Situation Awareness in Team Performance: Implications for Measurement and Training

Eduardo Salas, Carolyn Prince, David P. Baker & Lisa Shrestha
Naval Air Warfare Center Training Systems Division, Orlando, FL

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Situation Awareness in Team Performance: Implications for Measurement and Training

EDUARDO SALAS,[1] CAROLYN PRINCE, DAVID P. BAKER,[2] *and* LISA SHRESTHA, *Naval Air Warfare Center Training Systems Division, Orlando, Florida*

Situation awareness has long been recognized as an important variable in aviation performance. Research to date has focused on identifying characteristics of situation awareness for individuals, not on the behaviors and processes associated with team situation awareness. The purpose of this review is to delineate and identify characteristics of team situation awareness. In addition, implications are discussed and research questions are outlined that target the measurement and training of situation awareness in teams.

INTRODUCTION

Situation awareness (SA) has received a great deal of attention in recent years (see, for example, Endsley, 1988, 1989, 1990; Fracker, 1988, 1989; Sarter and Woods, 1991) because of its well-documented role in aviation and other complex environments. In a review of more than 200 aviation mishaps, Hartel, Smith, and Prince (1991) found that a lack of SA was the leading causal factor. Likewise, Endsley (1988) asserted that SA was the single most important factor in aviation mission performance.

Although situation awareness has been identified as critical, it is not well understood. Sarter and Woods (1991), in referring to SA of individuals, noted that "situational awareness has thus become a ubiquitous phrase. Its use is most often based on intuitive understanding; a commonly accepted definition is still missing" (p. 45). This lack of an accepted definition and clear knowledge about the concept is also a problem for team performance, in which SA is hypothesized to have a significant impact (Cannon-Bowers, Salas, and Converse, 1993; Prince and Salas, 1993). There are, however, some similarities across explanations that are sufficient to provide a common base that can help in understanding the concept and provide coherence for future research.

The purpose of this paper is to examine processes and behaviors that have been associated with team SA. This line of inquiry is important because SA plays a critical role in aviation teams and in military team decision-making environments. We postulate that this construct applies to other types of teams as well (e.g., medical emergency teams, firefighters).

In this article, we examine situation awareness on two levels. First, we briefly summarize some elements that are common to several of the proposed explanations of individual SA in order to provide a base for examining team SA. Second, we identify critical variables that are associated with team SA and describe processes and behaviors that have been proposed as contributors to its establishment and maintenance. Finally, on the basis of the information reviewed,

[1] Requests for reprints should be sent to Eduardo Salas, Human Factors Division, Code 4961, Naval Air Warfare Center Training Systems Division, 12350 Research Parkway, Orlando, FL 32826-3224.
[2] Now at InterScience America, Leesburg, Virginia.

we identify issues related to the measurement and training of team SA. These issues and the questions they raise should help to guide future research.

SITUATION AWARENESS

Most attempts to explain situation awareness have focused on the processes that lead to effective SA in individuals (Gravelle, 1991). These explanations are characterized by three factors: (1) a focus on cognitive processes in situation assessment that provide the integration and understanding of information, (2) a temporal component in which past and present events are used to project the future (Endsley, 1989; Fracker, 1988; Harwood, Barnett, and Wickens, 1988; Hollister, 1986; Sarter and Woods, 1991; Schwartz, 1990; see Shrestha, Prince, Baker, and Salas, 1995, for a more detailed review), and (3) a distinction made between situation assessment as a process and the state of situation awareness (Fracker, 1988; Sarter and Woods, 1991; Tenney, Adams, Pew, Huggins, and Rogers, 1992). In the following section we provide a brief overview of processes and behaviors that have been used in defining the concept of individual SA and summarize what has been proposed about its development and maintenance.

Situation Awareness in Individuals

SA has meaning for the operational flight community (Endsley, 1993), yet it is not commonly defined and attempts to explain it have contained a confusion of terms. In addition, some theorists have suggested that more emphasis should be placed on defining and classifying the "situation" (e.g., the task, information available) in situation awareness (Flach, 1994; Tenney et al., 1992), whereas others have pointed out that there is insufficient knowledge about how to improve information acquisition for "awareness" (Sarter and Woods, 1991). With regard to the confusion of terms, Gravelle (1991) suggested that a major problem with situation awareness is the lack of a common conceptualization. To illustrate this point, consider two definitions of SA that were developed at about the same time. Fracker (1988) defined it as "the knowledge that results when attention is allocated to a zone of interest (i.e., the volumes of space that surround a pilot) at a level of abstraction" (p. 102); levels of abstraction refer to flight elements such as mission goals and immediate states of specific situation variables. Endsley (1988, 1989, 1990, 1995, measurement article, this issue) defined SA as "the perception of the 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" (1988, p. 97). Thus the major components of SA in the first definition are attention allocation and the resulting knowledge (Fracker, 1988) and in the second, perception, comprehension, and projection (Endsley, 1988).

Although this suggests there is little coherence in this conceptual area, a search beyond the definitions for common elements in the explanations of a number of researchers (including Fracker, 1988, and Endsley, 1988) demonstrates underlying conceptual agreements that provide a framework for understanding. First, the distinction between situation awareness (the product or goal) and situation assessment (the process) is important. According to Sarter and Woods (1991), adequate situation assessments result in knowledge that may become part of situation awareness. Pew (1994) described the process of situational assessment as a type of "mental workload" (p. 19). He asserted that situational assessments are of the greatest interest in measuring individual differences and in developing understanding for training but that both situation awareness and situational assessments need to be understood for system design.

In describing the attainment of situation awareness (or the process of situational assessments), many agree that individuals perceive critical information in the environment from exploring and observing the environment with certain expectations for what will be perceived (Fracker, 1989; Neisser, 1976; Tenney et al., 1992). Expectations are based partially on the individual's preexisting task knowledge (Kass, Herschler, and Companion, 1990; Tenney et al., 1992). Next, individuals integrate and comprehend perceived bits of information in working memory (Endsley, 1995, measurement article, this issue); this integration/comprehension is enhanced by relevant knowledge, or schemata, stored in an individual's long-term memory (Endsley, 1988, 1989, 1990; Fracker, 1988, 1989; Sarter and Woods, 1991). According to Endsley (1995, measurement article, this issue) the schema selected is used to guide comprehension, future projection, and the selection of necessary actions, with the result that the SA achieved will be a direct function of appropriate mental models and the capacity of working memory. Fracker (1988) suggested that when preexisting knowledge does not readily match the environment, working memory may support additional searches of the environment for more information and may need to construct a new schema from others available to the individual.

Sarter and Woods (1991) emphasized the importance of the temporal aspect of SA and the requirement that it be continuously updated or modified through the process of integration of multiple situation assessments. This implies the ability to remember previous events. They pointed out the complexity of SA by declaring that it should be viewed as a continuously changing and open system that can be affected by a variety of variables, some of which may be interacting devices. They reasoned, therefore, that mental models of each device may affect SA through their contribution to situation assessment but that a single mental model cannot represent SA.

Situation assessments lead to anticipations that help to guide additional exploratory behavior (Tenney et al., 1992), and the information derived from situation awareness is used to guide individual activities and predict future events (Kass et al., 1990). Therefore, although we have referred to SA as a state, it should be noted that SA is dynamic and is continuously modified and updated over time.

In her effort to define SA as both a process and the product of that process (i.e., to incorporate situation assessment and situation awareness), Dominguez (1994) compared 15 definitions. She agreed with Tenney et al. (1992) that the perception of expected information from the environment occurs in a continual cycle. She described this as a "continuous extraction" (p. 11). She sidestepped the use of a specific term, such as schema or mental model, because she saw little agreement on what these terms mean or which is more appropriate. Instead, she described the step of comprehension as "integration" with "previous knowledge" into a "mental picture" (p. 11).

Finally, Dominguez included the future in her definition in terms of further explorations for data extraction and the anticipation of the future. Remembering the past, she stated, is implied in the definition. By her account, her definition—"continuous extraction of environmental information, integration of this information with previous knowledge to form a coherent mental picture, and the use of that picture in directing further perception and anticipating future events" (p. 11)—differs from Endsley's primarily by bringing more emphasis to the active, cyclical nature of the perceptual process.

Figure 1 presents a high-level view of the major constituents of situation awareness. Simply stated, SA occurs as a consequence of an interaction of an individual's preexisting, relevant knowledge and expectations; the information available from the environment; and cognitive processing skills that include attention allocation, perception, data extraction, comprehension, and projection. This results in an increase in the individual's knowledge, a change in expectations, and another cycle of information extraction.

SITUATION AWARENESS AND TEAMS

Most explanations of SA have focused on individual SA and have not been concerned with determining what is necessary for team SA. Team SA, however, represents far more complexity than does simply combining the situation awareness of individual team members (Schwartz, 1990) and requires study in its own right. For example Endsley (1995, this issue,

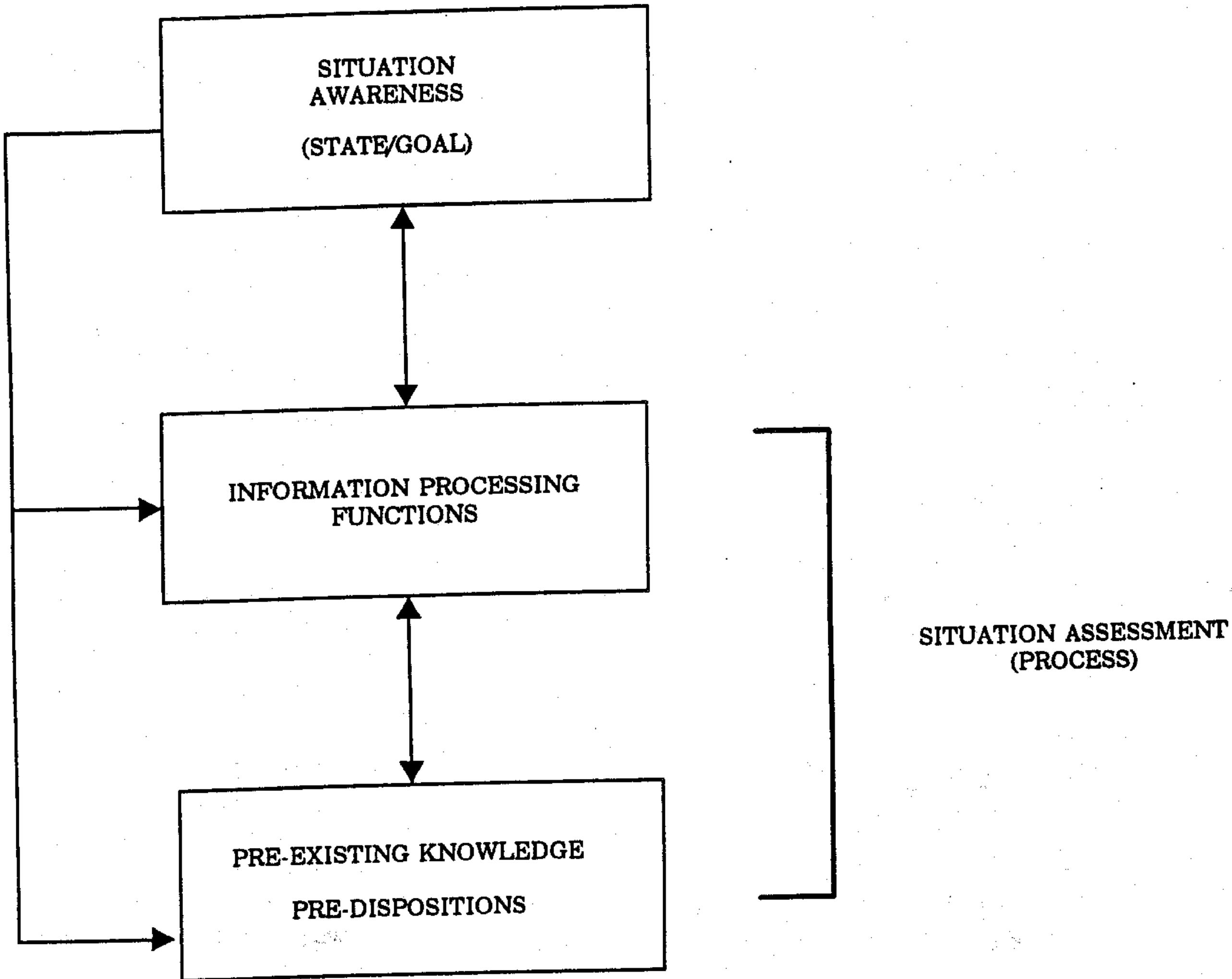

Figure 1. *Conceptualization of individual situation awareness.*

theory article) points out that whereas her theory of SA described cognitive processes that underlie individual SA (i.e., perception, comprehension, and projection), team SA involves unique activities, such as coordination and information sharing.

The study of team SA and how it is established is important for two reasons. First, as Cannon-Bowers and Salas (1990) pointed out, performance in many complex systems depends on the coordinated activities of a team of individuals. As noted earlier, SA plays a critical role in the performance of cockpit crews, and there is evidence that it affects some other types of teams as well (Cannon-Bowers, Tannenbaum, Salas, and Volpe, 1995). Second, although considerable research has been conducted in the area of team performance, relatively little is known about the nature and properties of teamwork (Salas, Dickinson, Converse, and Tannenbaum, 1992). Given that SA plays a vital role in how certain teams perform, further examination of team SA could prove beneficial for improving teamwork. Therefore, in the following section, after a brief introduction to the concept of teamwork, we review processes and behaviors by which SA may be established in teams and provide a framework for conceptualizing team SA. From this we generate a series of implications for measurement and training.

What Is Teamwork?

Recently Salas et al. (1992) defined a team as "a distinguishable set of two or more people who interact dynamically, interdependently, and adaptively toward a common and valued goal/object/mission, who have each been assigned specific roles or functions to perform, and who have a limited life span of membership" (p. 4). A number of other researchers have suggested similar definitions (Briggs and Naylor, 1964; Dyer, 1984; Morgan, Glickman, Woodward, Blaiwes, and Salas, 1986). This generally accepted understanding of the variables that define a team is important because it sets boundaries on what constitutes a team (e.g., such as the interdependency among team members), and these boundaries can be used to distinguish teams from other small groups (Orasanu and Salas, 1993).

Salas et al. (1992) reviewed team performance models and presented an integrated model of team performance and training. This was based on a system model with the basic categories of input, throughput, and output. *Input* included several "characteristics" such as those of the team members, the task, and work structure (e.g., the amount of interdependence). *Throughput* was described as team processes, and *output* included the quality and/or quantity of the team's work.

Even though researchers may agree on a definition of a team and may even use similar basic models to explain team performance, Dyer (1984) submitted that little effort has been devoted to understanding how team members interact and how these interactions change over time (the throughput of the system). A number of other researchers have echoed this concern (Baker and Salas, 1992; Salas, Blaiwes, Reynolds, Glickman, and Morgan, 1985; Salas et al., 1992).

The majority of team research has focused on military command and control teams and aircrews (Foushee, 1984; Helmreich, Wiener, and Kanki, 1993; Morgan et al., 1986). These efforts have attempted to establish the underlying team processes and behaviors that affect team performance. For example, Morgan et al. (1986) hypothesized that two categories of behavior could be distinguished in a team: a *taskwork* track and a *teamwork* track. Taskwork consists of behaviors that are performed by individual team members and are critical to the execution of individual team member functions. Teamwork consists of behaviors that are related to team member interactions and are necessary to establish coordination among the individual team members to achieve team goals.

In an in-depth examination of the teamwork track, Morgan et al. (1986) identified critical teamwork behaviors and organized them around seven behavioral dimensions: giving suggestions or criticisms, cooperation, communication, team spirit and morale, adaptability, coordination, and acceptance of suggestions or criticism. Two recent research efforts have shown that a number of team behaviors are related to team functioning and task outcomes (Oser, Prince, and Morgan, 1990) and are fairly consistent across different task types (McIntyre and Salas, 1995). In addition, Stout, Cannon-Bowers, Salas, and Morgan (1990) demonstrated that team behavior is directly related to the level of team performance observed.

Other researchers have focused on the more purely cognitive processes associated with teamwork. They have hypothesized that team members may develop and rely on shared mental models to enhance coordination and ultimately improve team performance (Cannon-Bowers et al., 1993; Converse, Cannon-Bowers, and Salas, 1991; Orasanu and Salas, 1993). According to Cannon-Bowers et al. (1993), shared mental models are organized bodies of knowledge that are shared across members of the team. They suggested that such models have the potential to affect teamwork at two levels. First, when communication channels are limited, they enable team members to anticipate other team member behaviors and information requirements (Converse et al., 1991). Second, shared mental models of a team task enable team members to perform functions from a common frame of reference (see Stout, Cannon-Bowers, and Salas, 1994, for a detailed discussion).

In summary, the results of team research suggest that teamwork appears to be composed of a relatively stable set of behaviors and cognitive processes. Specific team behaviors have been identified that define teamwork (McIntyre and Salas, 1995; Morgan et al., 1986) and that have been organized into a number of behavioral dimensions. It has also been hypothesized that individual team members' cognitive representations of the task and cognitive processes that are shared among team members (in the form of shared, organized bodies of knowledge) affect team performance (Cannon-Bowers et al., 1993).

Now that we have presented the construct of teamwork, we turn our attention to the definitions of team situation awareness. In doing so, we first review briefly what others have said about it and then provide an integrative framework that ties together the teamwork and team SA concepts.

Overview of Team Situation Awareness

Few efforts to explain either the processes or the state of team SA have been documented. Of those that have been published, most have focused on aviation teams. These efforts have sought to identify critical behaviors and cognitive processes that contribute to developing and maintaining situation awareness.

Bolman (1979) referred to team SA as the crew's *theory of the situation,* which he proposed was affected by two factors. First, Bolman suggested that team SA was affected by the *theory of practice,* which he described as the process by which individual team members test their theories of the situation by collecting and sharing information. Second, he suggested that team SA would be affected by the ability of team members to join their skills in "advocacy" and endorse a particular theory. Bolman stated that once a theory of a situation is established, team members share the theory as a common frame of reference for their team task. The team's theory of the situation is not static, however, and when inconsistencies arise, members are required to question those inconsistencies and modify their theories accordingly.

Bolman (1979) viewed several behaviors as essential in developing, maintaining, and modifying a team's situation awareness. They included monitoring position-specific information, confirming and cross-checking information within the team, communicating relevant situation information to others, and coordinating activities.

More recently, Schwartz (1990) defined aircrew SA as the accurate perception of variables that affect the aircraft and crew during a defined period. Schwartz stated that each individual crew member possesses a unique level of situation awareness but that team SA could not be calculated simply as the sum of the situation awareness achieved by each crew member. Schwartz said that team SA was moderated by the pilot in command, who must receive information about the situation from each crew member. Furthermore, Schwartz stated that the level of situation awareness achieved was related to the level and quality of communication observed in the crew. Incomplete communication was seen as an indicator of decreased situation awareness.

Wagner and Simon (1990; as cited in Shrestha et al., 1995) defined aviation team SA as the crew's understanding of flight factors that affect (or could affect) the crew and the aircraft at any given time and that subsequently have an impact on overall mission performance. Like Bolman (1979), Wagner and Simon suggested that aviation teams must monitor, process, and exchange information (i.e., mission objectives, orientation in space, environmental conditions, external support, equipment status, and personal capabilities status) from several sources to maintain situation awareness.

In an ongoing effort to determine important team processes and behaviors in military aviation teams, Prince and Salas (1989, 1993) used a literature review, critical incident interviews, and surveys of aircrew members to modify Morgan et al.'s (1986) list of teamwork behaviors. These data yielded behaviors that could be separated into seven dimensions that were meaningful for aviation teams: decision making, assertiveness, mission analysis, communication, leadership, adaptability, and situation awareness. With respect to the maintenance of team

SA, Prince and Salas (1993) noted that each crew member must seek and communicate information from both the internal and external environments. By communicating relevant situation information, crew members demonstrate knowledge of their overall mission goals and their individual task responsibilities. Furthermore, they asserted that this information exchange among team members contributes to coordinated activity on the part of the crew.

Wellens (1993) defined group SA as "the sharing of a common perspective between two or more individuals regarding current environmental events, their meaning, and projected future status" (p. 272). He suggested that group SA could be maximized by having each member monitor different segments of the environment with enough overlap among members to ensure opportunities for coordination. Wellens also briefly discussed shared mental models. His use of the term described two aspects—one for agreement on the operation of the group and one for the shared understanding of a particular problem the group faces. The latter aspect he used in terms of Orasanu's (1990) conceptualization of a shared problem model, which is developed through communication of situation assessments, determination of the problem, and development of plans to handle the problem. Although Wellens recognized the importance of communication in the maintenance of group SA, he pointed out that communication is achieved at a possible cost in effort and attention.

Endsley (1995, measurement article, this issue) suggested that team SA consists of both the situation awareness required of each team member and the overlap in situation awareness that is necessary among team members, particularly for coordination. Robertson and Endsley (1994) have noted the relationship between crew resource management (CRM) and team SA. They used this relationship as the base on which to build an explanation of how team SA may be studied and trained. Starting with the Line/Line Operational Simulation checklist that was developed for the measurement of CRM (Helmreich and Foushee, 1993; Helmreich, Wilhelm, Kello, Taggart, and Butler, 1991), they extracted attitudes and behaviors that were shown to be positively affected by CRM training and described how these could affect situation awareness. Robertson and Endsley drew a connection from the crew attitudes to the behaviors, to shared mental models, and finally to individual SA. Some of the behaviors they identified included communication, self-critique, preparation and planning, crew briefings, and task distribution.

Toward a Framework of Team SA

Although each of the definitions and descriptions of team SA listed previously differs somewhat from the others, they all contain terms that refer to individual SA and terms associated with team processes. These include, for example, perception of relevant variables and communication (Schwartz, 1990), understanding of relevant flight factors and exchanging information (Wagner and Simon, 1990, as cited in Shrestha et al., 1995), individual SA, and planning (Robertson and Endsley, 1994). We conclude that team SA involves two critical but poorly understood abstractions: individual SA and team processes (i.e., teamwork behaviors and cognitive processes that facilitate team performance). This cannot be a simple relationship, however, because each concept contains elements that are highly interactive (e.g., Dominguez, 1994, described individual SA as a continuous cycle, and Sarter and Woods, 1991, emphasized the dynamic nature of situation assessment). The team model is also dynamic. Although the interrelationships of the tasks are considered an input variable, the team processes can modify those interrelationships. This can be done directly (e.g., the team leader reassigns duties) or indirectly (e.g., team members provide backup to one another).

Figure 2 provides a framework for conceptualizing team SA. It shows the overview presented in Figure 1 for individual SA and an abbreviated system model for team performance. For individual SA the basic elements, knowledge and processing, influence each other. In teams,

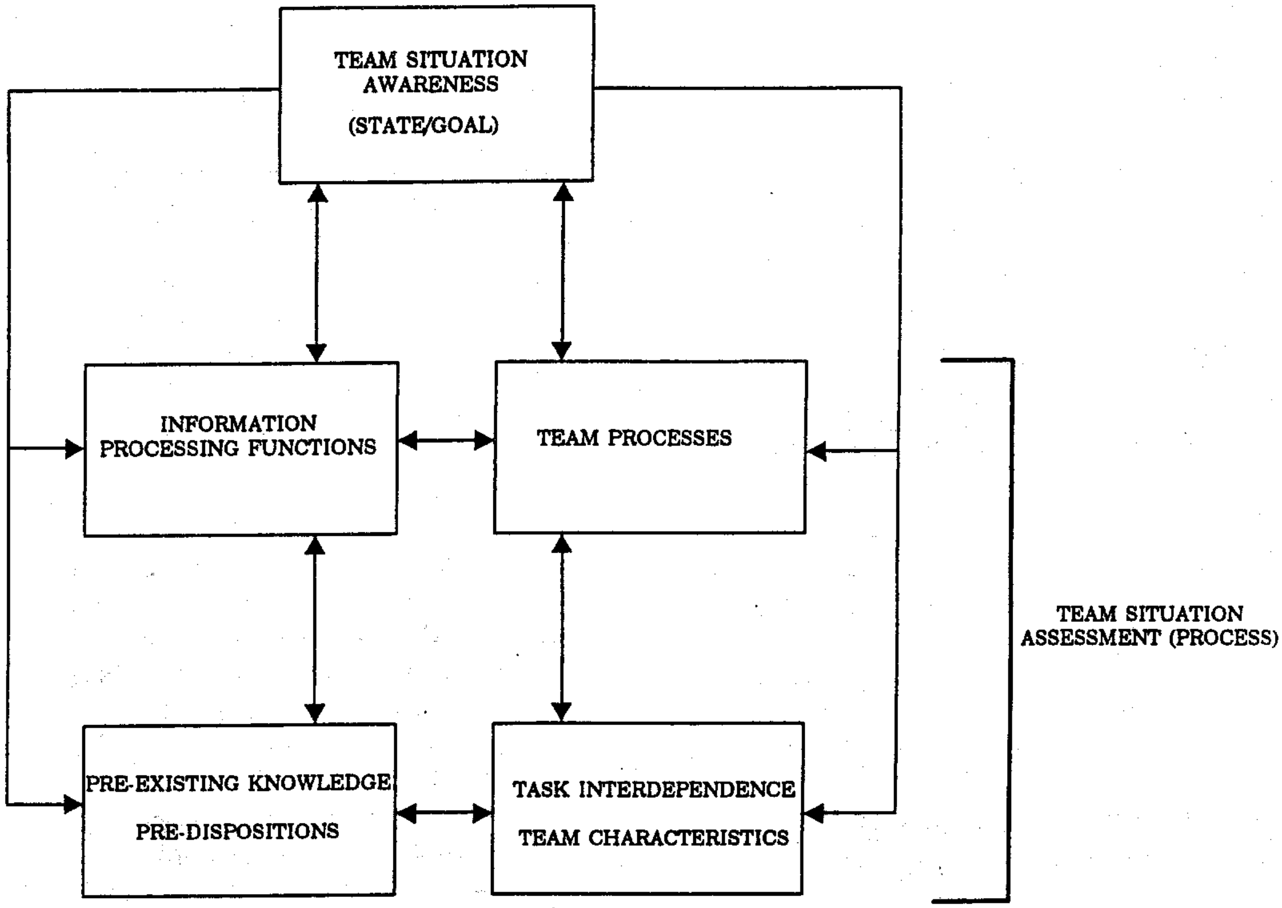

Figure 2. *Conceptualization of team situation awareness.*

the preexisting requirements for the team's work, the characteristics of team members, and the team processes interact and affect one another as well. The resulting situation awareness can modify all the contributing elements, both directly and indirectly.

To provide a solid basis for building team SA, team members need to have information that will help each individual develop relevant expectations about the entire team task. Team SA depends on communication at several levels (Bolman, 1979; Prince and Salas, 1989, 1993; Schwartz, 1990). The process of perceiving environmental information is affected by expectations developed from the communication of knowledge about mission objectives, own tasks, other relevant tasks, team capabilities, and other factors associated with team performance (Bolman, 1979; Prince and Salas, 1989, 1993). Limitations of each individual's relevant schemata in long-term memory can be offset in teams by the process of exchanging and confirming information (Bolman, 1979; Orasanu, 1990; Schwartz, 1990; Wagner and Simon, 1990, as cited in Shrestha et al., 1995). This information is made available through communication and coordinated activity among team members (Endsley, 1995, measurement article, this issue). Then, as information is integrated and comprehended, interpretations provided by other crew members may affect that comprehension. Thus, as new information is perceived from the environment by individual team members and is collected and shared (Bolman, 1979), the situation awareness of other team members may be modified accordingly. This helps team members to update their mental models and develop shared strategies (Orasanu, 1990).

Team processes that facilitate communication (e.g., assertiveness, planning, leadership that encourages an open cockpit) help in building team SA. An individual's communication of his or her situation awareness can affect the team processes in a number of ways (e.g., by helping to clarify a task, focusing the crew, providing inputs for decision making). Like individual SA, team SA is not static. In sum, team SA is at least in part the shared understanding of a situation among team members at one point in time. This state of awareness is facilitated by team processes or behaviors that allow shared assessments to be developed and maintained.

Elaborating the Team SA Construct

The framework presented in Figure 2 represents an overview of team SA. Based on recent research, two directions of exploration appear necessary. First, as noted, team SA is somehow interwoven with teamwork. There is apparent agreement among all researchers that at least one team process variable, communication, is related to team SA, and several other team process variables (e.g., planning, self-critique, task allocation) have been proposed as important (Robertson and Endsley, 1994). However, there has been no comprehensive consideration of the effect of other team process variables on team SA. The work of Robertson and Endsley (1994), in their attempt to integrate process research with situation awareness, is illustrative of a promising direction for team SA research. This needs to be expanded. Guidance for selection of these variables can come from a number of researchers' lists. From aviation research, for example, Prince and Salas (1989) suggested six categories of behaviors that are related to situation awareness and team performance, and Helmreich and Foushee (1993) have suggested others. In the area of more general team research, Morgan et al. (1986) identified seven categories of team behaviors, and, more recently, Cannon-Bowers et al. (1995) provided a framework for the investigation of team competencies. Efforts to conceptually and empirically link team SA to other team processes are needed.

Second, both Flach (1994) and Tenney et al. (1992) noted that more emphasis needs to be placed on the situation in individual SA. This suggestion is relevant for team SA. The situation determines team members' task assignments, which in turn may have an important effect on the specific requirements of team SA. Endsley (1995, measurement article, this issue) defined team SA in terms of the overlap of informational needs of the team members. The amount of overlap can change as informational needs of crew members change with the demands of the task, particularly if the crew is working in a dynamic environment such as a cockpit.

The literature reviewed here suggests some explanations for team SA and has implications for both its measurement and training. Based on this review, we next outline some important questions pertaining to the measurement and training of team SA.

IMPLICATIONS FOR MEASUREMENT AND TRAINING

An important step toward understanding team SA will be the development of measurement for this construct. As noted previously, a central problem in understanding situation awareness is the lack of well-developed measurement tools. This deficiency affects the development of instructional strategies for situation awareness. Of the measurement approaches that are currently available, most were designed to measure the situation awareness of individual team members (Endsley, 1990; Fracker, 1988). Bunecke, Povenmire, Rockway, and Patton (1990) pointed out that although these techniques may have some merit, they are inadequate for capturing team SA.

Measurement Issues

Brannick, Prince, Prince, and Salas (in press) discussed three reasons for the importance of measurement of team process. These reasons apply equally well to the measurement of team SA. First, theory cannot move beyond the conceptual stage without the development of psychometrically sound measurement tools. Measurement, in and of itself, will contribute to the building and validating of accurate models of team SA. Second, without quantifiable indicators of team SA, it is hard to articulate what constitutes good situation awareness. Such information is particularly important for providing performance feedback during training. Finally, measurement is vital in evaluating instructional approaches to training. Psychometrically sound measures will provide an indication of the extent to which training is effective. Using these three issues and the research reviewed, we outline three areas to consider with respect to the measurement of team situation awareness.

What to measure? Measurement of team SA as a concept in itself is premature until there is a clearer understanding of what the concept represents. Two critical measurements should first be made for team SA: (1) individual SA and (2) the team processes that team members use to build and exchange information and enhance team coordination. Because shared mental models have been hypothesized to be an important component of team SA (Robertson and Endsley, 1994; Stout et al., 1994; Wellens, 1993), the compatibility of mental models among team members should also be measured.

The measurement of individual SA is an important concern and is being addressed by a number of researchers (Endsley, 1995, measurement article, this issue; Fracker, 1988; Sarter and Woods, 1991; Tenney et al., 1992; Waag and Bell, 1994). Fracker (1991) presented a comprehensive discussion of the various methods available for the measurement of individual SA (e.g., self-report, verbal protocols, explicit and implicit measures). He found that each method has demonstrated weaknesses (e.g., intrusiveness, incompleteness) and none has demonstrated acceptable levels of both reliability and validity. This presents a formidable challenge for any effort to measure situation awareness.

As difficult a problem as the measurement of situation awareness may be, the measurement of mental models may present an even greater challenge. A few techniques are now available to assess team member mental models (e.g., Pathfinder; Schvaneveldt, 1990) but need further testing and development. Because the measurement of cognitive states is so vital to the understanding of situation awareness, efforts should be made to develop better measurement tools. Until such tools are available, we can continue to gain insight about team SA by concentrating on individual and team situation assessment processes. By focusing attention on these more behavioral aspects of performance, it is possible to draw inferences regarding the nature and quality of team SA.

For example, some of the indicators that have been suggested as being important to team SA are confirming and cross-checking information in the team, coordinating activities (Schwartz, 1990), sharing information (Wellens, 1993), planning, allocating tasks, and conducting pretask briefing (Robertson and Endsley, 1994). Prince and Salas (1989) identified indicators of team SA that can be observed and documented in crew communications when a team is performing. They include identifying a problem or potential problem, recognizing the need for action, attempting to determine the cause of discrepant information, providing information to another team member before it is required, noting deviations, and demonstrating an awareness of the task status and of one's own performance. The measurement of team process behaviors (Brannick et al., in press; Helmreich et al., 1991; Morgan et al., 1986) has received considerable attention in recent years, and because of its importance to team performance, work in this area is continuing.

When to measure? Team SA is not a static state but, rather, is the result of recurrent processes (i.e., information seeking, information processing, and information sharing) that take place within a team. It is clear that a single measurement is not adequate for determining situation awareness for a team throughout a particular task. Therefore, to produce higher temporal stability for both situation assessment and situation awareness, measurements should be made over a series of key events while the team is performing its tasks.

How to measure? Sarter and Woods (1991) suggested the use of complex scenarios to measure situation awareness, a method that has already been applied to measurement of both individuals and teams in a variety of settings. They recommended embedding events in the scenarios to elicit key situation assessment behaviors and processes. They also recommended that a number of such events be embedded in order to provide multiple opportunities to measure the team's situation awareness. To make this measurement work, methods that allow observers to document and rate team SA and behaviors throughout the scenario would need to be developed. Because this requires observation and judgment regarding the quality of that behavior, research should identify approaches to measurement that enhance rater reliability and validity. For example, checklists, behavioral-anchored rating scales, and behavioral observation scales (Muchinsky, 1990) have been shown to improve rater judgments when evaluating an individual's job performance. These formats have also been employed in team process research with some success (Baker, Salas, Cannon-Bowers, and Spector, 1992; Brannick et al., in press; Glickman et al., 1987; Morgan et al., 1986).

One technique for measuring team behavior is targeted acceptable responses to generated events or tasks (TARGETs; Fowlkes, Lane, Salas, Oser, and Prince, 1992). With TARGETs, expected responses are scripted for each scenario event and team responses are evaluated on the basis of their match with the scripted responses. TARGETs have been shown to achieve strong rater agreement (i.e., in excess of 80%) for determining presence or absence of team behavior and the matching of a behavior to a scripted response (Fowlkes et al., 1993).

One drawback to this technique is that TARGETs provide only a frequency count of the team behaviors and do not give information on the underlying team processes. Although research is required to evaluate the utility of TARGETs for assessing team SA, the TARGET methodology may be useful as a model for future measurement tool development.

Because a number of researchers have suggested that team SA is affected by the sharing of mental models (Endsley, 1995, this issue, measurement article; Stout et al., 1994; Wellens, 1993), some effort should be made to measure these knowledge structures. Before, during, and after the presentation of specially designed scenarios with embedded events are ideal opportunities for the measurement of mental models of team members. Until available tools to measure mental models are improved, the specific aspects of their contribution must remain in question.

Team Training Issues

Research on team training strategies will provide information that is useful at two levels. First, the results of research on the critical processes and behaviors to train can be used to refine the knowledge about team SA. Second, because the goal of team training is to improve performance, data from such research will provide insight into the effects of team SA on team performance. Therefore, we present three questions pertaining to training team situation awareness.

What to train? The acquisition and maintenance of team SA involves individual and team-level processes and behaviors, and training must be structured to address both (Endsley, 1995, this issue, theory article). For individuals, training should focus on critical information-seeking and information-processing behaviors needed for individual situation assessment and awareness. This may be accomplished by systematically exposing the trainee to a variety of scenarios in which, through guided practice and feedback, he or she may develop the knowledge structures necessary for rapid and accurate situation assessment. For team SA, training should focus on complex communication behaviors and team planning. Within these dimensions training should address both the pretask brief (in which communication and planning are key elements) and dynamic reassignment of workload and tasks.

Cannon-Bowers et al. (1995) have proposed that for teams in which turnover is routine (e.g., most aviation crews), the training emphasis should be on task-specific competencies. That is, training should focus on the roles or position in the team and the significance of those roles for the team, rather than on competencies for a specific team. They also proposed that individuals who fulfill the same role on different teams should be trained in transportable team competencies. These competencies are those associated with helping the individual to be a good team member no matter who the other team members are. For example, knowing good communication skills for building situation awareness would be a transportable skill that could be used in any team situation.

When to train? Teams are believed to possess a unique life cycle (Morgan et al., 1986). Therefore, a critical issue for research is to determine when training will have the greatest effect on team SA. Although some programs have focused on introducing training early in team development (Prince and Salas, 1993), questions remain as to when training will be most effective. Research on the sequence in which situation awareness develops should be conducted and should address the question of whether team process training should precede, follow, or accompany individual training to improve situation assessment. The result of sequences of different individual and team training is most likely affected by the type of tasks and research.

How to train? Two issues are of importance here: how to train complex communication behaviors needed to share situation-relevant information, and how to develop the team knowledge that is required for all members of a team. With respect to complex communication behaviors, research has shown that practice with feedback is critical for training transfer (Prince, Chidester, Bowers, and Cannon-Bowers, 1992; Salas et al., 1992; Smith and Salas, 1991). This approach includes four phases: presentation of skill information, demonstration of performance, practice, and presentation of feedback (Prince, et al., 1992). The nature and length of practice required for optimal team skill training has not been established and may be affected by the level of team members' baseline teamwork proficiency, the type of tasks, and the type of additional instruction used.

To build knowledge structures relating to the team, team training techniques, such as cross-training, have shown promise. In an empirical investigation of two-member teams, Travillian, Volpe, Cannon-Bowers, and Salas (1993) showed that cross-training improved team performance. These researchers hypothesized that this improvement was attributable to the development of shared mental models in the team. On this basis, individual team members should receive training on the task responsibilities and roles of other team members. Moreover, in the case of situation awareness, this training should focus on each team member's individual situation assessment requirements.

Although we advocate cross-training as an instructional strategy, there are still several issues to resolve. For example, there are no concrete guidelines on the degree of cross-training required or the effective instructional strategies for conducting such training (i.e., is simply providing information on the other team member position sufficient, or does cross-training require some hands-on practice and feedback to truly be effective?). Future research needs to examine the effectiveness of cross-training for developing team SA with the goal of establishing guidelines for the conduct of such training.

CONCLUSIONS

Although a great deal of information has begun to accumulate on team SA, there is still much to be learned. It is hoped that this paper will stimulate new theoretical development. More research is required on how and when to assess team SA, and new training strategies for team SA ought to be designed, developed, and evaluated. Collectively, these efforts will enhance understanding of situation awareness and team performance in general.

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