Concept

12TH ICCRTS
Adapting C2 to the 21st Century

Title of Paper:
Situation Awareness in Modern Military Operations

Name of Authors:
B. J. A. van Bezooijen
TNO Defense, Security, and Safety. Soesterberg, NL
Netherlands Defense Academy. Breda, NL

P. J. M. D. Essens
TNO Defense, Security, and Safety. Soesterberg, NL

Topics:
Cognitive and Social Issues; C2 metrics and Assessment

Point of Contact:
B. J. A. van Bezooijen

Name of Organization
TNO Defense, Security, and Safety

Address:
Kampweg 5, 3769 DE Soesterberg

Telephone:
+31 34 635 65 91

E-mail Address:
bart.vanbezooijen@tno.nl

Abstract

The extensive body of literature on situation awareness (SA) shows that this concept has proven to be very versatile in the domain of human factors studies over the last few decades.
The emergence of Network Enabled Capabilities (NEC) brought new challenges to the research area of SA. Whereas the concept is a central theme in NEC literature, researchers have to develop new theories and methodologies for SA in a NEC environment. We attempt to contribute to the development of both theory and methodology by studying the literature on SA, applying our findings into a military team perspective, and identifying the possible effects of working in a NEC environment on team SA.

Introduction

The extensive body of literature on situation awareness (SA) shows that this concept has proven to be very versatile in the domain of human factors studies over the last few decades.
Similar to some other concepts in the social sciences, such as intelligence or cognition, SA has long been surrounded with intensive discussion on conceptual and methodological problems (Stout, Cannon-Bowers, and Salas, 1994). First, there is the issue of defining the construct. Various articles address this problem and provide us with overviews of approaches to SA and corresponding definitions. In some cases, these overviews contain as much as twenty-six definitions of SA (see Breton and Rousseau, 2001; Durso and Gronlund, 1999; Shresta, Prince, Baker, and Salas, 1995). Second, the measurement of the concept is a complicated issue. The diversity of methods and techniques illustrates that measurement issues still hamper researchers and practitioners to exploit the construct fully (Cannon-Bowers and Salas, 2001).

Endsley made various important contributions in the development of SA. SA refers to knowing what is going on around you (Endsley, 1995a). In her well-known articles on the theory of SA (1995a) and the measurement of SA (1995b), she modelled SA at three levels: perception of the current situation (Level 1 SA), comprehension of the current situation (Level 2 SA), and projection of the future status of the situation (Level 3 SA). At the first level of this model, individuals perceive the elements of the situation. These elements are the status, attributes, and dynamics of the environment. This perception is an automated process. At the second level, individuals engage in creating a holistic picture of the situation (Endsley, 1995a). Here, comprehension of the situation is the product of: "(…) understanding the significance of those elements in the light of pertinent operator goals". The processes that individuals engage in for this understanding include combination, interpretation, storage, and retaining information. The third and highest level of SA is the ability to construct expectations about the near future based on information about the current situation. At this level individuals engage in higher-order cognitive tasks, such as integration of information, making comparisons, and making estimations about the probability that some particular event might occur.

Measurement. The measurement techniques associated with this conceptualization are questionnaires, observations, and interviews. The Situation Awareness Global Assessment Technique (SAGAT) developed by Endsley (1987; 1988; 1990) is a popular method to measure SA. This technique comprises a combination of observations, performance tasks, verbal and written communication, and questionnaires. An example of a SAGAT query for air traffic controllers is, for instance, "Which aircraft will need a new clearance to achieve landing requirement?" This is item for Level 3 SA, where information about the current situation is used to form expectations about what will happen in the near future (Endsley & Rodgers, in: Endsley and Garland, 2000). Other techniques, such as Situation Present Assessment Method (SPAM) (Durso, Hackworth, Truitt, Crutchfield, Nikolic, and Manning, 1998), the Situation Awareness Rating Technique (SART) (Taylor, in: Endsley and Garland, 2000) assess SA using similar methodologies.

There are few studies that compare different measurement techniques for SA simultaneously.
Endsley, Sollenberger, and Stein (2000) compared these three techniques (SAGAT, SPAM, and SART) in an air traffic control environment and found that SA measures have a low intercorrelation or even correlate negatively (-.326 to .306). The two most widely used measures and validated measures for SA (SAGAT and SART) correlated low (r = .306).

Second, none of the measures predicted performance significantly (Endsley, 2000). This is an important finding, as the link between SA and performance a key assumption in SA theory. This underlines the importance of the issue raised by Endsley, Sollenberger, and Stein (2000), which is the issue of whether SA measures really measure SA or something else.

A second issue on measurement arises when it comes to C2. The nature of the work that is done in this type of environments differs dramatically from the work that is done in a command and control (C2) environment. Commanders of military teams perform their tasks in the highly dynamic operational field, and base their decision making mainly on information they received in briefings prior to their missions. The differences between SA in an operator environment and SA in a C2 environment undermine the validity and reliability of knowledge that we have of SA. The problems in SA theory and measurement will be more prevalent in this research area because of these differences. Research of Salmon, Stanton, Walker, and Green (2006) support this reasoning. When it comes to measuring the construct, they conclude that SA measurement techniques are inadequate when it comes to C2. For this reason, we focus on SA in a C2 environment in the next section.

SA in command and control

SA is described as "the human process of gathering information (e.g. attention, pattern recognition, communication" (Gutwin and Greenberg, in: Burke, Stagl, Salas, Pierce, and Kendall (2006). Based on the literature on team SA, we make two remarks about SA in a C2 environment. First, the creation of SA is considered to be a sequential process (Endsley, 1995a). This might not be a valid assumption for modern military operations. We label the second issue the state-process distinction. This distinction represents the discussion on whether SA is the product of SA assessment (such as proposed in SA literature) or forms an integral part of team knowledge (such as proposed in team cognition literature). We discuss these two issues briefly below.

SA is not a sequential process. McGuinness (in: Nofi, 2000) points out that the hierarchical description of SA indicates that the creation of SA is a sequential process. Following the reasoning of Endsley (1995a), gathering information leads to Level 1 SA, adequate levels of SA can lead to Level 2 SA, and individuals with high levels of Level 2 SA can ultimately reach Level 3 SA.

As applicable as this step-wise representation of building SA may be for operator-environments, this may not apply to C2 environments. From interviews with operational commanders we learned that in their dynamic environments, they do not start with perceiving the situation, then start comprehending it, and finally begin with forming expectations about possible future events. In stead situation awareness is a continuous process while jumping back and forth between intentions, hypotheses, expectations, interpretations, understanding, sharing, confirmation: conceptually and data-driven, often intertwined with situation models and response patterns. The sequential processing of the situation is, however, what Endsley (1995) labelled situation assessment. We propose that the process of creating SA is more complex and dynamic in C2 environments. This discussion on the process of the creation of SA shares some similarities with the discussion on decision-making as described in the Observe, Orient, Decide, and Act (OODA)-loop of Boyd. Both theories originate in aviation, and share their human-centered approach.

The OODA-loop is a loop that originally describes the decision-making behaviour of a fighter pilot. According to Boyd, the decision-making loop starts with observation (of an adversary aircraft), leading to the orientation phase (creation of possible strategies), moving to the decision making phase (selection of strategy), and finally acting – the actual behaviour. The loop starts again when the pilot assesses the impact of his behaviour. This model has been very successful for analytically describing military requirements, and was adapted for business and public sector operational continuity planning[1]. The OODA Loop often strikes people as an intuitively accurate framework (Bryant, 2006). Nevertheless, criticizers have argued that the OODA-loop is simplistic and cannot contain all elements of today's C2 processes (Rousseau and Breton, 2004), and provides no guidance on how to define information needs from the commander's perspective (Bryant, 2006). Researchers proposed that military decision-making in many instances will be more complex and goal-directed, which means that after the phase of Orientation, an individual may discover that there is not enough information to make a decision.

The acknowledgement that decision making is a dynamic process rather than a sequential process such as the OODA-loop suggests, has led to the emergence of set of alternative OODA-loops, such as the extended OODA-loop that includes feedback mechanisms (Fadok, Boyd & Warden, in: Breton and Rousseau, 2005), the cognitive OODA-loop which focuses on the cognitive granularity (C-OODA-loop) (Breton and Rousseau, 2005), and the Dynamic OODA-loop (DOODA-loop) in which the importance of sensemaking, planning, and information collection are emphasized (Brehmer, 2006), or alternative models such as the Critique–Explore–Compare–Adapt (CECA) Loop which is explicitly based on the premise that goal-oriented mental models are central to human decision making as the means to represent and make sense of the world (Bryant, 2006).

The same applies to SA. Teams are increasingly important for modern military operations (Essens, Vogelaar, Mylle, Blendell, Paris, Halpin, Baranski, 2005; Salas, Cannon-Bowers, Church-Payne, and Jentsch-Smith, 1998; Mathieu, Goodwin, Heffner, Salas, and Cannon-Bowers, 2000; Zaccaro and Bader, 2003). As the SA construct moves from an (single- or multiple person) operator working environment to complex environments, including on-scene C2 in modern military operations, researchers have found new insights in and approaches to SA. At the generic level, these models and measurement techniques result from a shift to a team-centered perspective instead of an individual-centered perspective (Stout, Salas, and Cannon-Bowers, 1996). As teams are dynamic systems and modern military operations are increasingly dynamic and complex, we pose that the sequential representation of SA is not fully applicable. The measurement of SA has to incorporate the complexity of joint and combined teams in modern military operations. After we discussed the second issue below, we attempt to consider SA from a team-centered perspective.

The state-process distinction. Endsley's (1995a) article functions as a starting point in this respect as well. In her conceptualization of team SA, Endsley (1995) differentiates between SA elements that are relevant for the specific tasks of a team member and SA elements that are relevant to the team as a whole. The similarity of SA elements that are shared at the team level determine team SA. An increase in similarity leads to an increase in the level of team SA.

[1] http://en.wikipedia.org/wiki/OODA

The enormous interest of researchers in SA has led to a diversified spectrum in definitions, conceptualizations, and measurement techniques for team SA. As Endsley (1995a) introduced the term ‘team SA’, alternative terms that have been postulated are: common understanding, shared understanding, distributed cognition, distributed understanding, shared cognition, team awareness (Nofi, 2000), team cognition (Cooke, 2003), team knowledge (Cooke, Salas, Cannon-Bowers, and Stout, 2000) and team shared awareness (Cooke, Stout, and Salas, in: McNeese, Salas, and Endsley, 2001); collective cognition, team mental models, transactive memory (Cannon-Bowers and Salas, 2001).

The state-process distinction is focused on the *outcomes* of creating SA. According to Cannon-Bowers, Salas, and Blickensderfer (1999), team SA is the result of incorporating specific characteristics of the current situation in the pre-existing knowledge of the team. Cannon-Bowers *et al.* (1999) refer to team situation models as dynamic understanding, because the changes in the situation influence the team at the individual level, leading to changes in the team’s collective understanding of the specific situation. From a team perspective, SA is a dynamic and adaptive process that is continuously evolving.

Taking a team-centered perspective, team SA forms an integral part of the theory on team cognition. Teams are defined 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 been assigned specific roles or functions to perform, and who have a limited life span of membership” (Salas, Dickinson, Converse, and Tannenbaum, 1992; p.126-127). Team cognition refers to a wide range of cognitive phenomena at the team level, including decision making, and team vigilance (Cooke, Salas, Cannon-Bowers, and Stout, 2000). Team cognition can be thought of as a general metaphor to understand how users are shaped by the constraints of technology, society, work, and stress (McNeese, 2003). We propose that SA in modern military operations is a dynamic, adaptive, and continuously evolving process rather than the result of the assessment of a particular situation. We discuss SA from a team perspective below.

Team situation awareness

The shift to a team-centered perspective has been influenced by an increased use of technology in the workplace (Mathieu, Goodwin, Heffner, Salas, and Cannon-Bowers, 2000), and an increase in complexity of the tasks (Salas, Dickinson, Converse, and Tannenbaum, 1992). A lot of attention is given to team members’ mental models on team-related processes and behaviours.

The theory on mental models, or knowledge structures, has been popular since the mid-eighties (see Rouse and Morris, 1986). Mental model theory and SA are closely related, as mental models are used by humans for the description, explanation, and prediction of future events in systems (Rouse and Morris, 1986, p. 360). At the team level, team mental models enable teams to cope with difficult and changing task conditions (Mathieu, Goodwin, Heffner, Salas, and Cannon-Bowers, 2000). Adequate team mental models enable team members to adapt effectively to changes in the environment because team members can predict how other team members will react to a certain change, and determine how they are going to respond subsequently. In this way, team members can select actions that are coherent and coordinated with other team members (Cannon-Bowers, Salas, and Converse, in: Mathieu, Goodwin, Heffner, Salas, and Cannon-Bowers, 2000).

Team mental models either contain team-related information or task-related information. The description above was an example of team-related knowledge ('How will team member X respond to a change in the environment?'). Researchers identified team mental models for team-related issues as a valuable variable for team related processes and behaviours (Klimoski and Mohammed, 1994; Rentsch, Heffner, and Duffy, 1994, Stout, Salas, and Kraiger, in: Mathieu, Goodwin, Heffner, Salas, and Cannon-Bowers, 2000).

Alternatively, team mental models can also contain task-related information ('How does development X affect our task?'). Research on task-related mental models has mainly focused on team SA (Cooke, Stout, and Salas, in: McNeese, Salas, and Endsley, 2001; Stout, Salas, and Cannon-Bowers, 1996; Salas, Prince, Baker, and Shresta, 1995).

Team SA is defined as a team's understanding of a complex and dynamic situation at one point in time (Cooke *et al*, 2000), or more general as the team's collective understanding of the specific situation (Cannon-Bowers *et al.* (1999). Team situation models enable teams in determining strategies available to the team, assessing how the team is proceeding, predicting what teammates will do and need, and selecting appropriate actions to take. This coordination is crucial for team performance (Cooke *et al.*, 2000; Essens, Vogelaar, Mylle, Blendell, Paris, Halpin, Baranski, 2005).

A crucial element of the relationship between team SA and team performance is what various authors labelled *implicit coordination.* As opposed to verbal or written coordination, implicit coordination describes the team coordination behaviours when explicit communications are hampered (Cannon-Bowers *et al., 1993;* Kleinman and Serfaty, 1989*;* Stout *et al.*, 1996*)*. This concept shares a number of similarities to the NEC concept of self-synchronization. Self-synchronization is defined as "Ability of a force to act in a manner coordinated in intent, time, and space with other battlespace entities, without being ordered to do so specifically; synchronization of force entities without direction from their commanders (Gonzales, Johnson, McEver, Leedom, Kingston, and Tseng (2005). In NEC literature, the self-synchronization concept describes the behaviour of commanders who operate with high levels of authority (the power to the edge-principle). Commanders who synchronize their decision making with the overall objectives of the mission combine the flexibility of situation-driven decision making with jointly working towards a commonly shared goal with other military entities. This self-synchronization of commanders is what Alberts and Hayes, 2006, p.2) describe as 'the magic of NCW'.

Just as the shift from a single-person or multi-person operator perspective to a team perspective has implications for SA theory, working in a NEC environment will also affect our ideas on SA. This transformation is reflected in the theme for this year's International Command and Control Research and Technology Symposium (ICCRTS): *"Adapting C2 to the 21st Century"*. In the next section, we discuss the changes regarding team SA that we feel are most important and describe how we address these issues empirically.

Team SA and modern military operations

Decentralization. One important assertion of NEC theory is that military teams should be given more decision making authorities. This is the power to the edge principle – decisions should be made by those people who interact with the environment (Alberts and Hayes, 2003). This relocation of authority enables the situation-driven decision making that characterizes an agile organization.

The relationship between NEC and the communication of intent is, to our knowledge, not tested empirically. Following the principles of NEC benefits chain, the team's SA should increase because more information should lead to more information sharing, resulting in better team SA. The concept command intent has been developed to describe the provision of guidelines to military teams in decentralized C2. Command intent, as an alternative for commander's intent, is a broader set of information and guidelines that commanders use for their decision making. More information is given about the objectives and responsibilities of the team, and there is a lot of attention for the team's mission in the light of the overall intention of the mission (sensemaking). As opposed to commander's intent, command intent contains less guidance about how the team's objectives should be reached.

Distributed teams. Another key element of modern military operations is the physical dispersion of military teams. As multiple military entities work jointly towards a commonly shared goal, these units teams are geographically distributed yet coupled to each other by communication means (telephone, intranet, radio). This network of teams consists in most cases of elements of multiple forces (joint) and of multiple coalition forces (combined). An enormous body of literature is devoted to distributed teams. We do not even attempt to give an overview of the literature here. Key findings, however, are that working in a distributed environment affects team SA because of the lack of a common environment, insufficient/poor communications and collaboration tools, and absence of non-verbal cues to communication (Nofi, 2001).

Specialized teams and ad-hoc team collaboration. As discussed earlier, the increase in technology and complexity of the tasks that have to be performed in organizations has led to a team-centered perspective. This development also means that teams get more specialized. The principle of Effects Based Operations (EBO) accounts for this development, as these missions are done by 'team of teams', that is, multiple teams work jointly on the same mission. One might conclude that a team of teams is a team in itself (as it fits the definition of a team stated earlier in this article), but that issue will not be addressed here. Main point is that the interdependency between the various teams increases in EBO. This increased interdependency, we believe, increases the relevance for teams to get a deeper understanding of the mission, thereby enhancing team SA in a NEC environment.

Discussion

An important consequence of working in teams-of-teams in a distributed environment is that teams will differ in their possibilities to create SA. These differences may result from situational constraints, but moreover will be depending on the ability of teams to create SA in modern military operations. We feel that the experience with working in joint en distributed environments of a team is a key factor in this respect. Besides the detailed analysis of the SA process in complex multi-team environments, the issue is how do the differences in experience, background and perspectives in multi-service and multinational operations affect the ability to create SA in a joint and distributed environment?

In the recent year, we have run several pilots with air defence teams of two countries (Netherlands and Sweden) in a joint air defence task and a full experiment is planned for May 2007. The scenario and the related command intent and command authority allow the operators to take initiatives based on their understanding of the situation and emerging operational opportunities. From the pilot studies we have seen that despite the presentation of all relevant tactical information, routines and previous experience selected out the information fitting to these routines, and limited the understanding and use of the other, relevant operational information. Only when the intent was more explicitly directed to the use of other information it seemed that a more adequate situation awareness was developed in the team.

For the development and support of more effective networked operations the concept of SA needs to be based on a richer model of how situational understanding builds up in a dynamic and ongoing enfolding of situations in the world. Existing models should be tested in complex worlds.

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