$$

where $P(A, \bar{A})$ refers to the probability that A rather than $\bar{A}$ is true.

Bringing the discussion back to the search and rescue planning task, we can describe the hypothesis that the missing subject is in the designated search area as the focal hypothesis, while the possibility that he or she is somewhere else—the ROW—as the residual hypothesis. A typical application of the POA methodology described earlier, using the support theory terminology, is as such. After some discussion, the individual planners proceed to individually unpack the search area into smaller segments (all of which represent separate hypotheses about where the subject might be), and finally to allocate some probability to the residual hypothesis, that is, that the person is in none of those segments. At this point, we can begin to form our own hypotheses as to why this methodology sometimes fails.

According to Hill (1997), the single most common reason why a lost person is not found in a reasonable period of time is that the victim had traveled out of the designated search area and that search planners had not extended the search into the ROW soon enough. A similar problem is apparently encountered by the U.S. Coast Guard in their conduct of maritime SAR, such as searching for missing vessels at sea. Described as "scenario lock," it is said to occur "when planners become fixated on a particular. . . scenario to the exclusion of all others" (Frost, 1999). It is possible, if not indeed likely, that planners in these emergency situations are experiencing unpacking effects which tend to keep them unreasonably "locked" to their focal hypotheses. In other words, in considering all the many possibilities that could account for the missing person (or vessel at sea) to be in any of the search segments, planners estimate a consensus POA that is inflated for the focal hypothesis (that the target is in the designated search area) while underestimated for the residual hypothesis (that the target is somewhere else). Even if a Bayesian procedure is used for reevaluating POA as the search proceeds, the eventual decision to reject the focal hypothesis and to start extending the search into the ROW is delayed, to the detriment of the lost person's safety. For example, in the application of the Bayesian formula as applied to SAR (see Appendix A), POA's are updated each time a segment is searched and the subject is not found. With each iteration, the POA of the ROW grows slightly larger. However, when the initial POA of the "rest of the world" (the residual hypothesis) is unrealistically low, it will take considerably longer for the Bayesian updating to raise its POA to a non-trivial level, thereby delaying the extension of the search.

1.1 The current research

In this study we asked inland search planners to consider a fictional lost person incident in which a deer hunter apparently became lost in the woods while hunting. Subjects made initial estimates of POA to the (packed) designated search area as well as the (packed) ROW. Subsequently, half of the subjects unpacked the segments contained within the search area, while the remaining half unpacked scenarios which would result in the lost person having left the search area and entering the ROW. They subsequently made new estimates of POA to the search area and ROW. As such, the study was unlike previous studies in support theory, in that subjects made before and after probability judgments, rather than merely providing one omnibus judgment after being asked to unpack the focal hypothesis.

We hypothesized simply that subjects who unpacked the hypothesis that the lost subject was *not* in the designated search area (the residual hypothesis) would significantly increase their POA to the ROW, compared to subjects who unpacked the conventional hypothesis: that he was indeed somewhere inside the search area. We also expected that unpacking would lead to subadditivity in probability judgments, with cumulative POA totaling more than global (packed) judgments.

2 Method

2.1 Subjects

Subjects were 32 adult males recruited at a state search and rescue conference, attended by members of volunteer SAR teams, government emergency measures managers, and military search and rescue personnel. Ages ranged from 33 to 61, with a mean age of 39.4 years. Overall, subjects had been involved in SAR for a mean of 13.5 years and had participated in 75.8 SAR incidents. All subjects had previously completed formal training in search planning, as described earlier, including the assignment of subjective probabilities to segments in the search area and ROW. As a group, they had participated in a mean of 25.8 search incidents in the capacity of planner, although such experience varied considerably, with a range of 1 to 200 lost person incidents.

2.2 Procedure

Subjects were interviewed individually at the experimenters' booth in the exhibitors area of the conference center. The study was introduced as a "map problem" in which the participant's opinions about the fictional lost person's whereabouts were of interest. Subjects were assured that the incident was fictional and that there were therefore no correct answers as to where the "lost person" was actually located.

Subjects were shown a 1:50,000 topographical map of a fairly level, forested wilderness area with many streams and lakes (Appendix B). They were told that the target of the search was a 27-year-old deer hunter who was reported missing by his hunting partner. An X was positioned near the center of the map to designate the place where he had last been seen. A 29 square kilometer "primary search area" was indicated on the map by a solid line drawn with a colored marking pen. The search area was almost entirely determined by the edges of streams, lakes, and other watercourses. The participant's attention was drawn to the fact that there was a limited number of routes by which the missing hunter could have exited the search area without attempting the nearly impossible task of crossing water.

Half of the subjects had been randomly assigned to a *focal hypothesis* group, while the remaining half consisted of the *residual hypothesis* group. The (second) map presented to subjects in the focal hypothesis group showed the primary search area now sectioned into five segments. The (second) map shown to subjects in the residual hypothesis (or ROW) group did not contain segments, but now had five lettered locations where it was possible for the lost person to have left the search area and entered the "rest of the world". The locations were identified and described for the participant. The two maps were otherwise identical (see Appendix B for the scripts used in the procedure).

Before proceeding to unpack either the focal or residual hypotheses, all subjects first made general assignments of probability of area to both the (packed) primary search area and the ROW. In order to control for order effects, half of each group first assigned POA to the search area and then the ROW, while the remaining half assigned POA in the reverse order. After these initial probabilities were recorded, subjects in the focal hypothesis group then proceeded to assign POA to each of the five segments, while subjects in the residual hypothesis group assigned probabilities to each of the five possible scenarios by which the missing hunter could have left the primary search area.[1]

Following the assignment of POA to either the search area or the ROW, subjects repeated their assignments of

[1] We recognize the fact that these probabilities do not pertain to equivalent events: subjects in the focal hypothesis group were asked to estimate the subject's geographic location, while subjects in the residual hypothesis group made judgments based on possible behavioral scenarios. We reasoned that the expected unpacking effects should not be affected by these differences.

probability of area to both the focal and residual hypotheses.

3 Results

We defined an *unpacking effect* as referring to those occasions when a participant increased their assignments of probability to their respective hypotheses (focal or residual, depending on their experimental condition) after unpacking that hypothesis. We defined *subadditivity* as the assignment of summed, unpacked POA that was higher than their initial probability judgment for the focal or residual hypothesis, respectively. For example, if a participant initially assigned 75% POA to the search area (the focal hypothesis), then proceeded to assign a total of 90% POA to the five segments contained within the search area, then he or she has demonstrated subadditivity. Generally, we found significant evidence of both unpacking and subadditivity.

3.1 Unpacking effects

Overall, before the unpacking manipulation, subjects assigned a mean of .80 (*SD* = .16) to the designated search area, and .17 (*SD* = .12) to the "rest of the world". After unpacking either the search area or the ROW, overall mean probabilities remained virtually unchanged, with a mean of .81 (*SD* = .14) to the search area and .18 (*SD* = .13) to the ROW. However, as predicted, an analysis of change scores revealed that subjects who unpacked the residual (ROW) hypothesis, compared to those who unpacked the focal hypothesis, significantly increased their probability estimates that the lost person had left the search area, F (1,28) = 4.753, p = .038, η_p^2 = .145. As a group, subjects who unpacked the residual hypothesis subsequently increased their probability estimates to the "rest of the world" by over 4%, while those who had unpacked the focal hypothesis actually decreased their POA estimates to the ROW by nearly 3%, suggesting that their judged likelihood that the lost person was in the targeted search area had been enhanced (see Table 1).

It should be noted, however, that unpacking effects were shown by only 11 of the 32 subjects, or 34% of the sample. This observation raised the question regarding the source of the significant unpacking effect. Although we cannot answer this question fully, we can largely rule out the possibility that highly experienced subjects are less likely to show the effect. We performed a median split, dividing planners with high experience (15 or more incidents in the role of planner, *M* = 48.25) from those with relatively low experience (10 or fewer incidents, *M* = 3.4). We found that highly experienced planners were if anything *more* likely than low-experienced planners to show unpacking effects. Specifically, 8 of the 16 highly experienced planners demonstrated unpacking, while only 3 of the 16 low-experienced planners showed unpacking. Moreover, 5 of the 8 highly experienced planners who demonstrated unpacking effects were in the residual hypothesis condition ("the subject is not in the designated search area"). These results indicate therefore that the tendency to increase probability judgments to the residual hypothesis, after unpacking its components, was demonstrated mostly by the highly experienced search planners, although the difference was not statistically significant.[2]

3.2 Subadditivity

Twenty-five of the 32 subjects (78%) demonstrated subadditivity, that is, proceeded to assign more total probability to the individual segments (focal hypothesis group) or ROW scenarios (residual hypothesis group) than they had initially assigned to the search area or ROW, respectively, before the unpacking manipulation. Generally, subadditivity was demonstrated by both the focal hypothesis and residual hypothesis groups. Subjects who unpacked the focal hypothesis attributed higher summed probabilities to the five segments, *M* = 1.07 (*SD* = .33), than they had originally assigned to the search area, *M* = .82 (*SD* = .14). This difference was statistically significant, $t(15)$ = 3.14, p = .007. Similarly, subjects who unpacked the residual hypothesis—that the subject had entered the ROW—assigned higher summed probabilities to the five scenarios accounting for his having left the search area, *M* = .72 (*SD* = .58), compared to their original estimated probabilities, *M* = .19 (*SD* = .13). This difference was also statistically significant, $t(15)$ = 3.72, p = .002. Although the increase in POA for the residual hypothesis group (*M* = .52, *SD* = .58) seemed considerably higher than that of the focal hypothesis group (*M* = .25, *SD* = .32), the difference was not statistically significant, $t(30)$ = 1.61, p = .118. Also, the subadditivity scores of highly experienced planners (*M* = 0.42, *SD* = 0.59) were not significantly higher than those of the low-experienced group (*M* = 0.36, *SD* = 0.43), $t(30)$ = 0.346, p = .732.

4 Discussion

The planning process exhibited by a search management team could be described as what Hutchins (1995) terms "socially distributed cognition" from which an emergent decision is intended to be superior to any of the solutions proposed by individual planners. For such a process to work, suggests Hutchins, there should be a "diversity of

[2] Additional statistical tests using various continuous measures of experience were in the same direction and likewise not significant.

Table 1: Pre- and post-test mean probability judgments of Focal- and Residual-hypothesis groups (SD's in parenthesis).

Group	Search area 1	Search area 2	ROW 1	ROW 2
Focal	.81 (.14)	.85 (.13)	.16 (.13)	.14 (.10)
Residual	.78 (.17)	.78 (.14)	.19 (.17)	.22 (.14)

Note: Headings with "1" indicates pre-test, while "2" indicates post-test (after unpacking).

interpretations" of the available evidence, with specific limitations placed upon the degree to which individuals can be allowed to persuade others to adopt a particular interpretation. "By averaging the POA of several or more people with varying types of experience and points of view", wrote Hill (1997), "the consensus method [of search planning] will tend to counter the influences of individual biases and tendencies to underestimate or overestimate probabilities" (p. 115).

Unfortunately, as the results of the current study indicate, the consensus method of developing a search plan does not appear to adequately address one particular bias, the unpacking effect (Tversky & Koehler, 1994), that is, the tendency to increase the subjective probability of an hypothesis after considering the evidence that supports it. Of particular note is the finding that 50% of the search planners who considered five scenarios supporting the residual hypothesis—that the missing subject was not in the designated search area—subsequently assigned significantly higher probabilities to the "rest of the world", compared to their first assessment. Conversely, 27% of those subjects who unpacked the five components of the focal hypothesis proceeded to show increased confidence in their initial assessments. This latter finding would seem to contribute to the "scenario lock" described by Frost (1999), and the failure to extend the designated search area at an appropriate time (Hill, 1997).

Although the experiment had not been designed to assess the role of expertise in search planning, we did find that the most experienced planners in the sample (averaging 48 SAR incidents in the role of planner) were if anything *more* likely than were less experienced planners to show unpacking effects, especially in the residual-hypothesis condition. This tentative finding was unexpected and raises interesting questions about the possible effect that expertise might have in the reassessment of a global hypothesis after unpacking its components. The fact that five of the eight highly experienced planners who unpacked the residual hypothesis ("the subject is outside the search area") subsequently changed their minds and increased their probability estimates to "the rest of the world", is difficult to interpret without a measure of *correspondence*, i.e., the degree to which this reconsideration may or may not lead to improved probability judgments.

On the other hand, highly experienced planners were no more likely than those with less experience to show *subadditivity* in their probability estimates. Most subjects (78%) in this experiment demonstrated subadditivity, that is, proceeded to assign higher summed probabilities to the five scenarios than they had initially made to the packed, global hypothesis. Indeed, in some cases, summed probabilities exceeded 100%, thereby replicating previous studies of support theory (Cahan et al, 2003; Koehler, 2000; Tversky & Koehler, 1994). For example, Cahan et al, 2003, found that 65% of the physicians in their study demonstrated subadditivity when estimating the various causes of chest pain in a hypothetical patient. Similarly, Redelmeier, Koehler, Liberman, & Tversky (1995) found that their sample of physicians, asked to estimate the probabilities of various prognoses for a hypothetical patient with heart disease, provided summed probabilities averaging 164%.

As stated earlier, subadditivity appears to result from unpacking a global hypothesis, with the subjective probability of each component hypothesis growing as the evidence is considered. Although algorithms which correct for subadditivity are included in search management software such as CASIE III (Bownds et al, 1991; see also Bownds et al, 1994 for a discussion of the method for correcting subadditivity), such software cannot correct the unpacking effect itself, that is, the tendency to inflate the initial probabilities as a result of unpacking a global hypothesis.

We have stated that overconfidence in the focal hypothesis—that the missing person is somewhere in the designated search area—may lead to a kind of scenario lock, resulting in inflated subjective probabilities that may delay the expansion of the search area into the "rest of the world," even when the Bayesian methodology for updating probabilities is applied. We might propose as a solution for such overconfidence that the method of assigning POA be altered such that planners first unpack the residual hypothesis rather than the focal one. That is, after defining a designated search area, in which the subject is believed to be located, the planners could then proceed to consider the possibility that their focal hypothesis is incorrect, and to look for evidence which could in fact disprove it. After unpacking the ROW, planners could then proceed to assign probabilities to the segments within the search area, in the usual manner. As demonstrated in the present study by subjects in the residual hypothesis condition, this may likely lead to more realistic probabilities assigned to components of the focal hypothesis. As described, this "what if I'm wrong?" approach to decision making is similar to the so-called "crystal ball" technique and the "prospective hindsight" approach found by various researchers to significantly decrease overconfidence in a focal hypothesis (e.g., Mitchell, Russo, & Pennington, 1989; Koriat, Lichtenstein, & Fischoff, 1980; Veinott, Klein, & Wiggins, 2010).

On the other hand, it is possible that such a radical change in procedure could conceivably lead in some cases to *underconfidence* in the focal hypothesis (Griffin & Tversky, 2002), causing planners to assign probabilities to the designated search area that are too low. This could lead to an equally decremental impact on the overall search plan, causing the searchers to abandon the original search area much too soon. Indeed, victims are often missed by the first and even second search resource to pass their way (Hill, 1997), and some victims, such as small children and adults suffering from senile dementia, often require a nearly exhaustive search of their locale before they can be found (Koester, 2008). One possible solution might simply be a compromise, that is, to balance the planning process such that half the planners unpack the search area in the conventional manner, while the remaining half proceed to unpack various scenarios which could account for the subject having entered the "rest of the world". However, further research on probability estimates by search planners should be conducted before such recommendations can be made, including, we suggest, studies of the "calibration" or relative accuracy of their judgments (Koehler, Brenner, & Griffin, 2002).

We conclude this discussion by returning to the topic of emergency management, as raised earlier. For the most part, research on emergency decision making has been dominated by the work of Klein and his colleagues (e.g., Klein, 1993, 1998, 2008). His "Natural Decision Making" (NDP) approach, which emphasizes the expertise of a single decision maker, such as a fire commander, does not seem to apply very well to the planning stage of a SAR incident, in which a group of planners by necessity must prioritize various options. Indeed, he has been critical of what he terms the "heuristics and bias" approach of Kahneman and Tversky, arguing that such biases are "reduced or eliminated if we study people with expertise working in natural settings" (Klein, 1998). To the extent that the search planners in the current study could be described as having some degree of expertise, and that the map problem resembles those which they encounter in actual incidents, we propose that our findings demonstrate that emergency managers can indeed make decisions that are something less than rational, perhaps routinely. This is not to say that Klein's NDP approach does not apply to SAR. It is very likely that many of the initial actions of first-responding search coordinators arriving on the scene may well adhere to NDP, as they make urgent decisions regarding which trails to search or where to set up confinement (Hill, 1997). We are suggesting rather that when these same search managers meet with other planners, sometime after the initial response, and begin assigning probabilities to various scenarios, that a different decision-making model applies, one which is described by the tenets of support theory.

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Appendix A: Bayes Theorem for shifting POA

Step 1: Find the new POA of a particular segment (X) that has just been searched.

$$POA_{new}\ X = \frac{(1 - POD\ X) \times POA_{old}\ X}{1 - [(POD\ X) \times POA_{old}\ X]}$$

Step 2: Find the new POA for each remaining (not-X) segment (Y)—including the ROW—as a result of X having been searched.

$$POA_{new}\ Y = \frac{POA_{old}\ Y}{1 - [(POD\ X) \times POA_{old}\ X]}$$

Notes on terminology:

POA_{new}: the new or “shifted” POA after segment X is searched.

POA_{old}: the old POA for the segment, prior to segment X being searched.

$POD\ X$: the probability of detection by which segment X was searched. (Probability of detection is a measure of the thoroughness of the search, or the likelihood of finding the lost person if he or she had actually been in the area being searched.)

(Source: Hill, 1997)

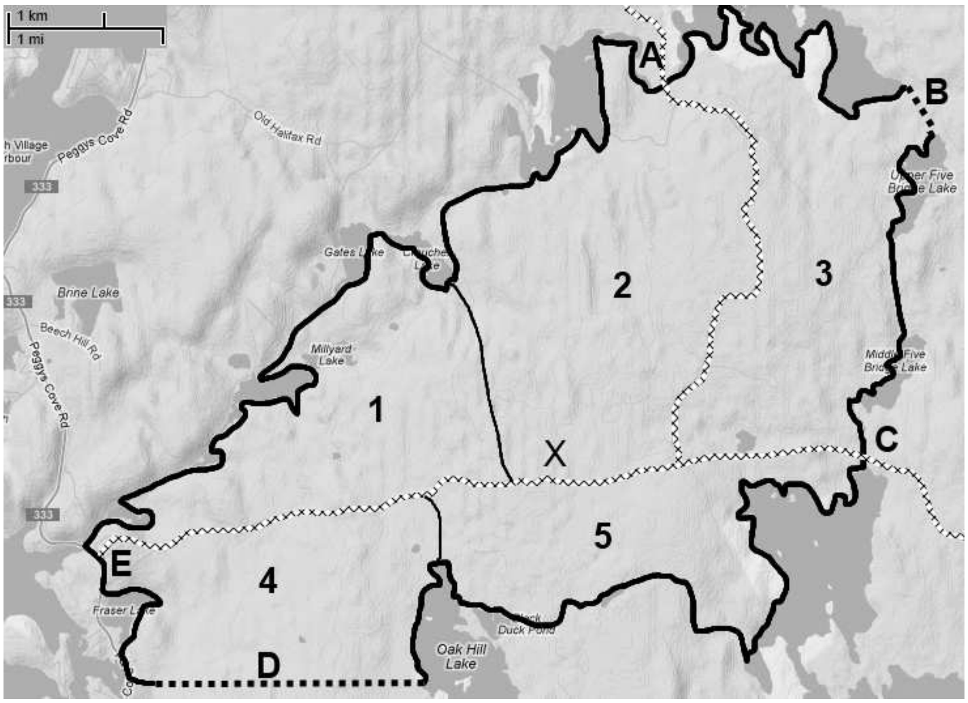
Appendix B: The map problem

Initial POA judgments

All subjects were initially shown a map containing only the defined search area and the two trails, without segment boundaries or ROW scenarios. They were told,

> This is a 1:50,000 topo map of a wooded area of Nova Scotia. As you can see, it’s mostly level terrain with some low hills, and lots of ground water. In this scenario, a 27-year-old deer hunter is reported missing by his hunting partner. The subject is fairly well prepared for the weather and is dressed in hunter orange. It’s October. The temperature is 5 degrees Celsius and there has been some recent rain. The ground is still damp and the streams are high and difficult to cross. The hunters parked their car on the highway at the western head of the trail [indicate on map]. They walked east on the trail for several kilometers, then decided to split up—the subject heading north and the partner going south. Here’s the point where the partner last saw the subject [indicate X on map]. They

Figure 1: Grey-scale compilation of the three maps used in the study (original maps were in color). The thick outer border defines the primary search area. The cross-hatched, horizontal line starting at “E” and passing through “C”, is a major trail bisecting the area. A second trail extends vertically from the first trail and passes through “A”. The two narrow (vertical) lines are streams serving as segment boundaries. The dotted lines are artificial boundaries emplaced by search teams using colored forestry tape. The X in the center of the map represents the position where the missing hunter was last seen.



split up at 4 p.m., and the plan was to hunt for another hour, then meet on the trail at the point where they separated. An hour later, the partner returned to the trail but did not find his friend there. After waiting until darkness—about 6 p.m.—the partner walked out to the highway and called the Royal Canadian Mounted Police. The RCMP were told that the subject had a compass, but no flashlight. The subject had limited woods experience.

The searchers arrived at about 7 p.m. This is the way the search managers on the scene defined the primary search area. Notice that most of the boundary is defined by streams, rivers, and lakes, although it was necessary to put down an artificial perimeter on the south with flagging tape [indicate on map], as well as one in the northeast between two lakes [indicate on map], and a trail that travels east out of the area [indicate]. So you see there are still some places where the subject could have left the area and entered the “rest of the world”.

What I’d like you to do is to image that you are one of the search planners for this incident, setting search priorities by assigning probabilities. So let’s begin. Consider a scale of 0 to 100, with 100 meaning a perfect probability, and 0 being no possibility. What do you think is the chance that the subject is inside/outside the primary search area at that time? What, then, is the chance that the subject is inside/outside the primary search area?

Half of the participants first made “inside” estimates, while the remaining half first made “outside” judgments.

Focal hypothesis condition

After making initial POA judgments to both the primary search area and ROW, subjects who made POA judgments to the focal hypothesis (the lost person is inside the search area) were shown a second map with the search area divided into 5 segments (numbered 1 to 5). No information about the residual hypothesis scenarios (letters A to E) was included. They were told,

> This is how the area was divided into five segments. I’ll describe each of the segments and ask you to estimate the probability the

subject would be found within each segment. Again, please use a scale of 0 to 100, with 100 meaning a perfect probability.

Segment 1.
Let's consider the possibility that the subject is located somewhere in Segment 1. As you can see, this segment is defined by the watercourse in the west and north, a stream on the east, and the trail to the south [indicate on map]. Have a look at the map and tell me what you think is the probability that the subject is in Segment 1.

Segment 2.
Now, let's consider the possibility that the subject is located somewhere in segment 2. This segment is defined by the watercourse in the north, a stream on the west, a trail to the east, and the trail to the south [indicate on map]. Have a look at the map and tell me what you think is the probability that the subject is in Segment 2.

Segment 3.
Now, let's consider the possibility that the subject is located somewhere in Segment 3. This segment is defined by the watercourse in the north and east, a trail on the west, and the trail to the south [indicate on map]. Have a look at the map and tell me what you think is the probability that the subject is in Segment C.

Segment 4.
Now's, let's consider the possibility that the subject is located somewhere in Segment 4. This segment is defined by the trail to the north, a highway and watercourse on the west, a stream on the east, and the flag line on the south [indicate on map]. Have a look at the map and tell me what you think is the probability that the subject is in Segment 4.

Segment 5.
Now, let's consider the possibility that the subject is located somewhere in Segment 5. This segment is defined by the trail to the north, a stream on the west, and watercourses on the east and south [indicate on map]. Have a look at the map and tell me what you think is the probability that the subject is in Segment 5.

Residual hypothesis condition

After making initial POA judgments to both the primary search area and ROW, subjects in the residual hypothesis condition (the subject is in the 'rest of the world') were shown a second map that contained the 5 ROW scenarios (lettered A to E), without segmentation of the search area. They were told,

> Although the search planners had defined the primary search area, there is always the possibility that the subject could have wandered out of the search area and into the 'rest of the world'. They identified five different ways that this could have happened. I'll describe those ways and ask you to estimate the probability of each. Again, please use a scale of 0 to 100, with 100 meaning a perfect probability.
>
> *Scenario A.*
> Let's consider the possibility that the subject left the search area through Location A . As you can see, this trail [indicate on map] extends to the north, crosses a stream, and exits the search area. Have a look at the map and tell me what you think is the probability that the subject left the search area near Location A.
>
> *Scenario B.*
> Now, let's consider the possibility that the subject left the search area through Location B. As you can see [indicate on map], Location B is an unconfining area to the northeast, where the search area boundary is marked only with forestry tape. Have a look at the map and tell me what you think is the probability that the subject left the search area near Location B.
>
> *Scenario C.*
> Now, let's consider the possibility that the subject left the search area through Location C. As you can see, this trail [indicate on map] extends to the east, crosses a stream, and exits the search area. Have a look at the map and tell me what you think is the probability that the subject left the search area near Location C.
>
> *Scenario D.*
> Now, let's consider the possibility that the subject left the search area through Location D. As you can see [indicate on map], Location D is a wide area to the south, where the search area boundary is marked only with forestry tape. Have a look at the map and tell me what you think is the probability that the subject left the search area near Location D.
>
> *Scenario E.*
> Now, let's consider the possibility that the subject left the search area through some other

> route, such as walking back out to the trail-head near Location E and leaving the area, or any other exit that the search planners had not identified. Have a look at the map and tell me what you think is the probability that the subject left the search area either through Location E or perhaps some other, unidentified location.

Post-condition POA judgments

After making their respective POA estimates for either the focal or residual hypotheses, all subjects were again shown the initial, unsegmented map with only the search area and major trails indicated. They were told,

> Now that you've had a chance to think more about the situation, I'd like you to take another look at the overall probabilities I asked you about the first time. What do you think is the chance that the subject is inside/outside the primary search area? What, then, is the chance that the subject is inside/outside the primary search area?

Half of the participants first made "inside" estimates, while the remaining half first made "outside" judgments.