Instructional Methods for Training Sensemaking Skills

Jennifer K. Phillips and Deborah A. Battaglia
Klein Associates, Inc.
Fairborn, OH
jenni@decisionmaking.com, debbie@decisionmaking.com

ABSTRACT

Two studies investigated the process by which sensemaking occurs in naturalistic settings and used those findings to develop training interventions to improve sensemaking skills. The first study conducted simulation interviews with Army Information Operations (IO) officers to observe the way they made sense of message streams during unfolding scenarios. Cognitive Task Analysis techniques were used with six highly experienced and six novice IO personnel to tap their interpretation of unfolding events. Reasoning strategies were found to be similar, but the experts drew on more domain knowledge to generate more powerful inferences. In the second study, 10 USMC second lieutenants were charged with making sense of unfolding events in a set of four infantry ambush scenarios. These sessions tested the use of electronic Decision Games (eDGs) for enhancing sensemaking skills and subsequent situation awareness. Expert infantry tacticians mentored the students, and the research team collected data on the students' situation awareness throughout the scenarios. Performance data from control and test eDGs show significant improvement in sensemaking as a result of mentoring and practice on the training scenarios. This improvement is attributed to a richer fragmentary mental model of the ambush operation, which in turn provides a "better" frame from which to undertake the process of sensemaking. These findings, coupled with incident data from navigation, nursing, and AEGIS operation studies, have produced a Data/Frame model of sensemaking that describes how individuals use a frame (a story, script, or map) to select information from the environment and interpret it to generate an assessment of the situation. In addition, this research shows promise for utilizing expert/novice differences and scenario-based techniques to enhance sensemaking skills.

ABOUT THE AUTHORS

Jennifer Phillips is a Research Associate at Klein Associates. Her interests include the nature and acquisition of expertise, and decision-centered training. Ms. Phillips served as project lead on an Army-sponsored effort to develop decision skills training for small unit leaders in military operations in urban terrain, and recently completed a similar effort to provide decision skills training to Air Force personnel for Operations Other Than War. Ms. Phillips has worked on several USMC-sponsored efforts to re-engineer existing command posts and design experimental combat operations centers. She is currently leading an Army-sponsored program to identify the process by which individuals make sense of situations as they unfold, and to develop training which will bolster sensemaking skills. She is experienced in using Cognitive Task Analysis methodologies to capture components of expertise in a range of domains, and has used Cognitive Task Analysis to identify training requirements and for purposes of knowledge management. Ms. Phillips received a B.A. in Psychology from Kenyon College in 1995.

Deborah Battaglia is a Research Associate at Klein Associates. Her interests include theories of leadership and organizational performance, the nature of expertise and skilled performance, and the development of training programs to support decision skills. Currently, Ms. Battaglia is the project leader for an effort sponsored by the Joint Advanced Distributed Learning Co-Laboratory to develop an online Vignette Development Tool to assist training developers in creating scenario-based online training. She also led an effort to develop classroom-based decision skills training for Navy pilots. She previously worked on an effort sponsored by the Army Research Institute to develop decision skills training in urban battle environments for Army platoon leaders. In addition, she was a core researcher on an Air Force project to examine the training needs that military operations other than war impose on the service. Ms. Battaglia holds a B.A. in Psychology from the University of Dayton.

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WHAT IS SENSEMAKING AND WHY IS IT IMPORTANT?

Sensemaking is commonly understood to be the process of understanding what is going on in a situation. The topic of sensemaking came into prominence with the publication of the book *Sensemaking in Organizations* by Karl Weick (1995). It has recently gained more attention as the Office of the Assistant Secretary of Defense for Command, Control, Communications & Intelligence (OASD/C3I) has sponsored a series of workshops and meetings to tackle the nature of sensemaking in earnest (see Leedom, 2001, 2002 for a summary of these activities). As new tools for gathering, sorting, searching, filtering and constructing meaning from multiple data sources are introduced into critical environments such as intelligence analysis and command and control settings, the Department of Defense is seeing a greater need to understand how sensemaking occurs in order to better apply and leverage information technologies. But sensemaking has not yet been described at a level of detail sufficient to have impact on such applications (Klein, Phillips, Rall, & Battaglia, in preparation).

Sensemaking is a critical cognitive activity because it drives decisions (e.g., Klein, 1989; Klein, 1998). Investigations of decision making in naturalistic domains have found that proficient individuals spend relatively more time assessing the situation before making a decision than do novices (Kobus, Proctor, & Holste, 2001). It is impossible to take appropriate action (or decide that inaction is more fitting) without engaging in sensemaking. Doctors do not prescribe medication without first assessing the patient's malady, and military commanders do not drop bombs without identifying which are the important targets. The sensemaking activity can mean the difference between high and low quality decisions. We are therefore compelled to develop a richer understanding of the process, and to explore means for improving people's sensemaking skills.

Durso and Gronlund (1999) have contrasted ecological accounts of sensemaking with information processing accounts. The former considers situation awareness as "the product (and process) of the cycle of perceptual exploration of environmental structure" (p. 285). The information processing framework considers situation awareness as a product of successive operations, from perceiving the data to drawing inferences to projecting into the future (e.g., Endsley, 1995). We are more closely aligned with the ecological account, distinguish-ing sensemaking as a *process*, from situation awareness as a *state* of awareness. We also choose to distinguish sensemaking from situation assessment, since "situation assessment" retains the notion of information processing, whereby data are turned into knowledge, which is turned into information, which is finally turned into understanding. Klein (2003) argues that this type of account is inaccurate and can be counterproductive to the design of support systems. The information processing perspective implies a passive perception of data as the basis for generating inferences.

As we shall discuss, we believe a key feature of the sensemaking is the active and deliberate process of defining and selecting pertinent data from a stream of signals occurring in the environment. Data are only utilized to generate inferences and understanding when they are recognized as relevant. Thus, skilled sensemaking requires the ability to recognize (and interpret) salient data. This difference, between the active and passive consideration of data, has substantial implications for training and other applications to support sensemaking.

THE SENSEMAKING PROCESS

We have been studying complex decisions and judgments in naturalistic environments for almost 25 years—firefighters deciding how to contain a fire and prevent its spread to a store of hazardous materials, military commanders predicting an adversary's goals and actions, nurses spotting early-stage infection in premature infants, and so forth. Our studies of decisions and judgments have exposed us to hundreds of examples of sensemaking in the real world. Recently, we have engaged in two studies that are explicitly investigating the sensemaking process in real world situations characterized by conditions of time

pressure, uncertainty, high stakes, and changing goals. Both projects have been expressly interested in how to help people become better sensemakers—how to train the skill of sensemaking.

Two Projects Exploring Sensemaking

Two parallel studies were conducted, one to examine the nature of sensemaking, and the other to examine techniques to improve the quality of sensemaking.

In the first project, investigating the nature of sensemaking, we began by searching for differences in the way that experts and novices approach a sensemaking task. We have found in the past that one of the most effective means of training complex cognitive skills is to capture the knowledge and strategies of the domain experts, and pass that knowledge down to the novices through experiential training techniques. We hypothesized that experts would use more complex reasoning strategies than novices to extract meaning from information, and that types of inferencing and reasoning strategies would account for expert/novice differences in large part.

To test this hypothesis, we recruited a group of highly experienced and a group of inexperienced Army Information Operations (IO) specialists. We prepared a sensemaking task in which they were required to generate an explanation based on a stream of situation reports. We looked at the types of inferences that participants used to draw meaning from the situation reports. For example, we saw upwards of 14 different types of causal inferences of various forms, such as "if a, then b" (i.e., if cause, then effect), "if a and b, then c" (i.e., if two causes, then this effect), and "if b, then a" (i.e., the effect infers the cause).

We were surprised by the findings. Experts and novices differed not in their inferencing strategies, but in the richness of the stories they could build from their inferences. We also found that the more experienced participants tended toward an action orientation, by engaging in the process with a goal in mind—to influence the situation to their advantage (Klein, Phillips, Battaglia, Wiggins, & Ross, 2002). This action orientation impacted how the experts looked for additional information, tested their hypotheses, and reduced uncertainty by acting on their environment. In contrast, novices were passively receiving the messages and trying to cobble them together.

In our second study, we investigated the utility of scenarios to boost the sensemaking skills of USMC lieutenants.[1] We hoped the training would have an impact on both generic sensemaking strategies applicable across situations, and context-specific sensemaking skill in the form of discrete domain knowledge. The scenarios in this study involved a platoon-level counter-reconnaissance ambush mission. When we tested the students to see if they could apply their learning from one ambush scenario to another, we found that the only learning that transferred took the form of highly specific domain knowledge. We did not see evidence of generic sensemaking strategies; instead, the findings suggested that sensemaking is a highly contextual activity. This is an especially significant finding given that the context and mission was the same in all the training exercises. Even within a single domain, sensemaking skill is driven by highly specific knowledge (Phillips, Baxter, & Harris, 2003).

In conjunction with our model development project we reviewed additional sensemaking incident data from neonatal intensive care nurses, Navy Tactical Action Officers, fireground commanders, and Army Captains learning tactical thinking skills. We reviewed these incidents to identify the process by which the individuals made sense of data to generate an assessment of the situation. We compiled these findings with the data from the IO specialists and the USMC lieutenants to generate a model of sensemaking.

The Data/Frame Model of Sensemaking

The Data/Frame model describes sensemaking as a process as opposed to a state (e.g., "situation awareness" is a state). We define sensemaking as the process of fitting data from the environment into a frame, and fitting a frame, or mental representation, around the data. The outcome of the sensemaking process is a constructed explanation for the situation that is experienced. The Data/Frame model is described in Klein, Phillips, Rall, and Battaglia (in preparation). Here we will focus on four critical aspects of the model, because they provide implications for improving sensemaking skills through training.

The Data/Frame Interaction

The central feature of our model of sensemaking, and what differentiates it from other accounts of situation awareness and situation assessment, is the interaction

[1] This effort was conducted under a subcontract to ISX Corporation. Mr. Jim Shoop was the Principal Investigator. General Keith Holcomb (USMC, Ret.) and Major John Schmitt (USMCR) provided the domain, scenario development, and mentoring expertise on the project.

between the data and the frame. Data are information elements in the environment. Data could be the coloring of an infant's skin or the reading on the heart monitor. A frame is a mental story, script, map, or other representation that guides the search for relevant data and the interpretation of those data. Frames are extensions of the sensemaker's experience base. For example, a frame could be the script we have learned to follow when we enter a restaurant—we expect to wait to be seated by a hostess, then order drinks from our server, then appetizers, then our meal.

The data/frame interaction posits that when people encounter data elements, they will try to make sense of them by finding or constructing a story to account for the data. Simultaneously, their repertoire of mental stories, scripts or maps will influence which data elements they consider and how they will interpret those elements. That is, the frame guides construction and interpretation of data from the signal stream. Meaning is made by fitting data into the frame and thereby building a more complete story, script, or map.

The following example is taken from a Cessna pilot and his experience getting lost in the skies of Ohio. It illustrates how his frame guided his search for data and impacted how it was interpreted.

As part of his training to become a private pilot, Joe flew a solo cross-country flight in a Cessna 172. He built a flight plan with a destination about 45 minutes south of his origination airport. The weather was nearly perfect – sunny, warm, a few clouds, and not much haze. He had several miles of visibility, but it wasn't unlimited. Joe got in the plane and went through his pre-flight routine, checking and calibrating the instruments.

He took off and turned toward south. During the initial several minutes he would be flying over somewhat familiar terrain because he had flown in this general direction several times during his training. However, this would be his first flight to this particular destination airport.

His flight plan had him flying over a few small towns and small airports. In the cockpit with him, he had a map illustrating the size of the towns (based on how much light they give off at night) and the directional heading of the runways at the airports. As he flew over the towns, he compared what he saw on his map to what he saw on the ground. The first town looked a little larger than it should have been, but Joe didn't think anything of it. The town had probably grown since his map was made. The runway at the first airport was off by about 20 or 30 degrees, but that didn't bother him either.

About 30 minutes into the flight, Joe started getting the feeling he wasn't where he was supposed to be. He had just flown over another town that didn't look quite right compared to the map, and now he was flying over another runway that seemed off. In fact, it was more than 45 degrees off what he had expected it to be. At this point he thought he might be lost, but he wasn't yet sure. He needed more data.

He checked his instruments. They were telling him that he was still on course, and they seemed to be functioning right. As he continued, he began to pay more attention to the ground beneath him. He noticed that the terrain below was covered with trees and vegetation. Looking at his map, he saw that his course should take him over flat ground for the entire route. The tree-covered land indicated to him that it must not *be flat—all flat land in Ohio has been cleared and is used for farming. He saw on his map that the elevation of the land to the east of his route was higher. Perhaps he had drifted off course to the east. But he still wasn't sure whether he was lost. His instruments told him he was on course.*

Fortunately, the Ohio River would be coming into sight soon. This is a distinct and unchanging landmark, and he should be able to figure out his actual position by comparing his map to the actual bends in the river and the smokestacks of the factories on its banks. Sure enough, when he reached the river he realized that he was 30-40 miles east of where he had intended to be. Using the river as an anchor to navigate along, he was able to replan a new route to his destination.

When he landed at the airport, he had maintenance check his instruments. It turns out that the directional gyroscope was off by about 20 degrees, which accounted for his problems.

In this incident we see that Joe explained the early data—the towns and runways—based on a frame that had him on course. As it turns out, he was actually flying over towns and runways slightly east of his expected route, but because his instruments told him he was on course, he interpreted the data as being additional indications that he was in the right place. It was not until he saw the tree-covered land below him that he thought he might be lost (i.e., that his frame might be inaccurate). And only when he reached the Ohio River was he unable to make the data fit into his frame. We will come back to this when we discuss the six sensemaking activities.

The Use of Fragmentary Mental Models

The frame that is brought to bear for a particular situation is based on the sensemaker's previous experience—his or her just-in-time construction of mental models. We posit that rather than applying comprehensive mental models in the sensemaking process, people use a set of fragmentary mental models. Rouse and Morris (1986), Johnson-Laird (1983), Gentner and Stevens (1983), and many others have explored the concept of mental models. While many authors discuss mental models, the concept itself remains fuzzy and poorly understood.

Our studies of sensemaking suggest one reason why there is confusion around the concept. In most of the incidents, the sensemakers did not have comprehensive mental models of the situation they needed to understand. They applied bits and pieces of causal connections, rules of thumb, and principles. Sometimes they applied principles from other domains as analogies. We believe these disparate types of knowledge—the fragmentary mental models—are culled together to make sense of the situation at hand.

In the example above, Joe linked the existence of trees on land in Ohio to the elevation of the land. As a general rule, he believed that flat land in Ohio is used for farming and is therefore clear of vegetation. This is an example of a fragmentary mental model. We believe the frame consists of a grouping of fragmentary mental models that the sensemaker, either consciously or not, deems useful for understanding the situation.

The Six Sensemaking Activities

The model describes six activities associated with sensemaking: elaborating the frame, questioning the frame, preserving the frame, comparing frames, seeking a frame, and reframing (see Figure 1). Not all activities occur in every sensemaking incident. Sometimes, the sensemaker will go no further than to elaborate the frame. At other times, we see the sensemaker elaborate the frame to the point where he or she recognizes that a new, better frame is available to explain the data elements collected. These activities assume that the sensemaking process has already begun, and an initial frame has already been subconsciously selected. Figure 1 depicts the model and the different activities. We will discuss them here in brief. For a full description, see Klein, Phillips, Rall, and Battaglia (in preparation).

When the sensemaker elaborates the frame, he or she is extending and building upon the frame by incorporating data from the environment. In this activity, the sensemaker is learning more about the situation over the course of time. Joe was elaborating his frame in the early stages of his flight when he judged the towns below him to match the stages of his flight plan. For him, the frame was his planned route and its waypoints, and elaborating the frame meant continually updating his actual location.

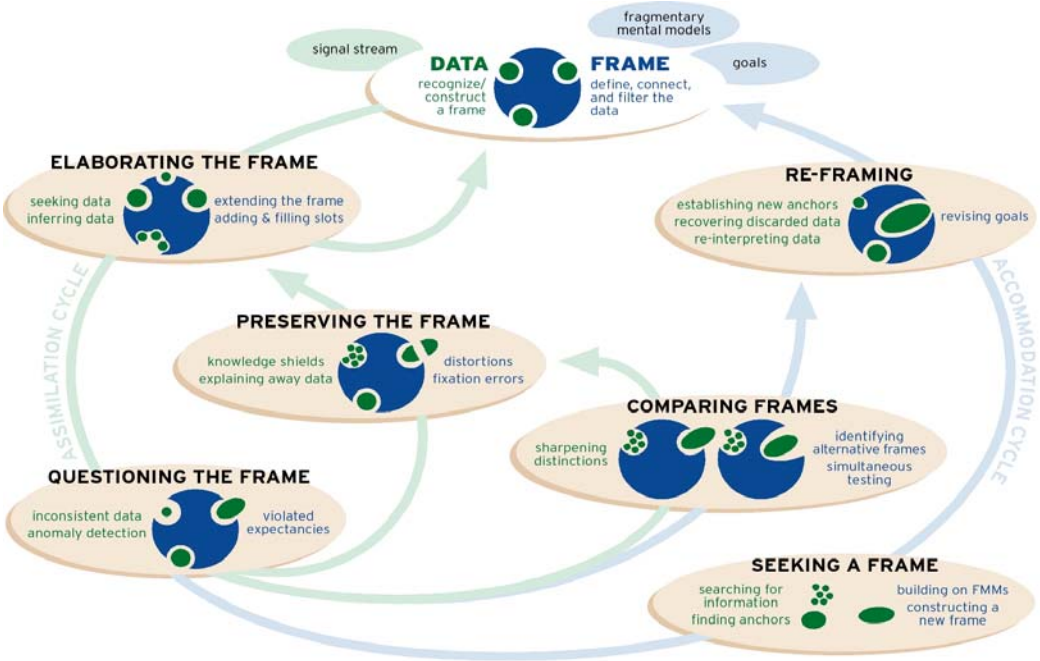

Figure 1. Data/Frame model.

If the sensemaker encounters data that are inconsistent with the existing frame, he or she may question the frame. The frame may be incorrect, or the situation may have changed, or the data may be inaccurate. One of the functions of the frame is to enable people to set expectancies about what is likely to happen next; when an expectancy is violated, the sensemaker is likely to question the frame. In this activity, the sensemaker is simply recognizing that the data do not fit the existing frame. In the example above, Joe began to question the frame when he flew over the runway that was 45 degrees off his expectation.

The third activity, preserving the frame, occurs when the sensemaker decides after questioning the frame that it is, in fact, still the "right" frame. Sometimes the frame is preserved because the data are judged to be incorrect or misleading. Other times the data are explained away, as Joe did when he kept flying according to his instruments even when the landmarks on the ground did not fit his frame.

Sometimes people compare frames. Joe did not. However, we have seen from our incident data that neonatal nurses often gather evidence in support of one, primary, frame—e.g., that the infant is healthy and progressing well—while at the same time elaborating a secondary, opposing frame—e.g., that the infant is developing an infection. The sensemaker attempts to fit the same data into two competing frames, and when a compelling case is built for one frame over the other, the preferred frame is the explanation used to guide actions.

When the sensemaker questions a frame and decides it is inadequate, he or she will seek an alternate frame. This involves a deliberate information search in order to find data that will assist in constructing a new frame. Joe looked for another frame—one that would account for his *actual* route and his *actual* location—when he reached the Ohio River and found that his first frame was most definitely inadequate. At this stage he could not explain away the bends in the river and the smokestacks he saw below. He knew he was lost. His task was to get found.

Finally, the sensemaker can shift frames, or reframe. Using the neonatal nurse example, when the secondary frame—the infant developing an infection—becomes more compelling than the original frame, then the first is discarded and the secondary becomes the one that is believed. Joe reframed using the features of the river to construct a new frame that would account for his actual location. He then utilized this new frame to replan a route to his destination.

Expert/Novice Differences

Experts do not out-perform novices on sensemaking tasks because they have superior reasoning strategies. Rather, they are more successful because they are able to construct richer and better suited frames based on their experience. Experts have more factual knowledge about their domain, they have built up more experiences, and they have more knowledge as to cause and effect relationships. That is, they have more fragmentary mental models, and those mental models are more accurate, include richer descriptions, and incorporate finer discriminations than those of novices.

To illustrate the differences between experts' and novices' fragmentary mental models, consider an experiment conducted by Feltovich, Johnson, Moller, and Swanson (1984). These researchers challenged highly experienced and less-experienced physicians to provide diagnoses for a set of patients. They chose cases in which a particular test finding could be interpreted according to the textbook (this was an incorrect interpretation), or if other factors about the patient's history were taken into account, could be interpreted differently (the correct interpretation). The more experienced doctors understood the implications of the patient's history and were able to generate the correct diagnosis. The less experienced doctors did not have mental models that were sufficiently descriptive to account for the all the factors. They diagnosed the disease incorrectly.

Another expert/novice difference we have noted in our studies is the action orientation of experts relative to others. People with more experience know how to act on the situation as a means of generating additional information that in turn gives them more data with which to gauge the situation. This is often referred to as a "shake the tree" approach to dealing with uncertainty (e.g., Schmitt & Klein, 1996). Experts also act on the situation in order to produce a desired result. We call this "functional sensemaking." For example, the more experienced IO specialists in our study tended to act in accordance with the mission goals set forth in our simulation while at the same time trying to figure out what was happening. The inexperienced participants, conversely, were passive recipients of the situation reports and did not take any actions. Functional sensemaking is a byproduct of the domains we have studied. The sensemaker always has a goal—to keep the infants healthy, to preserve human life, to protect the battle group, to extinguish the fire, and so forth. The bottom line is that with more experience comes a larger repertoire of actions, or routines, with which to functionally influence the situation or assist with the sensemaking task.

DERIVING TRAINING FROM THE DATA/FRAME MODEL

The Data/Frame model provides a description of the cognitive process people use to make sense of events. It is grounded in our observations of sensemaking in six different domains. We assert it will apply to most, if not all, other domains where explanations must be deliberately generated. If this is the process people naturally engage in to make meaning, then training to improve sensemaking skills should work in concert with that process. It is senseless to try to teach strategies that seem rational but are in fact artificial. As we derive implications for how to improve sensemaking skills, the training community should take note of a parallel experience in trying to teach decision making strategies. Many researchers have attempted to teach rational decision making techniques that are in direct conflict with naturalistic models describing how people actually make decisions. These techniques not only fail to improve decision making, but there is some evidence that they produce decisions of lower quality than if the techniques were not applied at all (e.g., Schooler, Ohlsson, & Brooks, 1993; Wilson, 2002) .

Rather than repeat this mistake with sensemaking, we should aim to improve sensemaking skills by giving people better tools with which to engage in their natural cognitive process. We can identify at least four leverage points in the Data/Frame model on which to base sensemaking training.

First, we see that the explanations that are generated are reliant on the frame that is brought to bear. When a person's frame is inadequate for the situation, then it is likely he or she will not generate a plausible explanation in a timely manner. This is why experts outperform novices on sensemaking tasks—they can construct better frames. Since the frames are constructed from a set of fragmentary mental models, it follows that we can improve sensemaking by helping people build more and better fragmentary mental models.

Second, we know that one way sensemaking fails is as a result of explaining away discrepant data. Others have referred to this as "fixation" (De Keyser & Woods, 1993; Feltovich et al., 1984). We believe we can structure training to focus on the types of fragmentary mental models that are needed to avoid fixation, such that people have more complete knowledge with which to question the frame and less propensity to fixate on a corrupt frame.

Third, we see that the activity of comparing frames proves useful for some sensemakers. We believe this strategy is more often used by highly experienced people, who have a broader range of fragmentary mental models, than by their less experienced counterparts, who do not have the mental models to generate an alternate explanation. It may be possible to help people generate plausible comparison frames as a means to improve their sensemaking skills by structuring training activities addressing the relevant fragmentary mental models.

Fourth, "shaking the tree" can be a useful strategy for aiding the sensemaking process. It may be possible to help people build fragmentary mental models that specifically address causal connections between particular actions and their outcomes.

In our projects to date we have utilized two training approaches aimed at building the fragmentary mental models of the trainee. We will present these approaches in the section to follow. We have not yet experimented with the training approaches based on the other leverage points described here. However, we do have ideas for how to proceed, and we will describe them in the final section of this paper.

IMPROVING SENSEMAKING THROUGH MENTAL MODEL DEVELOPMENT

We have attempted two training techniques for developing trainees' mental models in specified domains. Both utilized low-fidelity, context-rich scenarios that were constructed by researchers and subject-matter experts. The first technique builds upon the data collection methodology we implemented in the first project with IO specialists, in which trainees are presented with a series of situation reports in an evolving situation over time. In the training version of the sensemaking exercise, these scenarios were annotated with expert responses to the situation reports, such that trainees would have a window into the experts' fragmentary mental models and the application of those mental models in context.

The second technique has been utilized in the study of USMC lieutenants. Our colleagues, Gen. Keith Holcomb (USMC, Ret.) and Maj. John Schmitt (USMCR) developed a series of infantry ambush scenarios. The student is a platoon leader in the scenarios and thus must provide the command and control function for the platoon. The scenarios are scripted but allow for a great deal of interaction on the part of the student. The facilitators act as mentors, assisting the student periodically during the scenarios

to assess the state of the student's own platoon, the status of adjacent platoons, and the actions of the enemy. In this form of sensemaking training, the mentoring is conducted by highly skilled mentors and expert tacticians who consciously work to build the students' mental models around the dynamics of the ambush mission.

Expert Annotations

The training scenario, titled *Preparing for Winter*, incorporated a series of problems afflicting Bosnians living in refugee camps. Ultimately, the major theme of the scenario was that sewage problems in one camp resulted in a cholera outbreak that spread to another camp. The scenario consisted of eleven situation reports, each report containing between one and four individual messages. The reports were designed so that several themes that would be relevant to IO personnel were active at once, with a number of messages inserted simply as noise. The intended result was early confusion about the nature of the problem facing US peacekeeping forces, with continued clarity over the course of the situation reports. The task for participants was to make sense of what they were seeing in the situation reports, and to generate an explanation for the unfolding events.

Two sets of training materials were provided to the trainees. The first set contained the *Preparing for Winter* scenario with blank spaces designated for trainees to enter their responses to the situation reports and their questions. The second set contained the scenario supplemented with expert responses and analysis throughout the unfolding situation. These annotations were developed as a result of Cognitive Task Analysis interviews conducted with four experts to extract their domain knowledge as they progressed through the scenario. In other words, we captured the fragmentary mental models of the experts as they were being applied to the unfolding situation. The annotated training materials contained the responses of all four experts, to illustrate a broader range of relevant knowledge; the experts had responded similarly but not identically to each of the situation reports.

The procedure for implementing this training requires that students begin by working through the first set of training materials, entering their responses and questions as they go. They are asked to read one situation report at a time and analyze the information based on their own understanding of the environment and their role as an IO specialist. After writing their response for each situation report, they are given the expert annotation for that report and allowed to compare their response to the experts' notes.

We pilot tested this training technique with a small group of novice IO specialists at the Army's Land Information Warfare Agency (LIWA). The training was well received by the directors of LIWA as well as by the trainees. In fact, LIWA plans to utilize these materials in future training rotations.

While we did not have the opportunity at LIWA to test whether the training does in fact help trainees develop their fragmentary mental models, we collected good anecdotal evidence that it enabled participants to broaden their domain knowledge. The trainees were engaged in the training and asked that we provide them even more information in the scenarios. They requested access to background information and relevant tactics, techniques and procedures. They also suggested that the experts' email addresses be provided so that they can ask specific questions to better understand the expert's interpretation of the situation.

We learned a great deal about how to further refine the training. First, there was a clear benefit of presenting multiple expert responses rather than just one. The repetition stressed the importance of their insights and the credibility of their interpretations, and the variations in their responses highlighted slightly different types of expertise. Second, we found this technique to be somewhat taxing; trainees had a difficult time maintaining attention after about an hour. Third, we believe this training can be productive as a self-directed exercise with no facilitator. In most of our training addressing complex cognitive skills, we have found it necessary to build in skilled facilitation. We are encouraged that this instruction can stand alone, as flexibility increases and cost decreases. Fourth, we expect that this training can be implemented in paper and pencil form or electronically. This is a good candidate for online training or asynchronous distance learning.

Interactive Exercises with Mentoring

The goal of this training approach is to demonstrate that domain-specific fragmentary mental models can be built using interactive electronic sensemaking scenarios accompanied by one-on-one mentoring. If we can demonstrate that mental models can be developed with focused training, then we believe we can further refine the technique to make it implementable on a broader scale where one-on-one mentoring is not a requirement.

This approach has been tested with USMC lieutenants in the context of a platoon-level infantry ambush (Phillips et al., 2003). A series of scenarios were developed by two expert tacticians. The scenarios utilized an electronic (online) mapboard on which both the mentor and student could draw notations, move unit icons, and label features. The scenarios consisted of a series of realistic radio transmissions that would occur during an ambush mission, and the students were tasked to play the role of the platoon leader in the scenario, by directing subordinates and sharing pertinent information with other platoon leaders and the company commander (all simulated).

A skilled mentor facilitated the scenarios. Facilitation included role-playing other operators in order to respond to the student's transmissions, running the scenario in a manner consistent with the student's decisions and directions, and mentoring the student along the way by intervening during the scenarios. In these interventions, the mentor assisted the student in reading the data in the scenario, sizing up the situation based on available data, and understanding the implications for the near future. Mentors utilized a Socratic approach, probing to elicit, and in many cases challenge, the reasoning behind their assessments of the situation. In this way they were able to guide the student to a better understanding of the critical transmissions and, more importantly, to a more accurate assessment and mental model of the current situation, including projections of what might happen next.

The set of five scenarios was structured such that each one addressed a potential point of failure in an ambush mission—triggering the ambush too early, compromising the unit's position, encountering a larger enemy force than anticipated, getting flanked by the enemy, or falling victim to unconventional enemy forces. In a pilot study, we found no evidence that students were able to develop a generic sensemaking mindset or skill. Shifting from one scenario to another, from one challenge to another, did not lead the trainees to do a better job of anticipating the next trap, despite identical terrain, identical players, and an identical mission. Combined with our other research on sensemaking, we took this as additional evidence of the reliance on highly-specific fragmentary mental models in the sensemaking activity. We therefore designed a new set of scenarios, set in slightly different terrain, to test the particular fragmentary mental models that we were purporting to train. That is, we developed test scenarios that addressed a subset of the five potential points of failure. Students received two of the first set of scenarios, and then received the corresponding test scenario to determine whether they were able to apply their new fragmentary mental models to a similar situation on different terrain.

We found that students performed significantly better on test scenarios after they had trained on the corresponding teaching scenarios than when they did not have the opportunity to build relevant fragmentary mental models ($t = 2.69$, $p < .025$; $t = 2.85$, $p < .025$). This finding supports what we have articulated in the Data/Frame model, that sensemaking skills are highly context-specific and are based on the quantity and quality of the fragmentary mental models that are brought to bear to guide the selection and interpretation of environmental data. Moreover, this finding shows us that fragmentary mental models, and thus sensemaking, can be improved through training.

ADDITIONAL TRAINING CONCEPTS

The two training approaches described above address the development of fragmentary mental models. Those approaches have been tested to some degree, and they show great promise. We postulate that it is feasible to go one step further, by developing training scenarios and facilitation strategies that deliberately pinpoint and enhance certain types of fragmentary mental models. Particularly, we believe such training programs can improve people's ability to question their frame, compare alternate frames, and "shake the tree" to produce additional data.

Training to Question the Frame

The Data/Frame model illustrates how sensemaking can fail when fixation occurs and a corrupt frame is held onto. We believe it is possible to develop training scenarios that teach people fragmentary mental models that will help them question their frame and test it for corruption. Fragmentary mental models often take the form of causal concepts that permit inferencing from the patterns and events in the situation. These causal concepts are central to proficient performance. They reduce the complexity of the situation by enabling the sensemaker to generate expectancies—what should happen next if his or her assessment is accurate. Whether the expectancies are met or violated, the proficient sensemakers have data that drive them to either elaborate or question their current frame.

Feltovich, et al. (1984) and Rudolph (2003) utilized "garden path" scenarios intended to lead participants to one interpretation early in the scenario, and then later provided key information that should suggest a different interpretation. They demonstrated that less experienced people are more likely to fixate on the

garden path interpretation than to question their frame in response to the new, key piece of information. We believe we can use a "garden path" permutation of the training scenarios to deliberately develop fragmentary mental models that assist in generating context-specific expectancies.

Training to Compare Frames

A comparison frame enables the sensemaker to run the data through two (or more) different 'stories' to assess which story seems more plausible. It may be possible to encourage trainees to generate a comparison frame. For example, Cohen, Adelman, Bresnick and Freeman (2003) developed a Crystal Ball technique that requires the trainee to indicate an initial interpretation of the situation. Then, the trainee is informed that by looking into a crystal ball, it is clear that this interpretation is incorrect. The trainee must then produce a different interpretation for the same data.

We suggest an approach similar to the Crystal Ball technique to give people practice in generating alternative explanations of events. We speculate that we can devise a permutation of the training scenarios that explicitly requires trainees to generate alternate interpretations, thereby enhancing fragmentary mental models.

Training to "Shake the Tree"

Finally, we advocate another permutation of the training scenarios, focusing on the actions that can be taken in order to produce additional signals in the stream and thereby aid the sensemaking process. The range of appropriate actions will depend on situational factors. Therefore, this approach would develop fragmentary mental models that describe the actions that are available under a particular set of circumstances, and the type of information that is likely to result when the action is executed.

We have seen proficient sensemakers "shake the tree" in real world incidents. For example, an AEGIS commander assessing whether an incoming track on the scope was hostile or friendly acted on the situation by locking his weapon sights on the questionable aircraft. This action sent a clear message to the pilot, and in response he turned and headed the opposite direction. This additional data led the commander to assess the track as hostile but nonthreatening (at least for the moment). The commander's fragmentary mental models described the linkage between an action he could take and the responses available to the pilot. Choosing from those responses, the pilot would have to send key information to the commander that would assist his assessment.

In the infantry ambush training scenarios (Phillips et al., 2003), the mentors encouraged the lieutenants to probe the battlespace for necessary information. More importantly, they queried the lieutenants about how and when to probe the battlespace to avoid compromising the ambush mission. This mentoring built the students' fragmentary mental models pertaining to the use of terrain to shield actions, the timing of the actions relative to other events, and the effectiveness of particular tactics under various circumstances.

CONCLUSIONS

We summarize with three essential points. First, we have collected evidence that the sensemaking process entails an interaction between the data in the environment and the frame applied by the sensemaker. The environment (i.e., the setting and the goals of the sensemaker) drives the frame that is brought to bear. The frame guides the selection and interpretation of data from the signal stream. The data and frame in concert prompt the sensemaker to elaborate, question, preserve, compare, discard or shift the frame, or to seek new data. Frames are constructions that incorporate a subset of the individual's fragmentary mental models.

Second, we believe sensemaking skills can be trained, but only if the training techniques are extensions of cognitive models that describe actual sensemaking performance in the real world. We have done this with our Data/Frame model, and we have identified four leverage points for sensemaking training.

Finally, we assert that the nature of the sensemaking task calls for training that reproduces specific elements of context. There are no general, domain-independent strategies for sensemaking. Even within a domain, sensemaking skills are context-dependent because they are reliant on fragmentary mental models. Therefore we cannot improve sensemaking performance free of context. We have seen the utility of low-fidelity, context-rich scenarios as a format for improving fragmentary mental models and sensemaking skills. We posit that training scenarios and facilitation strategies that deliberately address questioning the frame, comparing frames, and generating additional data can be developed to further build an individual's domain mental models and improve sensemaking skill.

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