CHAPTER 2

Recognition Skills

2.1 Recognition Skills Training

Recognition skill is the ability to rapidly size up a situation and know what to do. When you are driving and see debris on the road, you may slow down, check your mirrors, and change lanes to avoid it. You can do this seemingly without thinking because you are an experienced driver and have developed recognition skills. When a paramedic comes to a scene, sees a patient hemorrhaging, and rapidly applies a tourniquet, they are using recognition skills.

Recognition skills are generally obtained and refined on the job, via experience. These skills are notoriously difficult to address in traditional training contexts, but for the domains in which they are critical – where there is time pressure, uncertainty, and often considerable risk – we see many examples of creative use of scenario-based training and apprenticeship/mentoring programs to support acquisition of recognition skills. Training designers in these domains are generally left to rely on a combination of ingenuity, trial and error, and adaptation of more general training principles to address training goals.

In this handbook, we propose a set of design principles specifically aimed at developing effective recognition skills training, with a focus on augmented reality applications. We leverage the training literature and our own experiences to articulate principles we have found to be particularly relevant to designing training for recognition skills. To be clear, many of these principles are based on learning theory (and related literatures) and are relevant for many types of training technologies. We focus on augmented reality because it is an emerging technology that paves the way to bring many of these theoretical principles to life in ways that were not practical previously.

Although we emphasize the value of recognition skills training, it is important to note that we do not expect novices to instantly become experts as a result of training. These skills take years to obtain in most contexts. Our intent is to design training that improves the learner's recognition skills for specific learning objectives, and also improves their *learning* skills. Effective training will help learners develop the skills they need to make the most of the experiences they encounter in training and in the real world. Recognition skills training is not about helping learners memorize facts and procedures; rather, our focus is on providing experiences that will help learners be better at using the information available to them to rapidly size up a situation and take appropriate actions.

2.2 Recognition Skills Theory

Our focus on recognition skills frames the design principles offered in this handbook. To set the stage, we share our perspective on recognition skills. There are many frameworks and taxonomies that are used to inform training design in general (e.g., Bloom et al., 1956; Norman, 2013). Although these taxonomies have been highly influential, we found them too general for our purposes. We are interested in developing training for people operating in dynamic, high-stakes environments. Our approach to training design extends naturally from the environments we train in; effective performance in high-stakes environments is typically driven by developing strong recognition skills.

Our theoretical approach to recognition skills is based on the recognition-primed decision model described by Klein and his colleagues (Klein et al., 1988). This model highlights that experienced people are often able to quickly recognize a situation as familiar, and based on that recognition, generate an effective course of action. In many cases, they are not even aware that they have made a decision. Daniel Kahneman describes this as "thinking fast" or "system 1 thinking" in his book, *Thinking Fast and Slow* (Kahneman, 2011). This model of decision-making is most thoroughly described in Gary Klein's book, *Sources of Power* (Klein, 1998). An illustrative example comes from a study of firefighters. One fireground commander described an incident in which he arrived on the scene of a fire and immediately recognized it as a kitchen fire in a single-family dwelling. He had seen this type of fire many times before and it was instantly recognizable. Based on his rapid assessment, he instructed his crew to enter through the front of the dwelling to knock down the seat of the fire in the kitchen. Because of this rapid reaction, they were able to save much of the structure. The fireground commander did not recall making a decision as he recounted the story. However, when probed further by the interviewer, he explained that he had seen other crews try to attack this type of fire from the back through windows, driving the fire further into the structure; he knew that was a poor course of action. He knew what to do without deliberation because he had seen similar fires many times, and observed which strategies were most effective (Klein et al., 1988; Klein et al., 2010).

In addition to the concept of quickly sizing up a situation and acting, another key component of recognition-primed decision-making is that decisions are not a single choice point. Rather, they are a process that includes assessing, acting, and reassessing. Often actions are taken with specific expectations about how the actions will influence the situation. Decision-makers continue to assess as the situation unfolds noting violated expectancies and surprising developments that refine their understanding of the situation. The decision-maker's assessment of the situation is in many ways a hypothesis that can be tested by taking actions and observing the results.

Recognition-primed decisions have been documented by skilled performers in many settings. A US Army Apache pilot described a situation in which he saw a small swirl of dust on the ground that was going against the current wind patterns in the desert. He quickly recognized this as an indicator that a huge sandstorm was about to roll in. He was able to rapidly divert and avoid getting caught in adverse weather conditions that would put his ability to safely fly the helicopter at risk (Militello et al., 2019). A neonatal intensive care nurse described a situation in which she conducted a routine assessment on a premature infant and knew immediately that the child was developing a potentially deadly infection in the bowel called "necrotizing enterocolitis." When asked to describe the infant, she recalled glassy eyes, pale skin, and a firm belly. She noted that the infant had not digested much of her most recent meal. These are all symptoms that are common in premature infants, but when observed in combination, the experienced nurse quickly recognized that this child was at risk (Militello & Lim, 1995).

These stories in which experienced personnel are able to quickly size up a situation and know what to do in spite of rapidly changing conditions, uncertainty, and distractions appear across many domains (Klein, 1998). The goal of recognition skills training is to help learners recognize critical cues and patterns so they can quickly intervene. We focus on three components of recognition skills: knowing what to attend to, creating meaning, and evaluating.

2.2.1 Knowing What to Attend To

Many researchers have come to the conclusion that experts are better at noticing relevant information than people with less experience (Gibson, 1969; Kellman, 2002; Kellman & Garrigan, 2009; Petrov et al., 2005; Shanteau, 1992). For some time, scientists thought that experts attended to more information than novices. However, Jim Shanteau and his colleagues at Kansas State University studied experienced and inexperienced accountants, physicians, nurses, and livestock judges only to discover that it is not the number of cues noticed that differentiates experts from others, rather, experts are better at determining which cues are important (Shanteau, 1992). Studies of medical radiologists (Hoffman et al., 1968), medical pathologists (Einhorn, 1974), stockbrokers (Slovic, 1969), and clinical psychologists (Goldberg, 1968) also found that skilled performers relied on a small number of particularly relevant cues.

Acquiring this skill of noticing relevant information is challenging because which cues are most important will vary depending on the situation. Less experienced people may be distracted by irrelevant information, slowing their reaction time. They may miss important cues, leading to incorrect assessments. They may find themselves anchoring on one piece of data and ignoring or explaining away contradictory information (Klein, et al., 2006a). Often, people learn to recognize critical cues by trial and error. When they make an incorrect assessment, they go back over the situation in their minds to determine what they missed. For example, in interviews with resident (trainee) emergency department pediatricians, resident physicians often recounted incidents in which other members of the health-care team recognized that a child was seriously ill before the resident did. The residents were able to describe the critical cues in retrospect, even if they did not notice them or understand their significance in the moment (Patterson et al., 2016).

2.2.2 Creating Meaning

Experts do not just know what to look for, they are also able to create meaning. An expert and a novice can look at the same situation and draw very different conclusions. Hoffman et al. (2010) emphasized that perception of cues is not sufficient for skilled performance; the cues must also be *meaningfully integrated*. As a result, expert recognition involves the ability to rapidly and effortlessly see meaningful information where others often cannot (Gibson, 2000; Goldstone & Barsalou, 1998). This is related to the

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concept of chunking, famously studied in the context of chess expertise. Researchers discovered that experienced chess players were able to extract meaning from brief exposure to chess boards depicting different configurations in ways that less experienced chess players could not (Chase & Simon, 1973b). Experts could view a midgame or endgame and remember it clearly, whereas novice chess players could not. However, when shown scrambled chess boards, the experts did no better than the novices at remembering the placement of chess pieces. For experts, the mid- and endgame configurations had meaning and were remembered as chunks rather than individual chess piece positions.

Patterson and her colleagues studied expert and novice differences in sepsis recognition by emergency department pediatricians (Patterson et al., 2016). Rapid recognition and intervention of sepsis is critical as delays in treatment often lead to significantly poorer outcomes and even death (Odetola et al., 2008). These investigators found that resident physicians (considered novices in this study) and experienced physicians recalled many of the same cues in recounting challenging incidents involving sepsis. The experienced physicians, however, also recalled the significance of the cues, the hypotheses they informed, and how others in the room often did not understand the significance of those cues initially. Experienced physicians used their understanding of the situation to form hypotheses about the patient's conditions. These hypotheses, in turn, informed which tests they ordered, what actions they took, and how they interpreted findings from tests and patient responses to interventions. The experienced physicians were able to create meaning from the cues available; the resident physicians noted many of the same cues but did not understand their significance, limiting their ability to develop plausible hypotheses that would drive their actions.

The data-frame model of sensemaking describes *how* people create meaning (Klein et al., 2006b). This model describes how an individual's prior experiences greatly influence what cues are considered relevant and how they are interpreted or meaningfully integrated. A person's cognitive "frame" drives what is considered relevant data, and what catches your attention. At the same time, the data in the environment influence what frame is invoked. As new information becomes available, the frame may be expanded, adapted, or discarded for one that better explains the situation. This implies that two experts may interpret the same situation differently, but both interpretations are likely to be reasonable and useful. Inexperienced people, however, may have difficulty creating meaning at all. An inexperienced clinician may carefully document a fever, lethargy, and elevated heart rate for a patient following surgery, but fail to put these individual cues together to consider that an infection or sepsis may be developing. These skills are typically acquired via experience on the job. Similarly, pharmacists sometimes notice drug–drug interactions that physicians miss. Both the pharmacist and the physician have access to information about the patient's symptoms and medication list. However, pharmacists tend to have a larger experience base of observing combinations of medications and side effects, allowing them to notice the right cues, see patterns, and make meaning that others cannot.

2.2.3 Evaluating

One key component of working effectively under time pressure is having strategies for quickly evaluating interventions *before* acting and continuing to monitor the situation for new information so that the plan can be revised as needed. The concept of mental simulation appears in many research traditions (Einhorn & Hogarth, 1981; Kahneman & Tversky, 1982; Klein & Crandall, 1995). It has been described as a way of starting with what is known and playing it forward to what might occur in the future, or playing it backward in time to imagine what may have occurred in the past to create the current situation. The recognition-primed decision model describes mental simulation as a streamlined strategy for imagining a potential course of action in one's head to identify flaws and refine the plan (Klein et al., 1988). The data-frame model of sensemaking describes how experienced practitioners update their understanding of the situation as new information becomes available (Klein et al., 2006b). Although evaluating one's understanding of the situation and planned actions is less prominent in the literature than knowing what to attend to and creating meaning, this skill is critical to noticing and recovering from errors and for avoiding fixation errors.

Our research team heard many examples of mental simulation during a project in which we interviewed US Army pilots. In Army aviation, mental simulation is used routinely in preparation for each mission. Referred to as mission rehearsal, team members meet to go over the plan and mentally walk through each component's role prior to a mission. Furthermore, individual pilots report that they continually mentally simulate as the mission unfolds, constantly comparing the current state of events to the plan, anticipating potential problems, and developing contingencies. For example, a helicopter pilot recounted an incident

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when he was serving as Air Mission Commander, supporting a team of Army Rangers on the ground:

> This pilot was responsible for managing a team of two Apache helicopters, four Black Hawk helicopters, and two drones. The Black Hawk helicopters would be used to carry a Ranger team including a dog and a translator to the area where they were needed, and the Apache helicopters and drones would be used to provide security. Timing was important because they were moving to an area of known hostile activity. This was a *hasty* mission, meaning there had not been days of planning; rather, a need had arisen and they were responding quickly to complete a time-sensitive mission. It was critical that they move as quickly as possible to give adversaries limited time to respond to the Rangers' presence. The Air Mission Commander recalled mentally simulating how they would manage a range of common problems if they were to arise. This included things such as reduced visibility due to dust and wind, as dust storms were an ever-present concern in this terrain. Another common risk for aging aircraft flying frequently in sandy, dusty conditions is delays due to maintenance issues. He was also aware that one aircraft had a faulty radio and was considering the implications and mentally simulating different workarounds. In addition to these common problems, on this particular mission, there were other elements that he needed to account for in his mental simulations. Specifically, they were transporting a dog and an interpreter with the Rangers. He knew that dogs required extra attention on helicopters because they get scared, so the dog would need to travel with his handler. He knew that the interpreter needed to travel with key members of the Ranger team. While they were still on the ground, before they had even picked up the Rangers, he was mentally simulating what would happen if one of the helicopters did not start up. How would he cross load the Rangers, the dog, the interpreter, and the personnel who were all key to the mission if they only had three Black Hawk helicopters rather than four as initially planned?

By mentally simulating a range of potential problems and evaluating various contingencies for managing them, Air Mission Commanders can anticipate and adapt to problems as they emerge, and sometimes prevent them altogether. To do this, the Air Mission Commander (or any operator) must have accurate and robust mental models (Rouse & Morris, 1986) that can serve as the basis for the mental simulation.

Our theoretical approach evolved as part of the Naturalistic Decision Making movement that emerged in the late 1980s. In addition to the recognition-primed decision model (Klein et al., 2010) and the data-frame model of sensemaking (Klein et al., 2006b), this community has conducted research that addresses many aspects of decision-making in complex environments including team coordination, managing uncertainty and risk, problem detection, establishing and maintaining common ground, managing attention, and planning (especially dynamic replanning as a situation unfolds). Given the breadth of cognitive processes explored by naturalistic decision-making researchers, many have begun to use the label "macrocognition" to describe this theoretical approach (Klein et al., 2000; Klein et al., 2003; Miller & Patterson, 2018; Patterson & Hoffman, 2012; Schraagen et al., 2008). In short, macrocognition is the study of cognitive processes used by people who make decisions in complex settings and includes processes such as sensemaking, managing uncertainty, detecting problems, managing attention, and coordinating (Klein et al., 2000). We adopt this same convention, using the term "macrocognition" throughout this handbook. For each principle in this handbook, we articulate important links to the macrocognition literature.

2.3 Scenario-Based Training

Our emphasis is on scenario-based training, so we consider each principle in this context. We use the term "scenario-based" to refer to training that places the learner in a situation they must assess and manage. The scenario may unfold over time, or could represent a snapshot in time. The scenario may be designed for individual learning experiences, or for team training. Scenario-based training encompasses a broad range of training media including text, live actors, augmented reality, and other simulation technologies, any of which can be used in combination with others. Scenarios are generally designed to address specific learning objectives. For the training we develop, learning objectives are generally associated with recognition skills, generally incorporating specific task components (e.g., distinguish hemorrhage injuries best treated with direct pressure from those requiring a tourniquet). We recommend learning needs assessment to articulate learning objectives, inform scenario design, support trade-off decisions regarding fidelity, and guide the design of scaffolding techniques. We find cognitive task analysis methods valuable for unpacking cognitive skills, critical cues, and complexities associated with recognition skills (Hoffman & Militello, 2008; Militello & Hutton, 1998).

With regard to content, each training scenario is designed to address specific learning objectives; often a series of scenarios will be combined into a learning module to support complex learning objectives. Scenario-based training can be instructor-led or self-guided. It can be relatively "tech-lite" using actors and simple tools, or it can be "tech-heavy" using advanced tools and automation. Stand-alone training (i.e., training with no instructor present) may be instantiated in an intelligent tutoring system that uses artificial intelligence to assess learner performance and provide customized support. The training session may include a didactic component to explain processes and concepts, as well as a debrief session to provide feedback and encourage reflection. Scaffolding and real-time feedback may be delivered by a live instructor, initiated by the learner, or introduced by artificial intelligence. The design principles discussed in this handbook are envisioned in the context of scenario-based training, emphasizing strategies for using augmented reality technologies to enhance the learning experience.

It is important to point out that although the focus of this book is on scenario-based augmented reality training design, creating compelling scenarios using augmented reality technology is an important part of training design but not the whole story. We use a Learn, Experience, Reflect framework to help us frame the entire training experience. The Learn component focuses on determining what declarative knowledge will be required for trainees to make the most of the training scenarios. The Experience component refers to the scenario-based experiential portion of the learning. The Reflect component refers to the training features that support the learner in reflecting on the experience, integrating knowledge, and discovering new insights. See Chapter 8 for more about the Learn, Experience, Reflect component.

2.4 Summary and Discussion

This handbook is intended to aid training designers as they create recognition skills training that leverages augmented reality technologies to implement training principles in new and creative ways. We have identified design principles that are particularly relevant to recognition skills training, drawing from the training and education literatures as well as our own work creating training for combat medics and medical students. The theoretical basis for our approach to recognition skills training is based primarily on the recognition-primed decision model (Klein et al., 2010). We articulate links to this model of decision-making, as well as other important research from the naturalistic decision making and macrocognition communities.

We emphasize three key components of recognition skills: knowing what to attend to, creating meaning, and evaluating. Our focus is primarily on training for dynamic, high-stakes domains characterized by uncertainty such as health care and military operations. The principles in this handbook are intended to create training that supports learners in building the foundation necessary for rapid recognition in these complex settings. Notably, acquiring recognition skills happens over time and with experience; thus, we aim to create training experiences that give learners the tools they will need to learn from and make the most of each training experience they encounter, whether in training or on the job.