Chapter 9
A Theoretically Based Approach to Cognitive Readiness and Situation Awareness Assessment

Cheryl A. Bolstad, Mica R. Endsley, and Haydee M. Cuevas

Military medical combat teams perform under stressful conditions, constantly dealing with life or death situations, including their own. It is imperative that their leaders have useful decision support tools to determine not only if their team members have the technical knowledge and skills needed to perform successfully but also whether or not they are "cognitively ready" to be deployed. To address this critical need, our research team developed the Medical Cognitive REadiness Survey Tool (M-CREST) to assess the degree to which military medical personnel are cognitively ready to perform their missions effectively. In this chapter, we first begin with a discussion of the theoretical foundation that guided our research project, highlighting the multidimensional nature of the cognitive readiness construct. We then focus more specifically on one important element of cognitive readiness, namely situation awareness (SA). Next, we describe our approach to assessing cognitive readiness (M-CREST) as well as offer recommendations for how to incorporate measures of situation awareness into cognitive readiness assessment. We conclude with implications for future research and development.

C.A. Bolstad, Ph.D. (✉)
SA Technologies, Inc., 76 Lillian Court, Forest Hill, MD 21050, USA
e-mail: cheryl@satechnologies.com

M.R. Endsley
SA Technologies, Inc., 8787 East Lost Gold Circle, Gold Canyon, AZ 85118, USA
e-mail: mica@satechnologies.com

H.M. Cuevas
Embry-Riddle Aeronautical University, 13863 Countryplace Drive, Orlando, FL 32826, USA
e-mail: hmcuevas@earthink.net

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9.1 Defining Cognitive Readiness

For our research, it was important to differentiate between military readiness and cognitive readiness. Military readiness is the ability of US military forces to fight and meet the demands of the national military strategy. More specifically, military readiness measures the ability of a unit, such as an Army division or a Navy carrier battle group, to provide the capabilities required by their commanders to successfully execute and achieve their assigned missions (Voith, 2001). This is derived from the ability of each unit to deliver the outputs for which it was designed. Conversely, cognitive readiness is a form of personal mental readiness that supports but does not replace military readiness. Greater levels of cognitive readiness facilitate enhanced cognitive performance, thus enabling military personnel to better perform their assigned duties. In both cases, readiness refers to the "potential" of these individuals and teams to achieve success rather than a measure of their actual success.

Morrison and Fletcher (2002) defined cognitive readiness as the "mental preparation (including skills, knowledge, abilities, motivations, and personal disposition) an individual needs to establish and sustain competent performance in the complex and unpredictable environment of modern military operations" (p. I-3). In our research, we built upon this definition, placing a greater emphasis on individual and team readiness and performance. Conceptually, we define cognitive readiness as possessing the psychological (mental) and sociological (social) knowledge, skills, and attitudes (KSAs) that individuals and team members need to sustain competent professional performance and mental well-being in the dynamic, complex, and unpredictable environments of military operations (Bolstad, Cuevas, Babbitt, Semple, & Vestewig, 2006). While somewhat broad in scope, this definition embraces the KSAs that are needed for superior cognitive readiness while still allowing for the specification of these KSAs to be tailored to targeted team skills and tasks.

9.2 A Multidimensional Construct

Cognitive readiness is a complex, dynamic, multidimensional construct that is formed and maintained when personnel interact with other team members within their operational environment. Therefore, central to understanding cognitive readiness is identifying the factors associated with this construct. Morrison and Fletcher (2002) identified ten factors underlying cognitive readiness: situation awareness, memory, transfer of training, metacognition, automaticity, problem solving, decision making, mental flexibility and creativity, leadership, and emotion. We revised and expanded this list to include several additional factors (see Table 9.1) based on findings from: (1) our critical review of Army combat support hospital after-action reports from Iraq and Afghanistan and the industrial/organizational, human factors,

Table 9.1 Candidate factors related to cognitive readiness drawn from different sources

Individual	Team	Organizational	Environmental
Behavioral style[a]	Cohesion[a]	Management	Fatigue[a]
Cognitive framing[a]	Collective efficacy	Organizational structure	Human–machine interaction
Cognitive resources[a]	Commonality of goals[a]	Satisfaction[a]	Noise
Creativity/flexibility[a]	Communication[a]	Social interactions	Temperature
Decision making[a]	Conflict resolution[a]	Success[a]	Tempo/time pressure
Emotion/anxiety[a]	Coordination	Team size	Uncertainty/ confusion
Experience	Leadership[a]	Training/education[a]	Vibration
Global response to stress[a]	Shared cognition		Work–rest cycles
Individual roles[a]	Shared mental models		Workload[a]
Memory capacity[a]	Team social processes[a]		
Mental models			
Metacognition			
Problem solving abilities[a]			
Self-efficacy			
Situation awareness			

[a]Factors rated by military medical personnel

management, and team performance literature; and (2) our interviews with military medical personnel (surgeons, medics, and nurses) about their experiences working in teams and what factors they found affected team performance and cognitive readiness (for a detailed description of this research, see Bolstad, Babbitt, & Semple, 2004). We were specifically interested in the identification of factors that best predict good team performance during dynamic and stressful situations, such as military combat operations. Based on this need, we paired down the list to a smaller subset of 21 factors (see factors marked with an asterisk in Table 9.1). We then asked 12 military medical staff members, who were currently deployed to Afghanistan and working in the same combat support hospital, to rate these 21 factors in terms of importance in performing their work (for a detailed description of this study, see Bolstad et al., 2004, 2006). Participants rated all 21 factors as moderately to highly important. None were rated as "unimportant" to pre-deployment cognitive readiness.

Building on this earlier work, we developed a theoretical framework that illustrates how many of these factors interact with other individual, team, organizational, and environmental factors to influence cognitive readiness (see Fig. 9.1). Several of these factors are inherent in the individual team member, such as, for example, memory capacity and other cognitive resources, problem solving and decision-making ability, and creativity and flexibility. Others are more relevant at the team level, such as communication, shared mental models, commonality of goals, and leadership. Although all these factors are important to cognitive readiness, in this chapter, we will focus more specifically on *situation awareness*, discussed next.

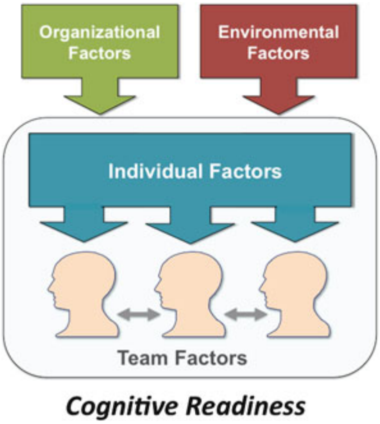

Fig. 9.1 Theoretical framework illustrating categories of factors influencing cognitive readiness

9.3 Situation Awareness and Cognitive Readiness

Situation awareness (SA) involves being aware of what is happening around you to understand how information, events, and your own actions will affect your goals and objectives, both now and in the near future. More formally, SA can be defined as "the perception of elements in the environment within a volume of time and space, the comprehension of their meaning, and the projection of their status in the near future" (Endsley, 1995b, p. 36). Having complete, accurate, and up-to-the-minute SA is considered to be essential in any domain where the effects of ever increasing technological and situational complexity on the human decision-maker are a concern (Endsley, 1995b). SA has been recognized as a critical, yet often elusive, foundation for successful decision making across a broad range of complex and dynamic systems, including aviation and air traffic control (e.g., Endsley, 2009; Nullmeyer, Stella, Montijo, & Harden, 2005), emergency response and military command and control operations (e.g., Blandford & Wong, 2004; Gorman, Cooke, & Winner, 2006), railroad operations (e.g., Golightly, Wilson, Lowe, & Sharples, 2010; Roth, Multer, & Raslear, 2006); power transmission and distribution (Connors, Endsley, & Jones, 2007; Salmon et al., 2008); and offshore oil and nuclear power plant management (e.g., Flin & O'Connor, 2001). Indeed, lacking SA or having inadequate SA has been consistently identified as one of the primary factors in accidents attributed to human error (e.g., Hartel, Smith, & Prince, 1991; Merket, Bergondy, & Cuevas-Mesa, 1997; Nullmeyer et al., 2005; Stanton, Chambers, & Piggott, 2001). Thus, SA is especially crucial in domains where information flow can be quite high and poor decisions may lead to serious consequences (e.g., piloting an airplane, functioning as a soldier, or treating critically ill or injured patients). Accordingly, it is not surprising that SA is an important component of cognitive readiness.

As described earlier, cognitive readiness represents the "potential" of team members to be ready to perform their job and SA is an essential element of this readiness. However, within the context of cognitive readiness, the focus is not on

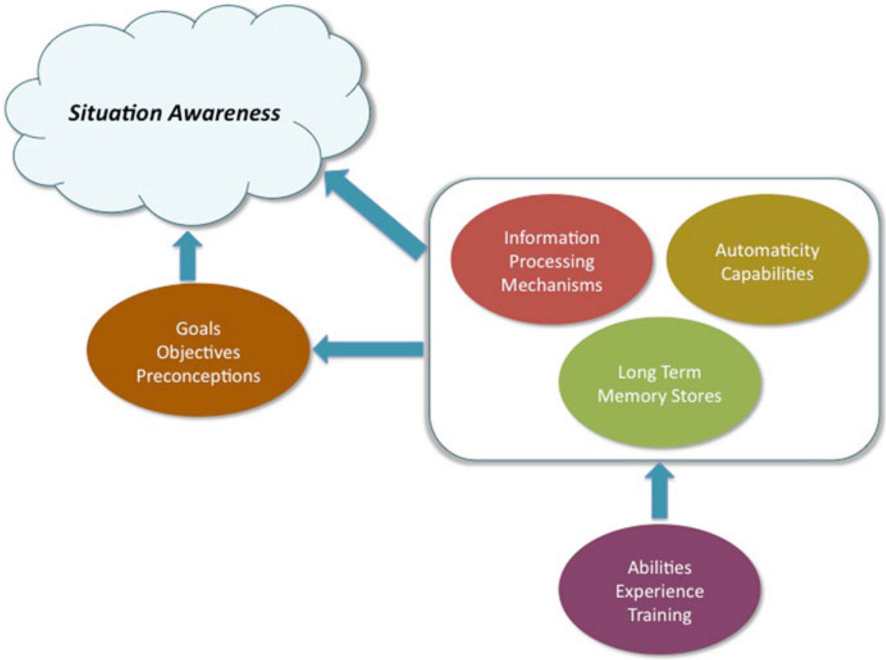

Fig. 9.2 Individual factors that affect situation awareness according to Endsley's (1995b) theoretical model

actual SA, but rather on the "potential" of an individual or team of individuals to achieve SA. The question then becomes what makes some individuals more likely to have better SA than others? Endsley (1995b) constructed a theoretical model of SA to describe how SA is formed and how it affects decision making and performance. As shown in Fig. 9.2, several individual factors influence SA. Many of these same factors also influence cognitive readiness (refer to Fig. 9.1).

Research has shown evidence for specific individual differences in abilities that potentially affect SA development. For example, Gugerty, Brooks, and Treadaway (2004) demonstrated how individual differences in perceptual and cognitive abilities (e.g., mental rotation, working memory capacity, divided and selective attention) are related to the performance of specific subtasks (e.g., navigation, maneuvering) in transportation operations (flying and driving) and to the ability to maintain SA while performing transportation tasks (see also Sohn & Doane, 2004). Similarly, other studies have shown that individuals who are better able to share attention on tasks exhibit better SA (Endsley & Bolstad, 1994; Gugerty & Tirre, 1997). In addition, Endsley and Bolstad (1994) found that individuals who performed better on psychomotor tasks also demonstrated better SA. While psychomotor skills may not be directly related to the cognitive task of developing and maintaining SA, it is hypothesized that greater levels of skill and automaticity in psychomotor tracking may free up the cognitive resources needed for SA.

Knowledge and information stored in long-term memory can also affect an individual's potential to form SA. Specifically, to understand patterns or trends in elements perceived in the environment, individuals retrieve analogous instances from their long-term memory that can then be used to compare against the current situation (Serfaty, MacMillan, Entin, & Entin, 1997; Sohn & Doane, 2004). Similarly, these long-term memory stores are also used to support predictions of future trends or changes in the situation. This repertoire of conceptual patterns or "mental models" stored in long-term memory is expanded through the development of expertise (Feltovich, Prietula, & Ericsson, 2006; Glaser, 1989; Smith, Ford, & Kozlowski, 1997). Thus, not surprisingly, expertise is related to better SA (Endsley, 2006). Experts, as compared to novices, are likely to have developed a greater sensitivity for detecting or recognizing patterns in specific types of data through training, extensive experience, better focused attention, or more effective use of data representations (Endsley, 1997; Garrett & Caldwell, 2009). In turn, this greater sensitivity may enable them to detect events with more accuracy and speed.

Beyond abilities, an individual's goals and objectives also directly influence the development of SA. Specifically, an individual's goals have a bearing on which specific cues in the environment are perceived, that is, individuals selectively direct their attention to information that is relevant to their goals and tend to ignore environmental cues that may not be as pertinent. Similarly, critical for developing and maintaining higher levels of SA is understanding how the current and future state of the situation affects one's goals.

To garner a better understanding of cognitive readiness and its constituent factors, valid and reliable measures of these constructs are absolutely indispensable. Although cognitive readiness and SA are both influenced by several similar factors, these constructs are also affected by different individual, task, and environmental factors. Thus, SA measures cannot be used to generally assess cognitive readiness and vice versa. Numerous well established measures of SA exist (see Endsley & Garland, 2000; Fracker, 1991a, 1991b; Salmon, Stanton, Walker, & Green, 2006; Wright, Taekman, & Endsley, 2004), yet very little research has been conducted on assessing cognitive readiness. Our research was aimed at addressing this important issue. Next, we describe our approach to assessing cognitive readiness as well as briefly discuss different approaches to assessing SA.

9.4 Assessing Cognitive Readiness

One approach to assessing cognitive readiness is to focus on members' subjective evaluation of their team's operational readiness. For example, Guerlain et al. (2004) developed a self-evaluation questionnaire that asked team members to rate their team's readiness to perform a mission or activity in terms of a suitable plan, sufficiency of personnel/skill sets, effective leadership, and effective communication. While this approach may have face validity, it cannot always ensure predictive validity. In contrast, our assessment approach is based on a theoretical framework that highlights the multidimensional nature of the cognitive readiness construct. In this section, we briefly describe the design, development, and initial usability assessment of our M-CREST (for a more detailed description, see Bolstad, Cuevas, Costello, & Babbitt, 2008).

Our theoretically based design approach involved developing a prototype measurement system that provides valid assessment of several essential factors that are indicative of successful performance at both the individual and team level. We focused on the more stable, enduring factors that are internal to the operator, that is, individual and team competencies (or KSAs), rather than organizational or environmental factors (cf. Cannon-Bowers, Tannenbaum, Salas, & Volpe, 1995). Although vital for optimizing performance, certain organizational (e.g., organizational structure, training/educational opportunities) and environmental (e.g., noise, temperature, task load) constraints are beyond the control of the operator and change from moment to moment, team to team, and mission to mission. Thus, it is doubtful that one could reliably assess performance under all these varying conditions.

The M-CREST prototype was designed to assess 12 essential factors associated with cognitive readiness. To facilitate the selection of the appropriate measures, we organized these 12 factors within categories that reflect how they are related to one another in terms of the individual's KSAs and team orientation (see Table 9.2). We then conducted an exhaustive search for off-the-shelf, validated measurement instruments from the education, business, and psychology domains (for a detailed description, see Bolstad et al., 2007). We developed and applied a comprehensive set of evaluation criteria to narrow down this list to six instruments to include in the design of our initial prototype. The M-CREST prototype surveys team members on 12 essential cognitive readiness factors, automatically scores their responses in real time, and provides recommendations to enhance their cognitive readiness.

The M-CREST interface consists of three components: user, administrator, and report generator. The entire system resides on a physically and electronically secure server and uses industry-standard software. All three interfaces are remotely accessible from virtually any location provided the user has an Internet connection and a standard Internet browser. Individual survey takers interact with M-CREST via the *user interface*, responding to each survey item using Likert-type scales. Upon completion of all the survey items, individuals receive their personalized M-CREST Individual Report (see Fig. 9.3), which provides the following information for each cognitive readiness factor surveyed:

- Overall score in terms of high, moderate, or low
- Layman's definition of the factor
- Description of the factor's relevance
- List of key KSAs that help ensure cognitive readiness for this area
- List of individual and team benefits associated with high readiness on this factor
- Up to three URLs for web sites presenting content intended to help individuals further enhance their cognitive readiness with respect to this factor

Table 9.2 Twelve cognitive readiness factors assessed by M-CREST prototype

Individual KSAs	Definition
Knowledge	
Thinking and planning strategies	How one approaches solving a problem, including the process of defining the problem to be solved, identifying the requirements (what information and actions are needed) for solving the problem, and effectively applying the appropriate techniques or strategies with the objective of solving the problem (O'Neil & Abedi, 1996)
Monitoring and self-checking strategies	Conscious and periodic self-checking of whether one's goal is being achieved, and, when necessary, selecting and applying different strategies (O'Neil & Abedi, 1996). Often referred to as metacognition or metacognitive skills
Skills	
Leadership	Ability to positively influence group members so as to help achieve the goals of the group (Kauses & Posner, 2001)
Individual roles on the job	Accepted, mandated, or assigned behaviors associated with a particular position within a group (Cammann, Fichman, Jenkins, & Klesh, 1983)
Attitudes	
Behavioral style	Attitude- and personality-driven patterns of behavior people exhibit in work and social settings (Cornelius, 2009)
Dealing with stress	How one manages stress in general, especially in ambiguous situations or when one must solve difficult problems (Heppner, 1988)
Flexibility/openness	Ability to be open to ideas that are different from one's own and to people who are different from oneself (Kelley & Meyers, 1995)
Self-confidence	People's judgments of their capabilities to organize and execute courses of actions required to attain designated types of performances … a judgment of one's capability to accomplish a certain level of performance (Bandura, 1986). More commonly referred to as self-efficacy
Team orientation	
Team cohesion	Active involvement and commitment driving the willingness to remain, and freely interact, in a group (Mullen & Copper, 1994)
Team common goals	Degree to which specific individual, team, or organizational goals are shared by members of a group (Stevens & Campion, 1994)
Team confidence	Members' shared belief in their team's ability or competence to perform a task or attain desired outcomes (Bandura, 1986; Pethe, 2002). More commonly referred to as collective efficacy
Team cooperation	Willingness on the part of team members to engage in coordinative or adaptive behavior; represents the attitudinal component underlying team coordination (Fiore, Salas, Cuevas, & Bowers, 2003)

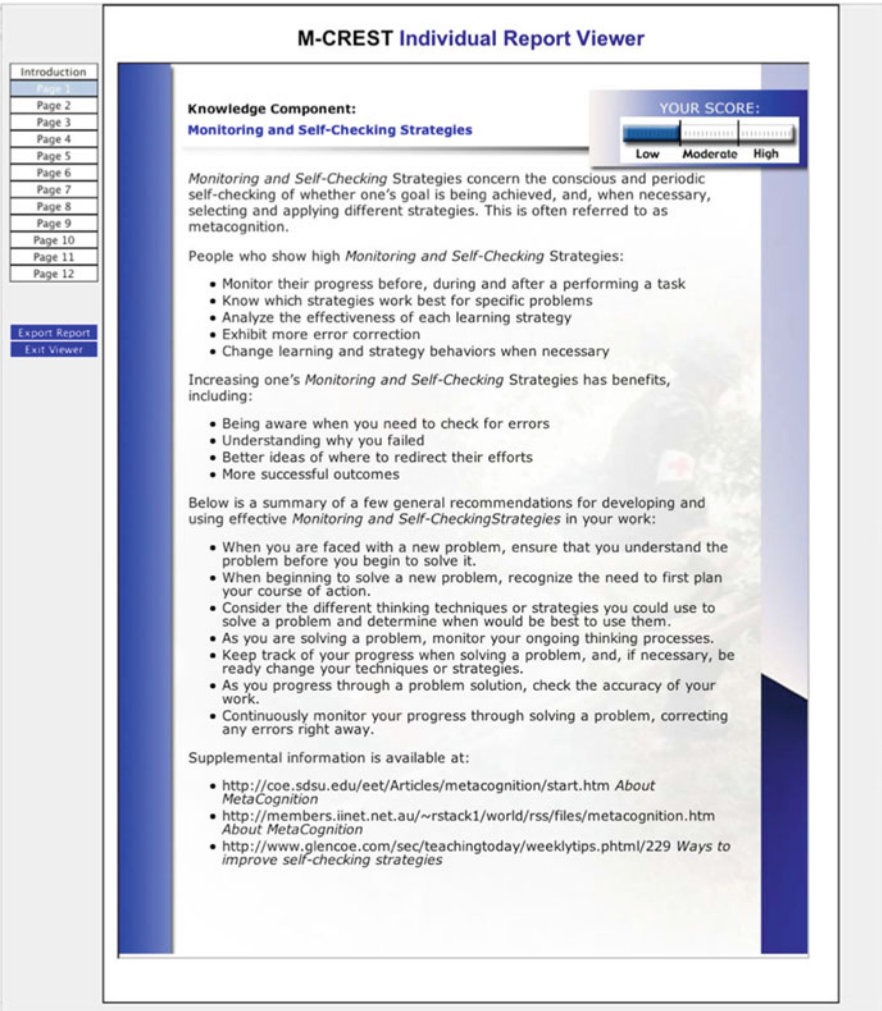

Fig. 9.3 Example page of M-CREST Individual Report

Supervisors interact with the *administrator interface* to identify and organize survey takers into groups and select the targeted cognitive readiness factors to be surveyed for each group. Once all group members have completed the survey, supervisors then access the *report generator interface* to view group-level summaries of the M-CREST survey results. Supervisors can request reports that compare a particular group's results on some or all the KSAs surveyed or compare different groups on specific KSA (see Fig. 9.4). It should be noted that the content of the M-CREST survey items and reports were not specific to military medical teams, but rather were domain-general, that is, were written using general terminology applicable to any domain.

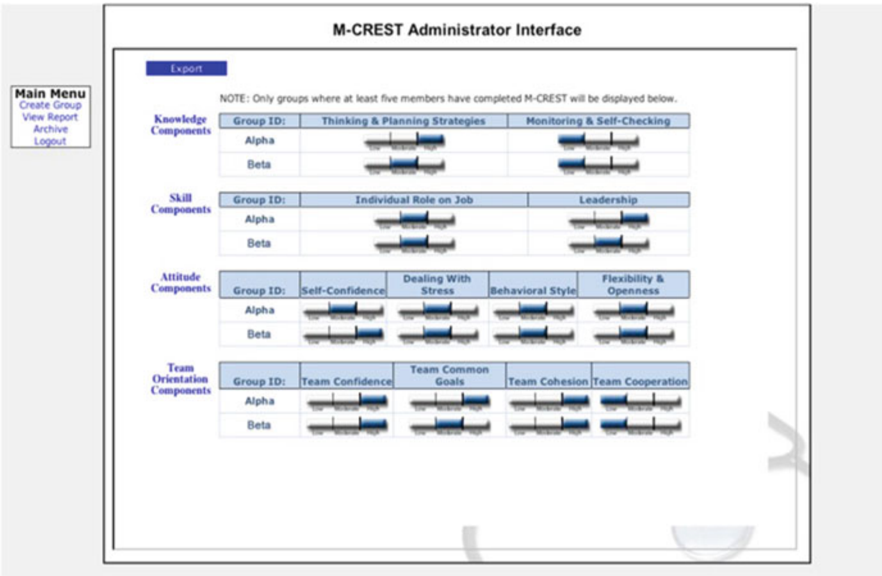

Fig. 9.4 Example of the M-CREST report generator output

The initial usability assessment of our M-CREST prototype was an important part of the development process, as feedback from potential users is critical to ensure that we meet our objective of designing a tool that can be used to assess and enhance cognitive readiness (for a detailed description of this study, see Bolstad et al., 2008). We did not have access to military medical teams for the usability evaluation of the M-CREST prototype. Thus, to increase the generalizability of the study's findings to military medical personnel, we solicited participation from an operationally relevant civilian population. Participants were recruited from three different test sites, and included firefighters, emergency medical technicians, and first responders (although nonmilitary, these individuals also perform in complex, high risk environments). Seven participants (all males; average age 45.4 years) from the three test sites participated in this study. Participants reported an average of 9.2 years on their current job and an average of 15.8 years in their career field. Participants were asked to complete nine sets of questions (total of 117 questions) hosted on the M-CREST prototype and were then presented with an M-CREST Individual Report summarizing their responses to the M-CREST survey as well as providing recommendations to enhance their cognitive readiness. Participants were also asked to provide feedback on their interaction with the M-CREST software, including ease of use and usefulness of information provided in their M-CREST Individual Report. Overall, participants found it easy to understand the M-CREST survey items, found the information and recommendations on enhancing their cognitive readiness presented in their M-CREST Individual Report relevant to their work, and were satisfied with the information they gained by participating in the study. Team leaders reported finding the interface easy to use and the information helpful for better understanding their teams.

9.5 Assessing Situation Awareness

Encouraged by the promising results of our initial usability assessment, we set out to explore the feasibility of expanding M-CREST to include measures of other essential cognitive readiness factors, such as SA. In this section, we offer recommendations for how to incorporate measures of SA into cognitive readiness assessment. In general, methodologies to assess SA vary in terms of direct measurement (e.g., objective real-time probes or subjective questionnaires assessing perceived SA) or indirect methods (e.g., process indices, trained observer ratings) that infer SA based on operator physiological states, behavior, or performance. Direct measures are typically considered to be "product-oriented" in that these techniques assess an SA outcome; indirect measures are considered to be "process-oriented," focusing on the underlying processes or mechanisms required to achieve SA (Graham & Matthews, 2000). The selection of which methodology to use depends upon the researcher's objectives and what data collection facilities or setup are available.

For example, the Situation Awareness Global Assessment Technique (SAGAT; Endsley, 1995a) provides direct objective measurement of SA by comparing an individual's perceptions of the situation or environment to some "ground truth" reality. SAGAT involves temporarily halting a simulation or operational activity at randomly selected times and removing task information sources (e.g., blacking out information displays); administering a set of queries that target each individual's dynamic SA information requirements (i.e., what they need to know at that point in time) with respect to the domain of interest; and resuming the simulation or activity (Endsley, 1995a). For settings in which disruptions to task performance are not practical or desirable, real-time probes (e.g., open-ended questions embedded as verbal communications during the task) can be administered to naturally and unobtrusively assess operator SA (Jones & Endsley, 2000). Real-time probes are similar to SAGAT in that these query operators on their knowledge of key task-relevant information in the environment; however, this methodology differs from the SAGAT in that task performance is not disrupted (i.e., the simulation or task is not stopped) but rather the queries are incorporated as a natural part of the task. Process-oriented indirect measures, such as the Situation Awareness Behaviorally Anchored Rating Scale (SABARS; Strater, Endsley, Pleban, & Matthews, 2001), also do not require interrupting task performance. Instead, these measures involve unobtrusive ratings by expert-trained observers of the types of overt team behaviors and communications that are indicative of good SA.

Because M-CREST is designed to be completed by individuals removed from the operational environment (i.e., not during task performance), assessment of dynamic constructs such as SA instead must rely on proxy measures to evaluate operators' predicted response in a given hypothetical situation. For example, short

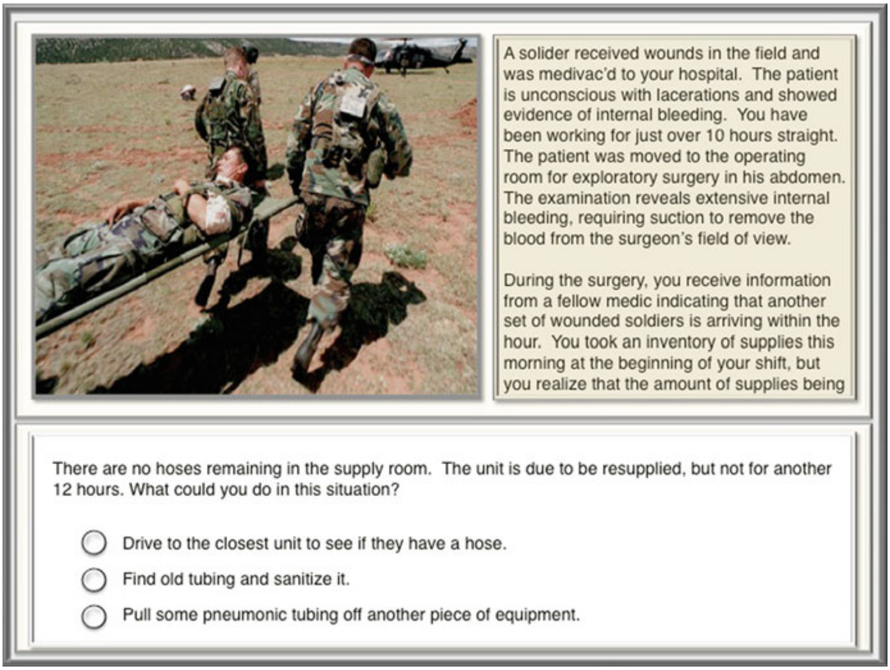

Fig. 9.5 Illustrative example of a scenario-based survey item for assessing situation awareness using M-CREST

text-based vignettes can be presented on the M-CREST that ask operators to predict what they would do or how they would react in a given situation (see Fig. 9.5). Responses for each individual and collectively for the team can then be examined to see if they have a shared understanding of the situation and know how best to respond. This could be used to gauge the "potential" of team members to develop SA when performing in the operational environment. The validity and utility of this scenario-based approach to assessment using text-based vignettes has been well documented (cf. Cannon-Bowers, Burns, Salas, & Pruitt, 1998; Rosen et al., 2008; Salas & Cannon-Bowers, 2000; Schmorrow, Cohn, & Nicholson, 2009; Vincenzi, Wise, Mouloua, & Hancock, 2008).

However, creating text-based vignettes for predictive SA assessment requires that scenarios be sufficiently detailed to engage the individual. In addition, to be operationally relevant to team performance, the vignettes must be specific to the team's domain. As such, developing metrics for this type of assessment can be very time-consuming and labor-intensive and the scenarios may not be readily generalizable to other domains. While M-CREST currently utilizes only domain-general measures, we, nevertheless, realize that incorporating domain-specific measures of cognitive readiness factors, such as SA, is absolutely vital to improve our tool's utility for providing a more comprehensive assessment of cognitive readiness.

9.6 Future Directions

Cognitive readiness is a new and continually evolving construct. Many questions still remained unanswered regarding what factors determine cognitive readiness and how cognitive readiness influences actual performance in the operational environment. Addressing these questions will require identifying existing as well as developing new valid and reliable measures of cognitive readiness and its constituent factors, which can then be incorporated into the design of M-CREST. Future research, therefore, is clearly warranted to establish the construct and convergent validity of measures for this important construct as well as the predictive validity of these measures with regard to individual and team performance. For example, operational assessments can be conducted with military medical personnel from Army combat support hospitals completing training at an Army Trauma Training Center as well as nonmilitary medical residents working at a high volume emergency room in a civilian hospital to statistically evaluate the psychometric properties of the survey items included in a more fully developed M-CREST (e.g., conduct a factor analysis of survey responses). Follow-up studies with participants can also be performed to determine if the feedback provided in the M-CREST Individual Report was utilized and proved helpful on the job.

M-CREST has been designed to enhance a team's cognitive readiness by drawing their attention to important KSAs that will enable them to more effectively deal with their new environment and responsibilities as well as improve their interactions with their team members and others in the field. For example, our research with military medical teams revealed several KSAs essential to team performance including problem solving, decision making, situation awareness, leadership, communication, and team cohesion as well as highlighted the importance of considering the effects of other factors such as fatigue, workload, and stress. M-CREST has also been designed to provide useful decision support to team leaders by identifying their team's strengths and weaknesses with regard to their cognitive readiness prior to task performance. As such, M-CREST can also potentially be used to balance or create teams based on their scores on different cognitive readiness factors. Further, because of its modular design, the surveys administered via M-CREST can be flexibly tailored to assess the KSAs deemed most critical for a given team or operational domain. Following assessment, M-CREST can then be used to evaluate the effectiveness of training interventions targeted at improving these specific areas of a team's cognitive readiness. Coupled with validated training programs, M-CREST, therefore, represents a valuable decision support tool that team leaders can use to prepare their teams to ensure successful performance in the operational environment.

Although M-CREST was originally designed for military medical training organizations and medical teams deploying worldwide, cognitive readiness is also applicable to Homeland Security, law enforcement, emergency, first responders, and other civilian medical personnel. Indeed, our initial usability assessment with firefighters, emergency medical technicians, and first responders demonstrated both M-CREST's potential usefulness for this population and its utility as a domain-general assessment tool. Thus, our development plans entail enhancing the design of M-CREST to make it applicable to a wider population by incorporating measures of other essential cognitive readiness factors, such as situation awareness. We also changed the product name to T-CREST (Team Cognitive REadiness Survey Tool) to reflect the nonmedical language contained in the survey items.

9.7 Conclusions

Human performance in today's technologically complex operations is influenced by a broad range of individual, team, organizational, and environmental factors. Therefore, from an applied perspective, cognitive readiness focuses on defining and optimizing the human dimension of the sociotechnical system by ensuring that individuals and teams possess the essential KSAs needed to perform effectively in these challenging domains (cf. Bowman & Thomas, 2008). Of particular interest is a team's cognitive readiness to maintain performance in foreign cultures, adverse climates, and demanding uncertain circumstances. Psychological researchers will play a vital role in helping optimize human performance through an understanding of the cognitive, behavioral, and attitudinal factors underlying individual and team performance, and through the identification of valid measures to assess these essential KSAs. The line of research reported in this chapter represents a theoretically based, operationally valid approach to addressing this important objective.

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