Learning to make sense

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Abstract: Sensemaking is the process of understanding situations of high complexity or uncertainty in order to make decisions. Individuals and teams that are good at sensemaking tend to collect and critically evaluate the available evidence, seek for consistency, and test assumptions underlying assessments. Furthermore, their experience allows them to have a high appreciation for how the context affects the problem. In this paper we will (1) present observations on successful and failing sensemaking in first responder teams, (2) discuss the development of sensemaking competency, and (3) present an approach for training the knowledge and skills that are critical for sensemaking.

Keywords: Sensemaking, decision-making, learning

1. Introduction

A fire commander suddenly ordering his men to evacuate a burning building just before it collapses. The teacher superintending the school's playground, knowing exactly when and where he has to be to prevent fights and bullying. Or the General Practitioner (GP) who decides to conduct additional tests for one patient with symptoms resembling the common cold, whereas another patient displaying the same symptoms receives cold medicine and is sent home. Three different professionals, in different situations, making crucial decisions. What they have in common is that they were able to make the right decisions at the right time, because they correctly anticipated a grave turn of events. In other words: They knew how to make sense of the situation.

Sensemaking is a process of explaining situations and predicting future events. It involves recognition and understanding of the underlying theoretical principles of situations rather than relying on surface features [1, 2, 3]. Furthermore, it requires the cognitive skills to monitor, critically reflect on, and adapt decision strategies to the irregularity of problem situations [4]. These competencies typically are not part of a training program for professional decision-making; they are mainly acquired as a result of experience in the field [5, 6, 7]. However, results from studies into general learning strategies, effects of instructional measures, and empirical evaluations of training concepts may provide guidelines and evidence based instructional concepts for designing adequate education and training programs in sense making.

2. Making sense of ill-structured problems

Sensemaking is a strategy that is applicable, or necessary for complex problem solving in non-routine situations, for which no simple analogies, automated, or rule-based solutions exist. Many of the crisis or disaster management problems that the first responders (police officers, firemen, military personnel) face are indeed complex and non-routine. Such task domains are often called ill-structured [8, 9]. In the following sections, the characteristics of ill-structured task domains are described first, then an example of successful real-world sensemaking in such a domain is presented, and similarly information on a real-world disaster is discussed focusing on how a lack of sensemaking lead to the dramatic turn of events. In the last section, we conclude with discussing the characteristics of successful sensemaking, illustrated by the analyses of the real world examples of disaster and crisis management.

2.1 Ill-structured domains

In ill-structured problem domains such as crisis management, military command and control, or medical diagnosis, decision makers often have to attend to knowledge from different conceptual structures (schemas) simultaneously and interactively [8]. And across comparable cases the conceptual structures involved and the way they interact differ. For example, in medical diagnosis, a patient's characteristics (e.g., age, gender) and context (e.g., work, culture) may serve as a base line for judgments on the probability of some disease given a set of symptoms. Thus, information on population probabilities has to be combined with information on the predictive value of symptoms for diseases. However, different patients suffering from the same disease may report different symptoms. And the same symptom may be indicative of different diseases, depending on the type of patient. A GP having to conduct a diagnosis can therefore be left with a very difficult decision problem [10], with far reaching consequences.

2.2 Multidisciplinary teams in ill-structured domains

A major mistake of operational multidisciplinary teams commonly made is a disregard of their own safety. It occurs regularly that they are so focused on managing problems of the teams on-scene, that they tend to forget to monitor their own environment and possible threats to their position. It was therefore remarkable that the operational team of Flevoland, during the exercise 'Waterproef' recognized that the flooding as a result of a dike break, would also become a threat to their own position. At the moment of the dike breaking, there were 4 to 6 hours left before a major city would be flooded. The task of the operational team was to manage all activities and lower crisis response teams to defer the risks for the area and local population. Evacuations, preventing other accidents, managing back up systems, and restoring to the normal situation were some of their responsibilities. The team quickly started to assess the situation, for which they incorporated information from the coast guard, and other observations. During this process of situation assessment they identified that they themselves were part of the situation, and that made them realize that they had to assess the threat to their own headquarters. Once they made this assessment, and correctly concluded that their headquarters were in danger, they decided to relocate.

However, sometimes situation assessments go wrong. A painful example of the kind is the disaster with the Liberian oil tanker Braer [11].

On January 3rd 1993 The Braer, holding 84,700 liters of oil, is sailing from Norway to Quebec. Heavy winds and high waves make the tanker pitch and roll extensively and water flows over the deck. The crew notices that 4 steel pipes are adrift on deck; however, the captain decides not to have any men go on deck to inspect the situation because of the bad weather. Despite the weather and the detached pipes, the tanker maintains its' course.

The steel pipes cause damage to the protective valve of the air pipe of the diesel tank and as a consequence, seawater starts flowing into the diesel tank through this pipe. This pollutes the flow to the heater and as a consequence the heater extinguishes. This is detected by the crew but their attempts to turn the boiler back on are to no avail. At the same time, seawater is now flowing into the main diesel oil pipe, the main engine and the generator.

After a while the crew detects seawater in the diesel oil and starts to clean the tank to remove the seawater. They do not realize that this seawater is flowing in through the damage valve from the deck. They work on separate symptoms – the boiler not turning on, the seawater in the tank, the steel pipes adrift on deck- but unfortunately an overall story of the situation is not build, let alone critically evaluated to come up with alternative explanations for all symptoms. The captain, not seeing the big picture of the situation but only acting on separate events, does not realize the seriousness of the problems and hence does not call for help or change his course.

The situations then aggravates because the ship looses its main power and the engine malfunctions. The ship is now uncontrollable and very close to the Shetland Islands. It runs aground and both the ship and its load are lost, causing major ecological damage to the islands' coastal area.

2.3 Sense making

Studies on naturalistic decision-making focus on how people make use of their expertise in real world judgment and decision making tasks [5, 12]. On the basis of these studies, Klein, Moon, and Hoffman [13] have formulated the data/frame model of sensemaking. This model distinguishes two levels: The level of *mental model formation* which is backward looking and explanatory, and the *mental simulation* which is forward looking and anticipatory. Klein, Moon & Hoffman argue that decision makers always apply a frame, that is, some mental model based on experiences, when they observe and interpret the world around them. This frame serves the two levels of sensemaking: It guides both explanation of the situation and prediction of future events. Expertise is characterized by large amounts of relevant representations of prototypical experiences in memory as well as efficient structuring and chunking of this information to facilitate instant retrieval [14]. It allows experts to represent problems in terms of deep theoretical principles rather than surface features as novices commonly do [1, 2, 3]. In other words, experts have better mental models allowing them to identify and select relevant cues and patterns in a situation [15, 16, 17] and to perform more effective searches for further information [18, 19].

3. Training to make sense

To develop the experience necessary to recognize a vast amount of situations, an individual needs to be confronted with many different situations and discover the relevant cues, rather than being told what aspects or cues are important [15]. Training should therefore be focused on presenting as many relevant problem situations as possible, and each situation should incorporate one or more relevant cues. But mere exposure to those situations is not enough for learning; there should be some process of deliberate or thoughtful processing of the context and cues to foster understanding and adequate skill acquisition. From the breadth of experience that is provided in such training, the learner may generalize abstract representations guiding judgment in novel situations [20, 21, 22].

In the following sections, instructional measures and training concepts facilitating the process of generalization and formation of abstract representations are discussed: Scenario, Learning Activities and Feedback.

3.1 Scenario

Scenarios determine the context for and scheduling of learning tasks. A scenario consists of a description of the background of the task or problem the learner has to solve, a starting point and events specified in time or in relation to other events to trigger behaviour that contributes to skill acquisition. Scenario based training programs have the advantage that they can present real world problems to the learner, embedded within a realistic context, and often with some level of interaction and time constraints that resemble real world situations.

A specific approach to scenario-based training is the Tactical Decision Game (TDG; see e.g. [23, 24]). In a TDG realistic problems are presented to individual trainees or teams in the form of a tactical assignment. The games confront the trainees with complex and challenging decision-problems, require active participation of the trainees to attain a specific goal. An adequate TDG has the following characteristics:

- *Dilemma* The scenario needs to contain uncertainty to present a dilemma for the trainee such that there is not one correct solution but rather several solutions that may be more or less adequate.
- *Role-play* Trainees are supposed to play a specific role in the game and make decisions in accordance with their role.
- *Limitations* Information on the situation and time to solve the problem should be limited.
- *Discussion* During and after the TDG trainees are prompted to discuss their own and their teams decision strategies.
- *Unexpected events* During the game, unexpected or surprising events (from the viewpoint of the trainee) should be introduced to encourage discussion on the effects of several alternative solutions.

TDGs provide trainees with the opportunity to study relevant tactical decision-problems and reflect on different solutions in a simplified task environment. This discovery oriented approach combined with the required discussion [25, 26, 27], and reflection [28] facilitate elaborate processing of the learning materials resulting in knowledge representations that allow trainees to abstract from the learning tasks to other tasks and situations.

Important in the design of scenarios, for TDGs or some other form of scenario-based training, is to guarantee *variability of practice* [29]. Because trainees have the opportunity to compare between different variations, discover the invariants and variants of the situation, and relate those to the effects of their own performance, they are expected to develop more elaborate mental representations of the task. And consequently, even if variability is not part of the required post training performance, the variability during practice has been proven to enhance post training performance, compared to constant practice, on a number of different task types [30]. Other scenario manipulations that may benefit post-training performance are to introduce *spacing of practice events* [30] and *contextual interference* [31, 32]. Spacing refers to presenting the same practice events distributed among other practice events. Instead of repetitive presentations, or massed presentations, now the practice events are distributed in time and sequence. Spacing is automatically introduced when contextual interference is enhanced by providing a practice schedule in which the different type of practice events are scheduled randomly instead of blocked.

The spacing of practice events encourages trainees to rehearse between the events, and process the semantic, perceptual or contextual aspects of each presentation more extensively, thus leading to more elaborate representations and more retrieval cues stored in memory. In massed presentations, in contrast, the contextual aspects of the learning task are similar, hence less contextual aspects are stored, and the perceptual or semantic aspects of the learning task are primed by earlier task presentations, requiring less processing with each repetition. The explanations for benefits of contextual interference, that is the interference as a result of the presentation of several task variations in sequence instead of blocked presentation of only one type of task, are similar. Explanations of the contextual interference effect involve trainees exhibiting more elaborate processing, not being able to rely on primed cues or solutions by preceding presentations, but instead having to reconstruct or retrieve solutions with each presentation. These explanations all assume that the random practice schedule requires more (elaborate) processing of the learning materials. Another explanation might be that the repetitive presentation of the same practice events lures trainees into believing that they already perform at an adequate level, thus they no longer put a lot of effort in processing the learning materials. Koriat & Bjork [33] refer to this phenomenon as developing an *illusion of competence*. Preventing an illusion of competence, e.g. by random schedules, motivates trainees to search for and reflect upon alternative task strategies and they thus gain a deeper level of understanding [34]. In this respect, Bjork [35] refers to the concept of desirable difficulty as something that should be strived for to prevent illusions of competence on the one hand, and frustration on the other. Bjork [35] mentions three instructional measures that may create desirable difficulty: (1) *spacing* (or interleaving) practice events, (2) increasing *contextual variability*, and (3) *using tests frequently as learning events* (see next section on learning activities). These measures often appear to slow the learner's progress during instruction or training, but lead to better transfer test performance [35, 36, 37]

Another measure that may be expected to enhance desirable difficulty is *scaffolded practice in the zone of proximal developmen*t [38]. For scenario design this means having a set of scenarios that present events that are categorized in different levels of complexity. Trainees may be practicing on scenarios that are somewhat too difficult for them, but in such scenarios support should be given to continue with the scenario. Trainees can benefit from such support by copying elements from an expert's approach, solution, or representation of the task, into their own task schemas. Scaffolds may be in the form of *augmented cues*, when specific relevant cues in a situation or problem description are augmented [15] to attract the trainees' attention and help the trainee distinguish between relevant and irrelevant information. Augmenting may be realized visually, for example, by increasing contrast values on a screen, or auditory, by presenting a warning signal. Another form of scaffolds can be *worked-out examples*. These will be discussed in the section on learning activities.

3.2 Learning activities

Learning activities encompass all tasks that trainees help to acquire knowledge and skill. These activities can be similar to the tasks to be, but they may also involve regulative, reflective or other activities that can contribute to learning.

Sensemaking skill is highly dependent on the availability and richness of cognitive schemas, that is, networks of abstract mental concepts [39, 40, 41, 42, 43, 44]. These schemas facilitate recognition and categorization of problem situations, thus guiding identification of an appropriate response [45]. Decisions in such a recognition-based strategy are not made once all information has been gathered, but rather are constructed along the way [46]. Therefore, early decisions may be based on simplified information and more relevant information for this decision may become available later in the process. And in complex, ill structured task environments, simple analogies and prototypes do not always suffice [9]. Critically testing and evaluating one's mental model are therefore considered paramount in the decision process, especially when high stakes are involved, when problems are dynamic and complex, or both.

So, training can focus on practicing as many relevant problem situations as possible to develop elaborate schema's necessary for sensemaking. Secondly, training should incorporate the critical thinking strategies that may guide the sensemaking process. Freeman & Cohen [47] developed a program for training military officers critical thinking:

1. Develop a story (i.e., form a mental model) of the situation. Incorporate history, intentions and capacities of all parties involved in your story to explain all your observations and predict future events.

2. Test your story for conflicting and/or missing information. Try to explain all observations within one comprehensive story, even if these observations do not seem to be related to your story. Identify gaps in your story and make explicit assumptions to cover these gaps.

3. Evaluate your story. There is the devil's advocate that tells you—part of—your story is false. Try to come up with an alternative story that can also explain your observations. Which story is more plausible?

4. Develop plans and contingencies for the weakest assumptions in your story.

Such critical thinking strategies may prevent learners to fall prey to typical judgment biases, as in the Braer Disaster (see previous section), but they also enhance processes of generalization and abstraction of the content of the tasks, because critical thinking encompasses elements of reflection and self-explanation (see e.g., [25, 28]). Several empirical studies have provided evidence that critical thinking training enhances post-training performance in complex judgment and decision-making skills.

Analyses of historic events may serve as training materials for story building. In such analyses, the decision processes of professionals involved are often documented, and as a consequence, all essential elements of a comprehensive story can be easily identified. If expert solutions are available, these can be used to develop *worked-out* examples: Problem situations for which (part of) an expert solution is presented to the trainee. Worked out examples are suitable when presenting problems to trainees for which they have not yet the schemas available to solve the problem. With an expert's solution, they can build or elaborate their own mental representation of the problem. For more experienced trainees, partly worked out examples may serve as a prime to elicit the correct schema for the problem. Several studies have shown that worked-out examples benefit learning in many problem-solving tasks (e.g., [48]).

Professional environments are characterized by increasing interdependency and complexity. As the complexity of the situation and environment increases, it becomes more unlikely that an individual will be able to manage the situation alone. That is, resources from many different areas of expertise may be needed [49, 50], and it may be effective to distribute the workload across several individuals [51]. Therefore, organizations are increasingly using teams to handle difficult, complex situations.

Sensemaking, as a consequence, is often undertaken by teams, or at least by individuals working in teams. For such a team to come to a common understanding of a situation, it is important to collaborate and communicate effectively. Knowing each team members (information) needs is paramount for such quick and effective communication and collaboration. Having team members practice each other's tasks, cross training, aims to provide them with insight into each other's tasks [52].

3.3 Feedback

For adequate learning, feedback on the effects of one's behaviour is indispensable. Within psychology and educational sciences a lot of research has been done on the efficiency and effectiveness of feedback for learning (see e.g. [53, 54]). Several types of feedback have been identified, such as positive and negative feedback, process feedback, outcome feedback, cognitive feedback, delayed feedback, peer feedback, to name a few. In general it has been concluded that positive feedback is more effective than negative [55] and delayed and infrequent [56] feedback generates better post training performance than frequent and immediate feedback.

The benefits of a feedback strategy depend on task difficulty [57, 58, 59, 60]. Outcome feedback only provides information on the correctness of a decision; cognitive feedback concerns characteristics of the person's cognitive processes as well as characteristics of the task [61]. In complex tasks, cognitive feedback often renders best performance, whereas in simple tasks, outcome feedback is better. Cognitive feedback may include information on the relationships between specific task variables, or on the validity of certain variables for a solution [62]. In addition, there is a form of cognitive feedback that provides the learner with knowledge on his own learning process. And lastly, there is information on the correlation between the participants' estimates on which task aspects they consider important and the actual importance of these task aspects. Cognitive feedback may include one or all three aspects mentioned above. For example, in a study by Gattie and Bisantz [63], investigating the effects of cognitive feedback on task performance in a dental diagnosis task, participants had to judge whether a dental condition was benign or malicious on the basis of a patient's age, gender, tumour growth location, growth size, growth colour, and cancer risk. In the cognitive feedback conditions, participants received information on the weights they ascribed to those indicators, calculated continuously based on regression analysis of their decisions. A second cognitive feedback condition consisted of participants receiving information on the task: the relationships between cues and criterion, the validity of cues, and so forth. The last cognitive feedback condition involved information on the correlation between the participant's decisions and the actual task properties. Both the information on decision strategies and task information improved participant's performance. The first type of feedback was especially helpful for novice participants, which suggests that participants unfamiliar with the experimental task or specific domain may need to understand their own decision policies to facilitate learning [63].

4. Empirical evaluations

We have conducted several training studies that have shown positive results for critical thinking approach using TDG's [24, 64]. These training studies were specifically designed to study the effects of our training manipulation. They were mini-training courses, conducted under controlled conditions. This is different from any normal training program in that it is more rigid (according to specific experimental protocols) and of short duration. A short training intervention may not provide the opportunity for trainees to really master critical thinking skills. In this section we report findings and observations of putting CT-training into practice.

Recently, the Operational school of the Royal Netherlands Navy revised its training program for CIC (Command Information Centre) commanders. This reorganisation offered an opportunity to identify shortcomings of the existing programs, and to bring about improvements in training concepts, methods and materials for the new training program. It was concluded that theoretical lessons should be redesigned in such a fashion that: (a) students can develop a satisfactory repertoire of tactical patterns, and (b) there is sufficient opportunity to practice situation assessment and decision making skills. This should prepare students better for training exercises on the tactical simulator, and for the on-board exercises. To achieve the objectives, we decided to embed critical thinking into TDG exercises. Prior to the training sessions, instructors were instructed extensively on the concept and principles of critical thinking. Observation protocols and performance measures were designed to support instructors in their tasks.

The majority of students were enthusiastic and motivated to co-operate. They appreciated the exercises as a suitable method for consolidating and applying their tactical knowledge, and for practising their skills in tactical assessment and decision-making.

Although the majority of students were distinctly positive, there were also some individuals who failed to appreciate the purpose of the critical thinking concept. It appeared that some of these students lacked the domain knowledge required to conduct critical thinking as intended. For instance, they were unable to identify a critical assumption in their assessment, or were unable to judge the tactical relevance of ambiguous information. As a result, trainees applied the critical thinking method in an obligatory fashion, more like a checklist to be completed, rather than as an approach to reflect upon the quality of tactical assessments. During after-action-reviews they were reluctant to elaborate on alternative assessments, because they considered them to be "too unlikely."

They felt that the required elaboration on the tactical issues presented in the TDGs helps students to develop tactical schemes, and that critical-thinking helps shaping the necessary skills for situation assessment or sensemaking.

5. Conclusions and recommendations

In this paper we have tried to describe sense making as a crucial skill for adequate problem solving in ill-structured domains. Our aim was to present a set of instructional interventions that may facilitate the acquisition of sense making skill. For this purpose, three parts of a training program were distinguished: Scenario, Learning Activities and Feedback. For each of these, we provided some information on approaches and interventions that may benefit post training performance in sense making. Below, we summarize the major recommendations.

First, scenarios have to provide the opportunity to practice real problems, in which the dilemmas and probabilistic nature of ill structured domain is represented. Such scenarios should present a variety of learning tasks; facilitate discussion and evaluation of alternative strategies. If learning tasks are too difficult for novice trainees, scaffolds can be provided in the form of augmented cueing, or worked out examples. Secondly, the learning activities should encompass both the actual tasks, as well as self-regulative, or meta cognitive, activities to monitor and control the learning process. Critical thinking training is a good approach for this. In team learning, the learning activities should encompass cross training, that is, training in each other's tasks to gain insight in the need for information and support of other team members, thus enhancing the coordination and communication within the team. And lastly, feedback for learning the difficult task of sense making has to focus on providing insight into the task properties and the trainee's own problem solving strategies, so called cognitive feedback.

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