CRM D0002895.A1/Final
November 2000

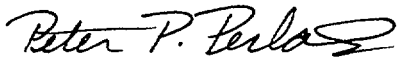
Defining and Measuring Shared Situational Awareness

Albert A. Nofi

Center for Naval Analyses
4825 Mark Center Drive • Alexandria, Virginia 22311-1850

Many people were helpful in the evolution of this paper. Particular thanks go to Marcy Stahl, Susan Shwartz, and Kathleen Broome Williams for their extensive and valuable comments and suggestions. Barry McGuinness was kind enough to answer some difficult questions. Other useful advice, ideas, or information was provided by Peter Perla, Michael Markowitz, Chris Weuve, Web Ewell, William Brobst, Julia Loughran, Larry Klein, Neil Carey, Don Murdock, Allen T. Hjelmfelt, Michael Webb, Ahmed S. Hashim, Dokhi Fassihian, Ronit Setter, and Theodore F. Cook. Graphics courtesy of Julia Loughan and Marcy Stahl, of ThoughtLink, and Michael Markowitz and Karin Duggan of CNA.

Approved for distribution: November 2000



Peter P. Perla
Director for Interactive Research Products
Office of the Senior Vice President for Research

Contents

Introduction

The Defense Advanced Research Projects Agency (DARPA) is interested in exploring key factors that affect how teams, particularly distributed teams, develop what is called shared situational awareness in an operational environment. The DARPA Program Manager for the *Wargaming the Asymmetric Environment* program asked the Center for Naval Analyses to address these issues, with subcontracting support from ThoughtLink Incorporated. The focus of the project was to demonstrate how wargaming could be used as a testbed for conducting experiments to explore these key factors in shared situational awareness.[1]

The concept of "shared situational awareness," which underlies some recent ideas about the organization of military staffs, is elusive and ill-defined, and does not lend itself easily to traditional scientific evaluation. Nevertheless, it is possible to compose a systematic definition and to develop objective approaches to studying the process by which "shared situational awareness" arises.

Although certainly important, the nature of situational awareness is uncertain. Although there is some confusion in terminology, there is a considerable agreement on *what* situational awareness is: the result of a dynamic process of perceiving and comprehending events in one's environment, leading to reasonable projections as to possible ways that environment may change, and permitting predictions as to what the outcomes will be in terms of performing one's mission. In effect, it is the development of a dynamic mental model of one's environment. There is also a measure of agreement on what constitutes *shared* situational awareness and how it develops by a process of integrating the mission-essential overlapping portions of the situational

1. See the final report of the project for an overview of the entire effort: Peter P. Perla et al., *Gaming and Shared Situation Awareness*, CNA Research Memorandum CRM D0002722.A1, November 2000.

awareness of individual team members—thus, developing a group dynamic mental model.

However, there is no clearly understandable, generally accepted, objective way to measure situational awareness, whether for individuals or for groups, and little evidence as to the effect of a distributed environment on the development of shared awareness. Nevertheless, despite the enormous uncertainty in the field, it does seem possible to develop situation-specific ways to *estimate* the degree of situational awareness that a person or group may possess, and from that to be able to make rigorous statistical inferences as to factors that enhance or degrade it.

This possibility has considerable importance, particularly for military and political decision-makers. By better understanding the process by which situational awareness and shared situational awareness develops, we may not only be able to strengthen our ability to develop situational awareness in crisis situations, but may also be able to better understand the enemy's situational awareness, which in turn might permit us to get inside his situational awareness loop to degrade his situational awareness, with potentially important benefits to ourselves.

What is "shared situational awareness"?

The development of the concept of information warfare and of modern electronic networking technologies has given rise to the belief that military staffs will be able quickly to develop a "shared situational awareness" that will greatly facilitate decision-making, thus permitting faster response to challenges by reducing the complexities of the military administrative and command structure. In addition, it has been asserted that these technologies will permit staffs to perform those duties in a distributed environment as well as they could possibly do in a collocated environment.

Richard J. Harknett, a political scientist from the University of Cincinnati, argues that the electronic networking technologies that will enable military staffs quickly to develop "shared situational awareness" are " . . . the key manifestation of an organizational revolution that could justify the designation of this period of human history as a definable age."[2]

That's a pretty sweeping conclusion, indeed it approaches hyperbole. Yet, nowhere in his article does Harknett actually *say* what he means by "shared situational awareness." Harknett presumes that we know and agree upon a definition. It's a failing that he shares with virtually everyone who is doing work on the subject.

Given the high risk and potentially serious consequences of military decisions, it seems reasonable to attempt to understand the nature of "shared situational awareness" in order to develop a systematic definition, to determine whether there are objective approaches to studying the question experimentally, and to evaluate the potential

2. Richard J. Harknett, Department of Political Science, University of Cincinnati, "The Information Technology Network and the Ability to Deter the Impact of Organizational Change on 21st Century Conflict." http://jciss.llnl.gov/deer.html

differences between the development of shared situational awareness by collocated and by distributed teams.

Some definitions

Most of what has been written about "shared situational awareness" presupposes that a generally accepted definition exists of what it is, how it comes to be, and what it is supposed to do. Nevertheless, neither "situational awareness" nor "shared situational awareness" can be found in a dictionary.[3]

Attempts at definitions abound in the literature.[4] Thus, shared situational awareness . . .

- ". . . [is] a common relevant picture distributed rapidly"[5]
- ". . . translates to a clear and accurate, common, relevant picture of the battlespace?"[6]
- " . . . refers to the degree of accuracy by which one's perception of his current environment mirrors reality."[7]

---

3. For example, it appears neither in *Webster's Third New International Dictionary* nor in *Merriam-Webster's Collegiate Dictionary.*

4. In addition to the definitions given here, Richard W. Pow and Anne S. Mavor, *Modeling Human and Organizational Behavior: Application to Military Simulations* (Washington: National Academy Press, 1998), p. 174, list nine more. Eduardo Salas, Carolyn Prince, David P. Baker, and Lisa Shrestha, "Situation Awareness in Team Performance: Implications for Measurement and Training," *Human Factors*, Vol. 37, No. 1 (1995), p. 125, cite a researcher who identified 15 different definitions.

5. Lt. Gen. Otto J. Guenther, Director of Information Systems for Command, Control, Communications, and Computers, 1997 Congressional Hearings on Intelligence and Security. http://www.fas.org/irp/congress/1997_hr/h970320g.htm

6. Lt. Gen. Paul J. Kern and Lt. Gen. John N. Abrams. Emphasis added. http://senate.gov/~armed_services/statement/980311pk.htm

7. Naval Aviation Schools Command (032), "Situational Awareness." http://www.act.navy.mil/Situational_Awareness.htm

- ". . . is adaptive, externally directed consciousness."[8]

Despite the lack of a common, generally accepted definition, there have been some attempts at explaining how "shared situational awareness" develops. Thus, it derives from

- ". . . information superiority . . . ."[9]
- ". . . a flexible and interoperable information picture."[10]

And there has been much speculation on the supposed benefits of "shared situational awareness," with often impressive conclusions. So that it

- "... [provides] a common operational picture"[11]
- "... provides everyone with the same near-real-term picture of their relative battlespace"[12]
- "... provides a clear and accurate common picture of battlespace to commanders at all levels"[13]

---

8. Kip Smith and P.A. Hancock, "Situation Awareness is Adaptive, Externally Directed Consciousness," *Human Factors,* 37, 1 (1995), p. 137.
9. Vice Adm. Arthur K. Cebrowski, President, Naval War College, "Network-Centric Warfare: An Emerging Military Response to the Information Age," Presentation at the 1999 Command and Control Research and Technology Symposium, June 29, 1999. http://www.nwc.navy.mil/press/speeches/ccrp2_htm
10. Lt. Gen. Otto J. Guenther, Director of Information Systems for Command, Control, Communications, and Computers, 1997 Congressional Hearings on Intelligence and Security. http://www.fas.org/irp/congress/1997_hr/h970320g.htm
11. Capt. Daniel C. Logan, USMC, "Back in Business: New Roles in JTMD for the Marine Corps," *C2 Issues Papers, CCSC-99,* Marine Corps CCSS, at http://www.ccss.quantico.usmc.mil/ccss/c2issues.htm
12. *Mario's Cyberstation: The Art of War, Fratricide,* a site devoted to the subject of "own fire" problems. http://mprofaca.cro.net/fratricide.html
13. Lt. Gen. William H. Campbell, Director for Command, Control, Communications, and Computers, Headquarters, Department of the Army. http://house.gov/hasc/testimony/106thcongress/99-02-23campbell

- "... will allow Force XXI armies to observe, decide, and act faster, more correctly, and more precisely than their enemies."[14]

There have been some attempts in the military literature to provide a more substantial definition of "shared situational awareness." Lt. Gen. Paul J. Kern, Military Deputy to the Assistant Secretary of the Army for Research, Development, and Acquisition, and Lt. Gen. John N. Abrams, Deputy Commanding General, TRADOC, provided one such definition of shared situational awareness as part of their testimony before the Senate Armed Services Committee in 1998,

> Shared situational awareness . . . translates to a clear and accurate, common, relevant picture of the battlespace for leaders at all levels and a reduction in the potential for fratricide. *Situational awareness answers three fundamental battlefield questions: Where am I? Where are my friends? Where is the enemy?* The sharing of timely information enabled by digitalization improves significantly the ability of commanders and leaders to quickly make decisions, synchronize forces and fires, and increase the operational tempo."[15]

That's a lot more of a definition than most. But it doesn't seem particularly comprehensive. Although it's nice to know where you are on the battlefield, as well as where your friends and enemies are, you need to know a lot of other things, too. What about policy, strategy, operations, technology, logistics, tactics, plans, command structure, personalities, posture, and environment, just to start with?

All of these definitions are essentially second-hand, attempts by military personnel and policy-makers to explain a concept that is not self-evident.

---

14. TRADOC Pamphlet 525-69, 1 August 1995, "Military Operations Concept for Information Operations. http://www-tradoc.army.mil/tpubs/pams/p525-69.htm

15. Kern and Abrams; emphasis in the original.

The professional view

The concept of "shared situational awareness" is rooted in that of "situational awareness" (SA). Michael Webb, former CNA representative to the Navy's "Top Gun" School, observed that situational awareness is "as squishy and ill-defined a term as you'll ever find," and goes on to note that "It's one of those indefinable human qualities like genius, championship ability, charisma. You're not quite sure what it is, but you know who has it and who doesn't." A review of the literature certainly bears out the idea that SA is "squishy and ill-defined."

Since February 1998, Oxford University has maintained a "Workgroup Bulletin Board" in Situational Awareness Brief and Requirements Engineering (SABRE).[16] Though the board is devoted primarily to the question of situational awareness in aviation, questions and responses on the board often touch upon broader issues.

In a post on SABRE dated December 5, 1999, Rico Milo, assigned by his company to assess a particular software system with regards to its utility in promoting situational awareness, summed up the issue succinctly, "Part of my problem is actually establishing what SA is! I've seen many, many, many definitions!!!"[17]

This is the essence of the problem. In the preface to a special 1995 issue of *Human Factors* devoted to situational awareness, the editors wrote ". . . the conceptual basis of SA is cloudy."[18] Elsewhere in that same issue, Mica Endsley, one of the principal researchers dealing with situational awareness and a principal in SA Technologies, a firm devoted to research in the field, commented, "The term [SA] has . . . become the victim of rather loose usage, with different individuals

16. The main SABRE bulletin board address is http://users.ox.ac.uk/~pemb0595/wwwboard/wwwboard.html

17. Rico Milo, SABRE, December 5, 1999. http://users.ox.ac.uk/~pemb0595/wwwboard/39-sa.html

18. *Human Factors* Vol. 37 No. 1, p. 3.

redefining it at a whim . . . ,"[19] a sentiment that echoes one made in 1991 by N. B. Sarter and D.D. Woods, "situational awareness has thus become a ubiquitous phrase. It is most often based on intuitive understanding; a commonly accepted definition is still missing."[20] The plethora of definitions, all unique to their definer, brings to mind the words of Humpty Dumpty, "When I use a word, it means just what I choose it to mean—neither more nor less."[21] Whoever coined a particular definition may understand what it means, but the multiplicity of definitions merely clouds the issue for the rest of us.

Milo's inquiry on the SABRE bulletin board was answered by Barry McGuinness, a psychologist at the Sowerby Research Centre of the British aerospace firm BAE. McGuinness began with a quote from a pilot, "SA is 'knowing what's going on so you can figure out what to do'." He then went on to write,

> This says it all. If you have a function to perform in a situation that is fairly complex and dynamic, such that you have to make decisions, then you have to be aware of what is going on—at different levels—if you are to make the right decisions to achieve your goals.
>
> We can unpack this further: To be aware of what's going on you have to
>
> (a) take in the available facts, and
>
> (b) understand them in relation to your expert knowledge of such situations. Furthermore, to make the best decisions you have to
>
> (c) anticipate/predict how the situation is likely to develop in future and
>
> (d) understand your options and courses of action relative to your goals.

---

19. Mica Endsley, "Toward a Theory of Situation Awareness in Dynamic Systems," *Human Factors,* 37 (1995), p. 35. Note that, like many others in the field, Endsley prefers the form "situation awareness."

20. Cited in Salas, Prince, Bakers, and Shrestha, p. 123.

21. Lewis Carroll, *Alice Through the Looking Glass,* Chapter 6.

(e) Finally, you also need to take into account how accurate/complete/reliable your SA is likely to be.

So you can identify these different aspects to SA. Endsley calls the first three PERCEPTION, COMPREHENSION and PROJECTION. I would say you have to include the last two as well, and call them INTENTION & METACOGNITION respectively.

Each of these factors is associated with specific cognitive processes and with particular contents (mental representations). For instance, at the "level" of perception you're monitoring, attending, detecting and identifying (processes), which gives you factual awareness of current objects, events, states and so on (contents).[22]

Dr. McGuinness' post offers a lot more to work with than is provided in the explanation by Generals Kern and Abrams. Interesting to note, although McGuinness cites her several times in his posts, he did *not* offer the definition advanced by Mica Endsley,

> . . . the perception of the elements in the environment within a volume of space and time, the comprehension of their meaning, the projection of their status into the near future, and the prediction of how various actions will affect the fulfillment of one's goals . . . .[23]

Endsley's definition certainly has the advantage of being concise. She has actually boiled it down even further, "Most simply put, SA is knowing what is going on around you," with the implication that what you

---

22. Barry McGuinness, SABRE, December 8, 1999. http://users.ox.ac.uk/~pemb0595/wwwboard/44-sa.html, slightly edited for clarity, but with emphasis as in the original. McGuinness credits the quotation to "a pilot, cited in E.C. Adam's 'Fighter Cockpits of the Future' (*Proceedings of 12th IEEE/AIAA Digital Avionics Systems Conference*, 1993, pp. 318–323)." Note, by the way, that McGuinness implies that Endsley's definition has three key points, when, in fact, she has four.

23. Endsley, "Toward a Theory . . . ,"pp. 32–64.

want to know is that which is important to the performance of a particular task, a definition that echoes that of McGuinness' pilot. [24]

Why McGuinness chose to substitute *intention* and *metacognition* for Endlsey's *prediction* is unclear, but certainly illustrates Endsley's point about "different individuals redefining [SA] at a whim."[25] Consider the differences.

Intention seems less an aspect of the process by which situational awareness is developed than a necessary precondition for its development. Situational awareness is essentially goal-oriented; our reason for being in a particular "situation" explains why we need to develop the "awareness" necessary to cope with it. Likewise, *metacognition,* implying "going beyond knowledge," would seem to be more appropriately a combination of projection and prediction.[26]

---

24. Mica R. Endsley, "Theoretical Underpinnings of Situation Awareness: A Critical Review," *Situation Awareness Analysis and Measurement,* edited by Mica Endsley and Daniel J. Garland (Mahwah, N.J.: Lawrence Erlbaum, 2000), p. 5. In this essay, Endsley omits "prediction," falling back on an earlier version of her definition, "the perception of the elements in the environment within a volume of space and time, the comprehension of their meaning and the projection of their status in the near future"; *cf.,* Mica Endsley, "Design and Evaluation for Situation Awareness Enhancement," in *Proceedings of the Human Factors Society 32nd Annual Meeting* (Santa Monica: Human Factors Society, 1988), Vol. I, p. 97.

25. Mica Endsley, "Toward a Theory . . . ," p. 35.

26. McGuinness' use of "metacognition," although etymologically correct (a bastard formation from the Greek prefix *meta* = "beyond" and the Latin root *cogito* = "thought,"), differs from the meaning in other fields of cognitive theory, as well as in philosophy and educational psychology. In those fields "metacognition" means, in the elegant definition of one wise elementary-school girl, "understanding what you are thinking, so you can explain how you got an answer," http://www.carr.org/ccps/fve/stu_ex7.htm. A number of much more learned, though neither more elegant nor particularly clearer, definitions may be found at http://www.augie.edu/department/educ/andrews/chaptereleven/thld01.htm, http://forum.swarthmore.edu/~sarah/discussion.sessions/schoenfeld.htm, and http://english.ttu.edu/kairos/3.1/features/english/metacog.html.

For the purposes of this discussion, it seems reasonable to stick with Endsley's definition and conclude that the critical factors in the development of situational awareness are

- *Perception,* acquiring the available facts
- *Comprehension,* understanding the facts in relation to one's expert knowledge of such situations
- *Projection,* envisioning how the situation is likely to develop in the future provided it is not acted upon by any outside force
- *Prediction,* evaluation of how outside forces may act upon the situation to affect your projections.

Despite his substitution of Endsley's fourth factor with two of his own, McGuinness makes the valuable observation that these factors should not be envisioned

> . . . as lying in a chain or sequence, but as interlocking cycles. None of them comes first. E.g., we don't suddenly enter a situation and gradually pick up raw information; we always have an ongoing action schema.[27]

This is an important point. In developing situational awareness we don't first perceive, then comprehend, then project, and finally predict. These stages occur virtually simultaneously, given the speed with which our minds work. As we perceive the information, we are already processing it for comprehension and its implications for our purposes. In short, the stages of what Mica Endsley terms "situation assessment,"[28] constitute a continuous dynamic process rather than a sequential one, and thus the end product of that process, our situational awareness, evolves continuously as well.

---

27. Barry McGuinness on February 24, 2000, at 16:49:32: http://users.ox.ac.uk/~pemb0595/wwwboard/64-sa.html. McGuinness, of course, is actually speaking of the five factors he has identified, rather than Endlsey's four factors, but the principle would remain unchanged in either case.

28. *Cf.,* Endsley, "Toward a Theory . . . ," p. 36.

As can be seen in the differences in definition offered by Endsley and McGuinness, Rico Milo is right: there doesn't seem to be a generally accepted definition of situational awareness, which precludes the development of a workable definition of "shared situational awareness," despite the frequency of the use of the latter phrase by people in the defense community.[29] Richard Klimoski and Susan Mohammed, from Ohio State University, put it succinctly when they observed that there is "confusion in the literature relating to group cognition."[30]

This certainly seems to be the case. At times, it seems that the term "shared situational awareness" (SSA) is being used in the sense of "awareness of a shared situation," while at other times it seems to imply "shared awareness of a particular situation." There's a considerable difference.

Used in the sense of "awareness of a shared situation," SSA implies that we understand that we are in a shared situation. In contrast, used in the sense of "shared awareness of a situation," SSA implies that we all understand a given situation in the same way. The latter is the sense in which the phrase is used by Endsley and McGuinness, as well as by the aviation and military communities.

Moreover, some commentators seem to imply that situational awareness is a process, rather than a thing. It seems more reasonable to think of it as a thing that is the product of a process that involves the matrix of perception, comprehension, projection, and prediction. This is why Mica Endsley suggests that the process by which situation awareness develops be termed "situation assessment."[31]

With these considerations in mind, it seems reasonable to try to examine some of the problems in the definition of situation awareness in

---

29. The term does not appear in *The Department of Defense Dictionary of Military and Associated Terms* (Joint Pub 1-02).

30. Richard Klimoski and Susan Mohammed, "Team Mental Model: Construct or Metaphor?," *Journal of Management*, Vol. 20, No. 2 (1994), p. 404.

31. *Cf.*, Endsley, "Toward a Theory . . . ," p. 36.

an effort to reconcile them, so as to develop a more accurate, clearly understandable working definition, which can then be used to develop an understanding of shared situational awareness, with the goal of engaging in objective examination of the nature of the phenomenon.[32] In short, to try to move from an essentially philosophical discussion of the subject, based on reasoning from limited evidence, to a more mathematical treatment, based on quantifiable data.

32. I will not attempt to get into the sterile deconstructionist argument that holds that "cognition" and "reality" are constructs rooted in particular social contexts; *Cf.*, J. M. Levine, L. B. Resnick, and E. T. Higgins, "Social Foundations of Cognition," *Annual Review of Psychology*, Vol. 44, pp. 585–612.

THIS PAGE INTENTIONALLY LEFT BLANK

Thinking about situational awareness

"Situational awareness" is actually a fairly common usage. This can be determined by asking a few randomly selected people what "situational awareness" means. We hear it in relation to driving, playing basketball, or even walking down a street in a tough neighborhood. In this regard, it is always used in the sense of "knowing what's going on—what could go on—what options exist—in one's present environment." Actually, this is substantially the triad of "perception," "comprehension," and "projection" that both Endsley and McGuinness put at the core of their definitions of the concept.[33]

But the above is pretty self-evident. Is there more? Both Endsley and McGuinness say there is, but don't seem to agree on what it is. Endsley adds "prediction," estimating how various actions will affect the fulfillment of one's goals.[34] McGuinness adds "intention," understanding one's options and courses of action relative to one's goals, and "metacognition," taking into account how accurate, complete, and reliable one's situational awareness is likely to be.[35] So although the two agree on the basic triad of comprehension-perception-projection, there's little overlap about what comes next.

The concept of "situational awareness" entered military usage through the aviation community. Referring to it in this context, Webb observed that "In its most basic form, it means an aircrew's ability to

33. This discussion will omit consideration of what constitutes a "situation." Is it my perception of reality? Is it yours? Or is it "objective reality," a concept somewhat out of favor in deconstructionist-influenced intellectual circles. For the purposes of this discussion, I take a "situation" to mean the mission one has to perform and those factors in the environment that are mission-critical.

34. Endsley, "Toward a Theory . . . ," *passim.*

35. Barry McGuinness, SABRE, December 8, 1999. http://users.ox.ac.uk/~pemb0595/wwwboard/44-sa.html

know what's going on around him or her (in the cockpit, on the ground, in the 'around' around, in the strike package, on the flight deck, etc.)." It's something that "comes as a by-product of training and experience, and some never get much of it, while others seem to develop it with ease."

Webb's definition is similar to that found in common usage. It's essentially the same thing that drivers, basketball players, or people walking down dangerous streets need to have—a mental picture of their environment, both real and potential. And that would pretty much seem to apply to troops in combat as well.

But is it valid to take the common-usage definition of situational awareness, the "knowing what's going on—what could go on—and what options exist—in one's present environment," and apply it across the board?

In another exchange on the SABRE bulletin board, Ron Davis observed,

> In my experience, it seems to me that Situational Awareness in one environment is very different to that in another and therefore, to generically 'treat all as one' is probably rather foolish. For example, SA in a cockpit is a very different beast to that of SA in a Control Room. In the latter, there seems to be an element of 'Shared SA,' whereas in the former, SA is very much a personal attribute.[36]

That last bit, "very much a personal attribute," seems to be crucial distinction in understanding "situational awareness" and "shared situational awareness." Davis' post to the SABRE website generated some interesting traffic.

---

36. Ron Davis, SABRE, September 20, 1998, http://users.ox.ac.uk/~pemb0595/wwwboard/19-sa.html. There seems to be a false distinction here. Although the pilot and the air controller each necessarily has a unique individual SA, in order for the mission to be performed—getting the airplane safely from place to place—they also should have a degree of shared SA, based on communications and common access to certain information.

Barry McGuinness' comment on Davis' post was,

> I agree that SA in different environments (situations?) isn't all the same. You can't say that an air traffic controller has better or worse SA than a car driver, for instance; it doesn't make sense. . . . .
>
> Taking a single, big number for an operator's SA (eg, 80 %), whether by objective or subjective means, reduces out a lot of valuable data.[37]

In response, Daniel Robinson wrote, "It's extremely interesting you both agree that SA is different in different environments. I agree, too, but then wonder how we can make generalisations about SA."[38] He then went on to ask, "Are there generic issues which we can apply or do we need to look at each environment independently?" McGuinness replied, "I haven't found the answer to this one yet." In a later post, McGuinness added,

> I think there is an aspect of SA that is umbrella-like, the integration of all info into a big picture, and the coherence (or otherwise) of this is what gives rise to the subject's subjective sense of his SA as high (reliable) or low (uncertain, info missing). I believe this applies no matter what the environment. I'd also go along with the Perception-Comprehension-Projection model as a generic description of SA, although I'd add in there Intention (knowing what you're doing). . . .
>
> So, I think yes there are generic issues, and yes we may need to look at each environment independently! It depends, of course, on what the research is aiming to find.[39]

This is not notably different from McGuinness's definition cited earlier, nor from that offered by Endsley.

---

37. Barry McGuinness, SABRE, October 1, 1998. http://users.ox.ac.uk/~pemb0595/wwwboard/21-sa.html

38. Daniel Robinson, SABRE, October 5, 1998. http://users.ox.ac.uk/~pemb0595/wwwboard/22-sa.html

39. Barry McGuinness, SABRE, October 5, 1998. http://users.ox.ac.uk/~pemb0595/wwwboard/24-sa.html

Robinson went on to say, "I'm also intrigued by your remark on subjectivity and objectivity. Probably a whole new, but still related, discussion. It seems to me that these two 'labels' are two extremes of a continuum, rather than discrete means."[40] McGuinness added,

> I have a model of SA measurement which grossly differentiates between SA as revealed by objective queries (e.g., which target is highest priority?) and SA as revealed by subjective measures (e.g., rate your SA on a scale of 1–7). There can be real differences between what an operator "knows" (having assimilated or inferred the relevant items of information) and what he *thinks* he knows overall. Imagine a 2 x 2 square grid. The area to the left of centre = "objective SA good, all relevant info present and correct"; the area to the right of centre = "objective SA impaired, some info missing". The area above the centre = "subjective SA high, subject is confident in info", the area below the centre = "subjective SA low, operator is

Measuring SA

	Objective Assessment: High	**Objective Assessment: Low**
Subjective Assessment: High	Objective High: All relevant info present and correct Subjective High: Subject is confident in info	Objective Low: Some info missing Subjective High: Subject is confident in info
Subjective Assessment: Low	Objective High: All relevant info present and correct Subjective Low: Operator is uncertain	Objective Low: Some info missing Subjective Low: Operator is uncertain

40. Daniel Robinson, SABRE, October 5, 1998. http://users.ox.ac.uk/~pemb0595/wwwboard/22-sa.html

> Now, the ideal place for your operator to be is the top left square, where (a) he has the right info and (b) he knows it. The worst place to be is top right, where he (a) has lost info but (b) doesn't realise it. If he's in bottom left, he has the right info but doesn't feel sure about it (maybe he's a novice). If he's in bottom right, he's lost info but at least he feels his SA isn't right. Presumably, any operator in the lower two boxes is going to go straight into active information-seeking mode (you can see it happen!).
>
> This is a crude way of conceptualising SA measures apart, but the implication is that if you take just one type of measure (say subjective), you never know what's going on with the other type and you may never know which of the four boxes the operator's actually in.[41]

The foregoing series of quotations from SABRE traffic suggests several ideas about situational awareness that may make it easier to understand the concept:

- SA is subjective, that is, what constitutes SA varies with circumstances, with "the situation," as it were.
- What is meant by SA when applied to an individual differs from what is meant when the term is applied to a group.
- SA is a dynamic phenomenon, constantly evolving.

Accepting these premises as a basis of discussion, it's possible to address each of them separately, in the hope that, having done so, we can come up with a better understanding of the concept.

SA is subjective

What constitutes SA changes depending upon one's "situation" and how it develops. To put it most clearly into military terms, in a wartime environment, the things that are important to a soldier dodging bullets in combat are going to be different from those that are important to a soldier shuffling papers in the rear. The things that are likely

41. Barry McGuinness, SABRE, October 5, 1998. http://users.ox.ac.uk/~pemb0595/wwwboard/23-sa.html

to concern the front-line soldier are different—more immediate and instinctive, perhaps—than those that will be of importance to the rear-echelon soldier, which are likely to be longer-term and more studied. One could, with considerable ease, develop contrasting models of what matters most in the situational awareness of each of the two soldiers, given their differing environments. Indeed, the use of mental models would seem to lend itself to the study of situational awareness. A "mental model" is a "psychological representation of the environment and its expected behavior."[42] The purpose of a mental model is "to provide conceptual framework for describing, explaining, and predicting future system states."[43]

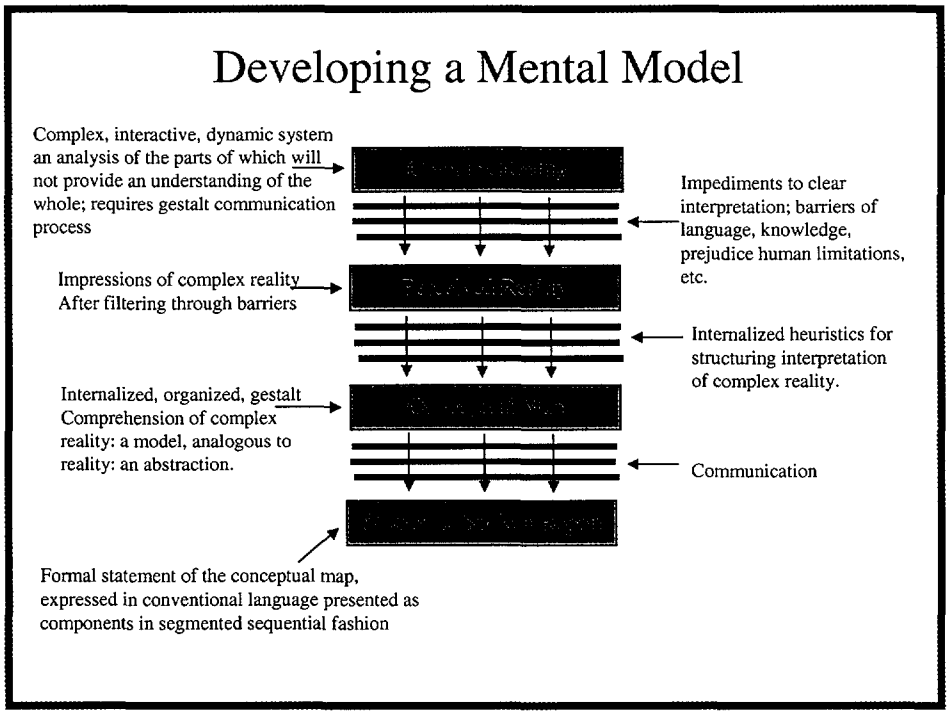
Barry McGuinness argues that situational awareness postulates the construction of a "mental model,"[44]

> In the context of SA, it is usually assumed that the human operator working in a complex, dynamic task environment must construct and maintain a mental model of 'the situation'. So this is in effect an organized set of 'working hypotheses', rather than a stored-away file.
>
> The two types interact, however: When I 'understand' the present situation, it is because all the details fall into a familiar pattern that corresponds to a generalized model I have learned; but when something new or odd occurs I have to generate hypotheses about it which I can hopefully test out with further information.
>
> So the contents of a person's SA at any one moment can be thought of as a set of
>
> 1. references to confirmed schemas (e.g., "landing phase"),
> 2. yet-to-be-tested hypotheses ("I expect to see runway once below cloud"), and
> 3. specific details of significance, like so-and-so's call sign.

---

42. Klimoski and Mohammed, p. 405.
43. Klimoski and Mohammed, p. 405.
44. Barry McGuinness, SABRE, January 17, 2000, http://users.ox.ac.uk/~pemb0595/wwwboard/56-sa.html. Note his use of "schemas" *rather* than "schemata."

This can be represented graphically.



The definition of "situational awareness" as a "mental model" seems to be the one that is assumed by military users. Thus, we find, with reference to the functioning of an AEGIS Command Direction Center,

> Each officer has a mental model of the position he is manning, its responsibilities and requirements, and he also maintains a highly dynamic mental model of the current tactical situation. The tactical situation mental model may include a model for the tactical situation of his own ship, as well as a separate, but related model for the entire ship group.[45]

So "situational awareness" embodies some of the characteristics of a "working hypothesis" or a "mental model." Since, as McGuinness points out, our "situational awareness" changes as our environment

---

45. Stottler Henke Associates, "Intercepting Missile Control Adaptive Training System." http://www.shai.com/projects/missile_control.htm

changes, situational awareness is a subjective condition, a "dynamic mental model," as it were. [46] Although McGuinness' belief is that situational awareness is a subjective condition, he also believes that is can be examined by objective techniques.[47]

Individual *vs.* shared SA

That individual situational awareness differs from group situational awareness would seem to be rather self-evident. We all certainly have been involved in collaborative projects and found that our individual understanding of the goals and tasks can sometimes vary considerably from those of the other members of our team.

Given these differences, it would seem appropriate to suggest that perhaps "situational awareness" be reserved for the idea of "knowing what's going on—what could go on—what options exist—in one's present environment" as applied to individuals, and use an alternative term for the collective version of the concept. By doing so, we would avoid carrying over to the group concept the intellectual baggage associated with the idea as it applies to the individual.

Quite a number of possible alternative terms are already in use. At the very least, this multiplication of terminology suggests the degree of confusion that exists in the field.

---

46. Barry McGuinness, SABRE, February 24, 2000, http://users.ox.ac.uk/~pemb0595/wwwboard/64-sa.html; Barry McGuinness, SABRE, November 10, 1998. http://users.ox.ac.uk/~pemb0595/wwwboard/29-sa.html

47. See, for example, Barry McGuinness' model cited earlier, as well as his November 10, 1998, comments at http://users.ox.ac.uk/~pemb0595/wwwboard/29-sa.html, and Barry McGuinness to Albert A. Nofi, email, received May 5, 2000.

Thus,[48]

Common Understanding
Team Shared Awareness
Shared Understanding
Distributed Cognition
Distributed Understanding
Group Situational Awareness
Shared Cognition
Shared Visualization
Team Awareness
Coherent Tactical Picture

Arguably, any of these terms might be better than "shared situational awareness," if only to make clearer that there is a distinction between individual and shared situational awareness.[49] Despite this, it seems likely that "shared situational awareness" will remain the term of preference, if only due to inertia.

---

48. Terms culled from: Statement of the Under Secretary of Defense for Acquisition and Technology, the Honorable Paul G. Kaminski, Before the House Permanent Select Committee on Intelligence on Enabling Intelligence Technologies for the 21st Century, October 18, 1995; Endsley, "Toward a Theory . . .," pp. 38–39; William T. Hunt, "Shared Understanding: Implications for Computer Supported Cooperative Work," http://www.dgp.utoronto.ca/people/WilliamHunt/qualifier.html#RTFToC1, which, although a student presentation, is a very perceptive paper with a number of interesting ideas; Marcy Stahl, "What are the Issues for Shared Cognition?" (Fairfax, Va.: ThoughtLink, 2000), unpaginated; Allen T. Hjelmfelt and Marvin A. Pokrant, *Coherent Tactical Picture,* CNA RM 97-129 (March 1998), p. 3.

49. A related term is "Coherent Tactical Picture," which is suggested as a necessary tool in building shared situational awareness (the use of "tactical" implies that the idea has no applicability to the operational or strategic level, which hardly seems reasonable). A web search using "Coherent Tactical Picture" turned up about a score of sites that make use of the term. As is the case with "Shared Situational Awareness," "Coherent Tactical Picture" is never defined. It is not in *The Department of Defense Dictionary of Military and Associated Terms* (Joint Pub 1-02), though it does have an official Navy abbreviation, "CTP" (*cf.,* http://www.navy-aadc.org/glossary/pr_glssc.htm#top).

Individual SA

Individual situational awareness is very much a personal attribute.[50] We see the world around us in individual terms, based on our cultural background, education, and experiences, not to mention the strengths and limitations of our senses. The "mental model" we evolve as a result of these inputs is essentially self-centered, as it necessarily must be, given that the self is the prime referent. Moreover, that model exists within the cognition of our individual mind.[51]

Individual SA may be difficult to measure,[52] but we can quickly grasp the basic notion, the essential "knowing what's going on—what could go on—what options exist—in one's present environment."

Factors promoting individual SA are both structural and situational. Structural factors include background, training, experience, personality, interests, and individual skill, while situational factors are such things as the mission that is being performed, and the circumstance under which the person is operating.[53]

---

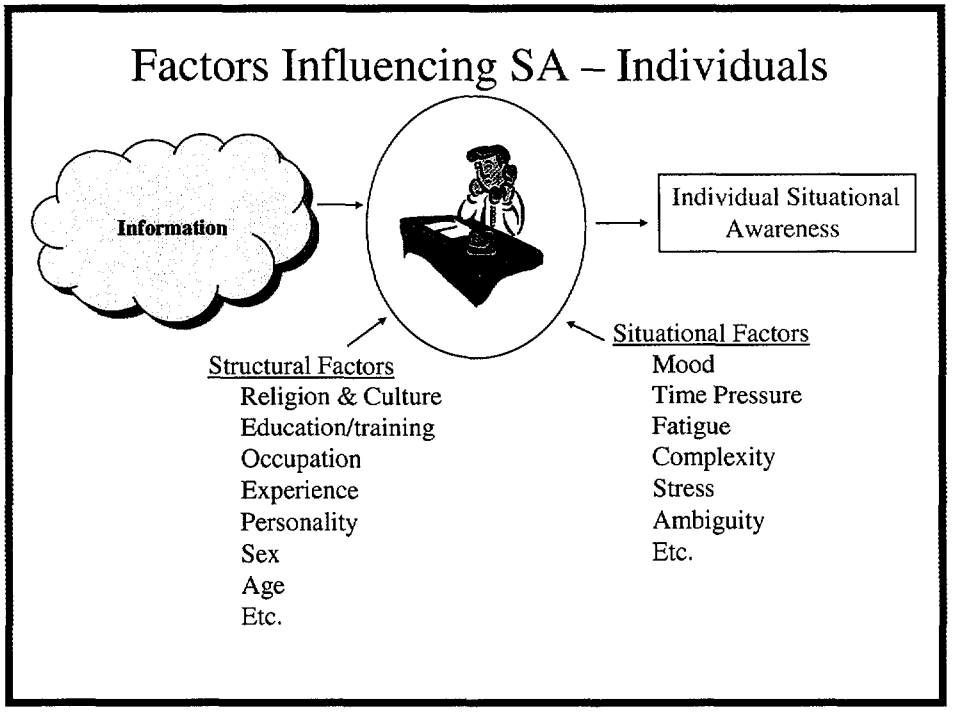
50. Ron Davis, SABRE, September 20, 1998. http://users.ox.ac.uk/~pemb0595/wwwboard/19-sa.html

51. Endsley and Jones, p. 35.

52. Ron Davis, SABRE, September 20, 1998. http://users.ox.ac.uk/~pemb0595/wwwboard/19-sa.html

53. *Cf.*, Hjelmfelt and Pokrant, p. 8.

We can illustrate this process graphically.



Individual talents are obviously of importance. For example, some people are better observers or "noticers" than others, a trait that would certainly influence their ability to develop situational awareness. In this regard consider people who fall into the Myers-Briggs personality classes of "Sensors" and "Intuitives." Sensors like to operate in an exact and systematic fashion, preferring to focus on facts and details, while Intuitives look for possibilities, meanings, and relationships, and try to take a holistic look at problems. Would a Sensor or an Intuitive be better at developing situational awareness?[54] Thus, it seems reasonable to conclude that different people will have different abilities to achieve good SA in different situations. The SA of a veteran soldier under fire will probably be superior to that of a veteran

54. Otto Kroeger and Janet M. Thoresen, *Type Talk: The 16 Personality Types that Determine How We Live, Love, and Work* (New York: Dell, 1988), pp. 24–25. Consider also research which demonstrates that experts approach problems differently than tyros.

archaeologist in the same circumstances. It will certainly be different. But however effective that veteran soldier's SA is in his own milieu, it will probably be less effective if we ask him to assist the veteran archaeologist in rummaging for relics in a peaceful environment.

Group SA

There is considerable agreement as to the nature of situational awareness in groups. Shared situational awareness obviously differs from individual SA because it involves a number of persons trying to form a common picture. In any given "situation" these people each have their own "individual SA," a unique dynamic picture of the situation, which exists in their minds. How can they share that picture to come up with a common one, so that all team members have the same SA in terms of the mission they have to perform? To get the members of the group to develop a shared awareness of the situation requires that they

- Build individual situational awareness within the framework of the mission to be accomplished
- Share their individual situational awareness, which requires being "aware" of relevant actions and functions of other team members
- Develop the group "shared situational awareness."

Of the three functions, the first, building an individual awareness of the situation, is the simplest to attain. After all, we do that all the time. However, if we are to build individual situational awareness with the purpose of sharing it with others in order to build a common situational awareness, we will certainly have to establish some "common ground." Common ground is shared "knowledge, beliefs, and

assumptions," that provide a foundation for effective communication.[55] William T. Hunt observes that

> . . . common ground does not mean strong unification; it does not imply that everyone has the same goals, shares the same view of the world, and acts the same way. A common ground allows for certain diversity and individuality, enables shared views and vocabularies, and tolerates sub-communities, sub-disciplines, and the like. However, there is always a core of common concepts and views.
>
> The common ground is dynamic in nature and therefore is often a matter of explicit negotiation and communication. A common ground can fall apart and eventually can get lost; hence, it needs constant maintenance in order to keep the community, culture, and discipline alive.[56]

So a critical element in building a shared situational awareness must necessarily be the existence or establishment of common ground. This will have to be done through training and experience. Given that the military is often referred to as a "culture," and the various branches within it are considered to have their own "sub-cultures," a great deal of socialization will also be necessary. This has been done before, at least in theory, if one considers the Prussian General Staff. The stated goal was to train staff officers to the point that different staff officers, given the same problem and the same information, would come up with the same solution. Although the actual extent to which the *Kriegsacademie* successfully developed such abilities in its

---

55. Hunt, p. 6. "Common ground" seems to be more or less interchangeable with "common frame of reference", *cf.,* Pow and Mavor, p. 176, "mutual knowledge," *cf.,* Robert M. Krauss and Susan R. Fusssell, "Mutual Knowledge and Communicative Effectiveness," *Intellectual Teamwork,* edited by Joelen Galegher, Robert E. Kraut, and Carmen Egido (Hillsdale, N.J: Lawrence Erlbaum, 1990) *passim,* and "shared context," Victor Zue, "Interdisciplinary Research and Human Language Technology," *Learning and Intelligence Systems: Symposium Proceeding* (Washington: National Science Foundation: 1996), unpaginated. In its way, "common ground" or "mutual knowledge" is almost as complex a notion as "situational awareness": *Cf.,* Krauss and Fussell, p. 112, n. 2.

56. Kevin Schofield and Michael J Tauber, "Common Ground." http://www.acm.org/sigchi/chi96/CommonGround.html

graduates cannot be determined, there certainly were several notable instances in which precisely that occurred.

Consider the Tannenburg Operation in East Prussia in 1914. The commander and chief-of-staff of the German Eighth Army having been sacked for losing their nerve, Paul von Hindenburg was called out of retirement and assigned as commander, while Erich Ludendorf, who had demonstrated extraordinary initiative during operations on the Western Front, was named as chief-of-staff. The two met for the first time on the train carrying them to the front. As they traveled to East Prussia, Ludendorf outlined a plan for successive counterattacks against each of the two attacking Russian armies, by making use of superior interior lines ("win, hold, win," as it were). Upon reaching Eighth Army Headquarters, the pair were joined by Col. Max Hoffman, who had been at the front since the outbreak of the war as the army's operations officer. Hoffman had his own plan for a counterattack, one that had already been approved by the just-ousted commander. It was virtually identical to Ludendorf's. This was the ideal of Prussian general staff training in action.[57]

Accomplishing this presupposes an extraordinary degree of careful training, which included not only a common doctrinal outlook, but a shared vocabulary of known unambiguous meaning and even an insistence on a standardized style of handwriting to ensure absolute clarity. It was also very costly, and only a few officers could be trained to such high standards.[58]

---

57. For background, *cf.*, Walter Görlitz, *Deutsche Generalstab: History of the German General Staff, 1657–1945*, translated by Brian Battershaw, with an introduction by Walter Millis (New York: Praeger, 1953), which though old remains the standard treatment. A graphic view of the Tannenburg Operation can be found online at http://www.dean.usma.edu/history/dhistorymaps/WW1Pages, Maps 25, 26, and 27.

58. During World War II there were an average of only 1,500 general staff officers in the German Army, which averaged five million troops. It's also worth recalling that, despite its extraordinary reputation, technical expertise, and remarkable accomplishments, the German General Staff hasn't won a war since 1871.

The second element, sharing individual "mental models," is essentially a matter of effectively communicating each person's perception of the situation to the other members of the group,[59] so that a "consensus flow" develops. *Communications is the most critical issue in creating shared awareness.* And it is reasonable to conclude that sharing our individual model of the situation with other team members is markedly easier in a collocated environment than in a distributed environment.

In a collocated environment we can talk about the situation and our understanding of it; we can also pass paperwork back and forth. Our understanding—or lack of same—can be communicated by facial expression, gestures, and body language, tone and hesitation, and the many other clues that regularly supplement conversation.

> In the material world, social conventions are built into houses and schools and offices, signaled by modes of dress and codes of etiquette, posture, accent, tone of voice, and hundreds of other symbolic cues that let people guess accurately how to behave in a particular social situation or society. People learn how to adjust their behavior to conform with a learned mental model of conventional behavior.[60]

Similarly, in a collocated environment, members of the team who are temporarily absent will find themselves quickly brought up to speed by the other members, directly or indirectly.

Communications are essential to the development of effective distributed systems. Korean General Paik Sun Yup once observed that "The key to success in war, certainly to success in combined operations, is lucid communication. Indeed, clarity of communication may be more valuable than combat skills."[61] Communication by electronic means eliminates much of the context that influences face-to-face communication; body language, tone, hesitancy, and all the other

---

59. *Cf.*, Hunt.

60. Howard Rheingold, *The Virtual Community: Homesteading on the Virtual Frontier*, Chapter 6, p. 5. http://www.rheingold.com/vc/book/6.html

61. Paik Sun Yup, *From Pusan to Panmunjon: Wartime Memoirs of the Republic of Korea's First Four-Star General* (McLean: Brassey' 1992), p. 42.

social conventions that facilitate conversation are not there to help us understand each other. Their absence necessarily makes communication in a distributed community more difficult.[62]

To be sure, when we communicate in writing, such as by letter, these clues as to our meaning are also absent. But when we write, we usually take greater care in composing the contents of our communications. Information is conveyed by nuance of meaning, word choice, style of construction, underscoring, and so forth. These types of clues are not usually present in electronic modes of communication, in which, typically, we tend to make replies off handedly.

Regarding an experiment in learning using a distributed system, one participant observed,[63]

> It is a cold medium. Unlike face to face communication you get no instant feedback. You don't know how people responded to your comments; they just go out into silence. This feels isolating and unnerving. It is not warm and supportive.

Moreover, a member of the group who is temporarily absent is likely to have lost the thread upon returning, and may not be able to catch up.[64]

---

62. John Wianch, SABRE, August 9, 1999, http://users.ox.ac.uk/~pemb0595/wwwboard/34-sa.html; Rheingold, Chapter 6, p. 2, http://www.rheingold.com/vc/book/6.html In this regard, I recently spent several hours in an air control center in a major European country. It was a medium-sized installation that managed a well-trafficked area of land and sea about twice the size of New York State. The experience was quite educational, despite the fact that it was during the midnight shift. For one thing, there were times when the controllers actually just shouted at each other across the room, as it was easier than using the available electronic communications systems.

63. Rupert Wegerif, "The Social Dimension of Asynchronous Learning Networks," *The Journal of Asynchronous Learning Networks,* II, 1 (March 1998), p. 6 of downloadable version. http://www.aln.org/alnweb/journal/jaln.htm

64. Wegerif, p. 6. Anyone who has participated in a listserv, bulletin board, or online chat group will certainly have had much the same experience as the young woman quoted.

> If a bit of time is missed it is hard to catch up. You feel an observer of someone else's conversation. Before making a point you wonder if it has already been made and so have to read back—by the time you are ready the debate has moved on. It is therefore necessary to log on regularly—perhaps every day. This is especially true of collaborative work where your time and the other participants' time have to mesh together.

Of course, distributed communities have been around for more than 20 years now, and there have been some developments that substitute for the social conventions of face-to-face conversation.[65] For example, many people make use of "emoticons" in email and online chat groups to indicate common facial expressions or tonal clues.[66]

A Sampler of emoticons

:-O	dismay	<G>	grin	:-C	incredulity
:-)	smile	:-J	tongue in cheek	("""")	raised eyebrows
;-)	wink	:-x	kiss	(zzz)	boredom
:-(	frown	O:-)	innocence	[ ]	hug

Shorthand techniques such as emoticons will have to be used to substitute for some of the many physical cues we customarily use to supplement words when engaged in conversation in a collocated community, or for the more careful choice of words and structure we may use in writing a letter. After all, different cultures rely on non-verbal cues in communication to different extents and in different ways. Italians and Japanese both make extensive use of gestures, tones, facial expressions, and body language, but in very different ways; Italians use broad, grand gestures and expressions, Japanese far

---

65. For a look at some of the conventions that have been evolved to facilitate online communications, *cf., Webmonkey Guides.* http://hotwired.lycos.com/webmonkey/guides/

66. James Marshall, *The Canonical Smiley (And 1-Line Symbol) List.* http://www.astro.umd.edu/~marshall/smileys.html

subtler ones, while Norwegians are much less physically expressive.[67] It seems reasonable to conclude that techniques such as emoticons will necessarily have to be formalized, given the importance of the missions involving the need for shared awareness in a military situation, and that they will have to be incorporated in the training of personnel. Military or police radio communication protocols would seem to be an appropriate model, with their numerous standardized formulaic phrases. There will probably also be considerable cultural problems in developing such a system.

The third element in building shared awareness is the integration of the different individual mental models of the situation. Presumably the effectiveness of the group effort will be shaped by the degree to which the members develop a common understanding and common commitment, a "consensus flow" that will lead to a common picture.[68] However, this does not mean that there must necessarily be a single "team mental model." As Klimoski and Mohammed observe, "There can be . . . . multiple mental models co-existing among team members at a given point. . . ."[69] These models need not be identical, but they do have to overlap sufficiently to make it possible to perform the mission.

---

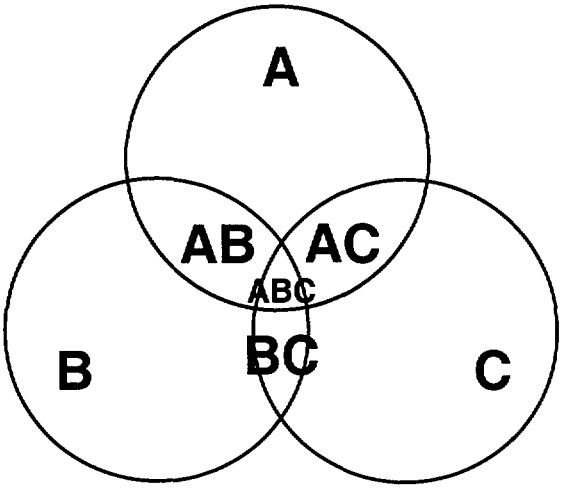
67. Rheingold, Chapter 6, p. 17, has some remarks about the experience with online communities in Japan. http://www.rheingold.com/vc/book/6.html

68. Klimoski and Mohammed, p. 410.

69. Klimoski and Mohammed, p. 432.

We can represent this graphically.

Shared Situational Awareness



This diagram represents a team of three members. Each member has a unique situational awareness, represented by the circles lettered A, B, and C. The areas denoted by AB, BC, and AC represent the extent to which the situational awareness of any two of the three overlap, creating a common situational awareness. The degree to which they "share" situational awareness is naturally smaller than their individual awareness, and no two pairs necessarily share awareness to the same extent. The still smaller area in the middle marked ABC represents the degree to which the situational awareness of all three members of the team overlap. This is the team shared situational awareness, which is naturally even less than the awareness shared between any two pairs

of team members.[70] Of course, what is important is not how much the members of the team share awareness, as how much awareness they *need* to share. This depends on the mission to be performed and upon the extent to which the team members share an understanding of that and the process by which it is supposed to be attained.

Accomplishing this may not be as difficult as it seems, given careful training, a common doctrine and methodology for integrating the information as effectively as a computer wargame does, and a thorough understanding of the mission.

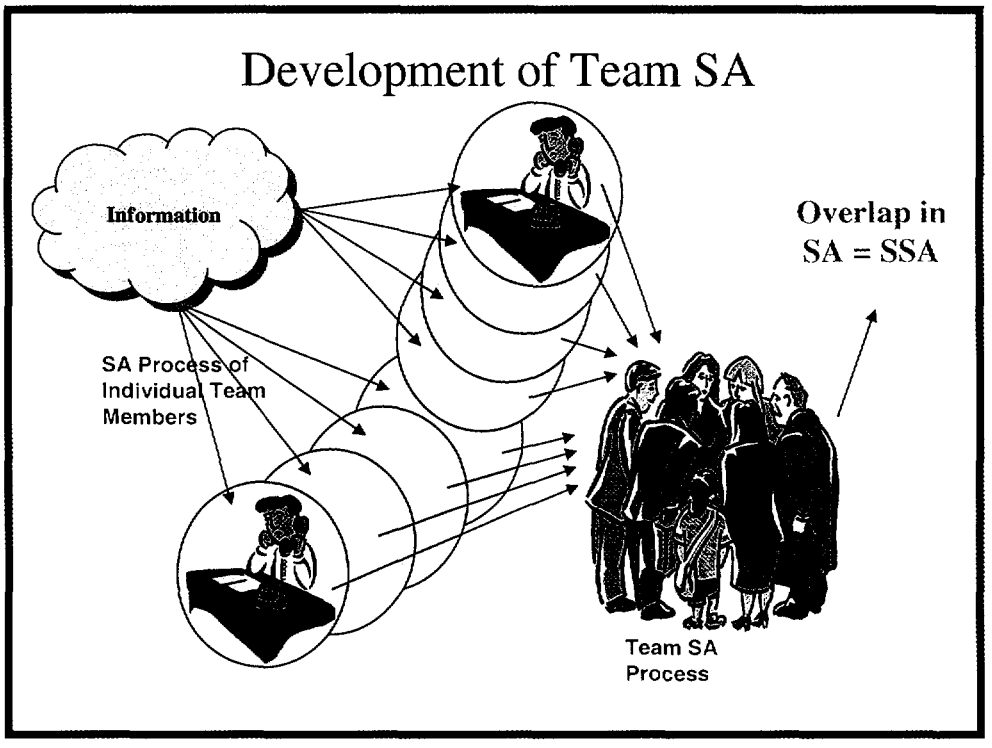
So where does that leave us in terms of understanding what constitutes shared awareness?

It seems reasonable to conclude that "shared situational awareness" is the common "picture" of the mission-critical factors affecting a situation that the members of certain groups—air controllers, military staffs, surgical teams—must develop to perform their duties at peak effectiveness. In effect, it is an understanding of what is in their environment that the members of a team must share to understand what's going on, why it's going on, and how it will affect their mission.

---

70. For larger groups the complexity multiplies rapidly. A similar graphic for a team of four would have to be three dimensional, providing overlaps for each of the four pairs of members, as well as for the four triads, and then one for the group as a whole. Still larger groups would be even more complex as the intersections among perceptions multiply. This complexity can be expressed mathematically, as a function of factorials, the products of all integers up to a point, represented by the notation, n! = n(n-1)(n-2). Thus, a team of four would have 24 intersections (4!= 4x3x2x1=24), while one of five would have 120 (5!=5x4x3x2x1=120).

We can represent this in a graphic.



Of course we have to deal with differences between collocated and distributed teams. The fundamental concept behind the idea that a team will be able to develop shared awareness is that "through interaction over time, group members become more alike, and their attitudes and beliefs become correlated."[71] Unfortunately, the bulk of the evidence supporting this notion is that physical proximity is critical in building such a common outlook.[72] This would suggest that building a similar outlook in a distributed team will be more difficult. "Dysfunctional SA is faster and more mysterious in a virtual group because there are no overt physical cues and because leadership is measured, frequently, by articulacy."[73]

---

71. Pow and Mavor, p. 309.

72. Pow and Mavor, p. 309.

73. Susan Shwartz, July 15, 2000.

SA is dynamic

All the principal researchers concur that situational awareness—whether individual or group—is not a stable phenomenon, but rather a dynamic state, a continuous cycle of perception, comprehension, projection, and prediction.[74] This is reasonable. The "situation" changes even as we experience it. And our awareness of the situation will necessarily change as well. So, although we speak of the "state" of someone's situational awareness, we are really speaking about a transitory phenomenon. One's situational awareness is constantly evolving and changing. And one might have excellent situational awareness one moment and very poor situational awareness the next, depending on the way in which the situation unfolds and one's effectiveness at integrating the available information in the ongoing process of perception, comprehension, projection, and prediction.

In a 1998 paper, two CNA analysts, Allen T. Hjelmfelt and Marvin A. Pokrant, outlined the principal elements involved in understanding a dynamic situation, one in which appropriate responses may change over time:[75]

- Participants must monitor and integrate information from multiple data streams.
- Participants must mentally evaluate information to avoid overload.
- Participants must be able to detect and focus on problems without losing the "big picture."

These points directly address the question of how we communicate and integrate diverse mental models to come up with the "big picture."

74. *Cf.*, McGuinness, SABRE, November 10, 1998, and February 24, 2000; Salas, Prince, Baker, and Shrestha, p. 129; Hjelmfelt and Pokrant, p. 7.

75. Hjelmfelt and Pokrant, p. 5.

Hjelmfelt and Pokrant made some interesting observations about SA based on the definition advanced by Mica Endsley, which, though cited earlier, is perhaps worth repeating,

> . . . the perception of the elements in the environment within a volume of space and time, the comprehension of their meaning, the projection of their status into the near future, and the prediction of how various actions will affect the fulfillment of one's goals . . . .[76]

Based on Endsley's definition, Hjelmfelt and Pokrant conclude that situational awareness,[77]

> . . . is a volatile mental state. In most cases SA, is built up over time. That is, it requires a knowledge of the current state of the environment and at least some past history. Because SA is strongly time-dependent, without continual refreshing it decays as the environment changes.
>
> . . . refers to one's perception of the dynamic state of the environment. It does not directly refer to static factors such as the knowledge of established procedures and doctrine. Nor does it refer to an individual's skills. *It is assumed that the individual is competent in all of these.*
>
> . . . does not encompass awareness of all available information. The basic information elements required for SA are bounded by time, space, and the individual's goals.
>
> . . . requires the ability to predict how the situation will change due to one's action or lack of actions.
>
> . . . is goal-oriented and not task-oriented. Tasks are performed through a mission to accomplish goals, but the goals remain relatively constant for the duration of the mission. Based on SA, one makes decisions to do certain tasks to accomplish the high level goals.

Coping with this dynamism is likely to be even more difficult for a team than it is for an individual, given that the members of the team each have their own SA, which they must attempt to integrate with

---

76. Endsley, "Toward . . . .'

77. Hjelmfelt and Pokrant, p. 7–8, emphasis added.

that of the other team members to develop a shared SA, and even more so for a distributed team, which will not be able to communicate with the ease of a collocated team.

Measuring situational awareness

Given the uncertainty attending the formulation of a commonly accepted definition for situational awareness, it's natural that there is also a lot of uncertainty in trying to measure it, whether for individuals or for teams. In fact, there seem to be almost as many different proposed modes of measurement as there are definitions of the basic concept.

The state of the art

Hjelmfelt and Pokrant have observed that the various experimental methods that have been proposed to measure SA fall into three general categories, each of which has many variations, not all of which are always applicable to every situation.[78]

- Subjective. The subject rates his own SA, either by merely being asked to evaluate it or through responses to directed questions.
- Implicit Performance. This presumes that a subject's performance correlates with SA, on the assumption that improved SA will lead to improved performance.
- Explicit Performance. Researchers engage in an ongoing effort to "directly probe the subject's SA by asking questions designed for that purpose," by suspending the activity being studied for short periods.

All three approaches are flawed. They attempt to quantify certain human behaviors that are not particularly quantifiable. They are all also more or less inherently subjective, since someone has to make judgments as to how things stand, though in this regard implicit performance is much less subjective than the others. And all three can

78. Hjelmfelt and Pokrant, pp. 15–16.

easily run afoul of the problems that may arise because the very act of observing certain phenomena, such as human behavior, may inevitably influence them.

Despite this subjectivity, the assumption that SA is quantifiable is strong. As Allen Hjelmfelt of CNA has observed, "given that SA is a mental state, at least in principle it could be measured." The only way to establish that something exists is to attempt to secure measurable results, albeit that in the case of situational awareness we're dealing with a "squishy" concept to begin with. By attempting to generate quantifiable data, we can begin establishing a mathematical way of evaluating what has hitherto for the most part been a philosophical discussion. However, for the most part, the approaches suggested for developing quantifiable data on SA seem highly subjective.

Consider Barry McGuinness' "model of SA measurement." This purportedly "grossly differentiates between SA as revealed by objective queries . . . and SA as revealed by subjective measures," so that the reliability of a person's SA can be evaluated by resorting to the grid he utlined in an earlier posting.[79]

79. McGuinness, SABRE, October 5, 1998. http://users.ox.ac.uk/~pemb0595/wwwboard/23-sa.html

Measuring SA

	Objective Assessment: High	**Objective Assessment: Low**
Subjective Assessment: High	Objective High: All relevant info present and correct Subjective High: Subject is confident in info	Objective Low: Some info missing Subjective High: Subject is confident in info
Subjective Assessment: Low	Objective High: All relevant info present and correct Subjective Low: Operator is uncertain	Objective Low: Some info missing Subjective Low: Operator is uncertain

McGuinness gave some tips as to how to accumulate data to help determine the quadrant into which a person or group belonged:

> First, as ever I'd recommend approaching the problem from both 'objective' and 'subjective' angles; in other words, a combination of actual knowledge queries and subjective ratings of SA. SA is optimal when objective content is high AND the operator(s) is/are subjectively aware of that. SA is disastrous when the content is off and the operator doesn't realize it. There are other combinations, of course, so it's always best in my book to measure the two together if possible.
>
> For subjective measurement, you could get each operator to rate the quality of SA of both himself and the team as a whole.
>
> I've developed a scale (CARS—crew awareness rating scale) which focuses on 4 dimensions:
>
> 1) awareness of perceptible data
> 2) awareness of the big picture

3) awareness of future developments
4) awareness of response options.

> This was designed originally for the single subject, but can be used team-wise, I think. Also, the scale can be used as a general SA metric or can be addressed to specific tasks of interest, e.g., flight awareness vs. systems awareness.
>
> For objective assessment, our preferred method at present is to identify key items of information pre-trial, then present sets of queries at intervals; somewhat like SAGAT's approach, but different. We use a "situational report" (sit-rep) format, which many operators are used to. The subject is given a sit-rep form to complete (in mid-run). For each item, he can either give the requested information (e.g., expected time of arrival) as he is aware of it, or tick a box:
>
> [ ] Information not available
> [ ] Information not relevant
> [ ] Information not my responsibility[80]

McGuinness concludes by saying, ". . . my best guess is to give a subjective rating scale and an objective sit-rep type assessment to each team-member, but incorporate the team aspect into them."[81] Note that he uses the word "guess," suggesting the degree of uncertainty. And in any case, McGuinness' "objective queries" are likely to elicit highly subjective responses that are not likely to be spontaneous.

Asked about this, McGuinness replied,

> You say his responses to objective queries like sit reps may be "studied," formed once the queries are given. Well, we have to make sure we're asking questions that he SHOULD know the answers to anyway; then we can insist in our instructions that if he doesn't immediately know the correct answer then

---

80. Barry McGuinness, SABRE, November 10, 1998, http://users.ox.ac.uk/~pemb0595/wwwboard/29-sa.html. With regard to the "situational report," he adds the telling comment, "The last response is particularly interesting in terms of team SA. What if all operators in the team tick it for a particular item!"

81. Barry McGuinness, SABRE, November 10, 1998. http://users.ox.ac.uk/~pemb0595/wwwboard/29-sa.html

> he should say so and not sit there trying to figure it out; we can also time his responses to each query and reject (or question) those that run over some criterion response time allowance. You can find ways to tell when someone is figuring it out rather than reporting their knowledge directly.[82]

This is not a very satisfactory answer, and the method is inherently flawed. Not everyone is honest enough to follow instructions and admit that he doesn't know the answer when he might be able to "figure it out." Moreover, some people naturally speak faster than others. If we query someone from New York City and someone from West Texas, the latter will likely regularly violate our "criterion response time allowance" without any intent to figure out a better answer. Moreover, McGuinness' criteria are not likely to indicate whether there's sufficient information to perform the task or whether it's being performed, although the sufficiency of information is probably measurable using some objective criteria. In fact, both of McGuinness' scales essentially focus on the subject's *perceptions* of the state of his SA. What happens if the subject's confidence in his SA is wrong? Say he thinks he's in the upper left quadrant, when in fact he should be in the lower right one? Is that quite the same thing as being in the upper right? As the saying goes, "It isn't the stuff that you don't know that gets you, it's the stuff you know that ain't so."

Mica Endsley focused more on evaluating the factors that are needed to develop situational awareness, whether individually and in groups.[83]

> We've developed a model of team SA and Shared SA that describes 4 major factors:
>
> 1) Shared SA Requirements,
> 2) Shared SA Devices,
> 3) Shared SA Mechanisms, and
> 4) Shared SA Processes.

---

82. Barry McGuinness to Albert A. Nofi, email received June 5, 2000.

83. Mica Endsley, SABRE, January 4, 2000. http://users.ox.ac.uk/~pemb0595/wwwboard/50-sa.html

We've been conducting studies based on this model and found empirical evidence to support it and the role of these factors in affecting Shared SA.

These factors certainly are necessary for the development of situational awareness. But they are not sufficient to ensure that we will attain SA. Scoring high on each of Endsley's factors does not inherently mean we have a coherent mental model.

What has to be measured?

Many questions remain. Can one score high on "objective" measures of SA and still fail at the assigned task? This would seem to be an objective measure of the state of a group's shared situational awareness, but in fact isn't necessarily so. At best, accurate SSA will improve the chances for the successful execution of the mission. But accurate SSA cannot guarantee that the mission will be carried out successfully. After all, decision-making may be flawed, or the mission may be impossible, or the enemy's SSA may be superior.

On the other hand, can one score low on "objective" measures of SA and still manage to complete the mission? Perhaps, with luck, or good leadership. But there's more: How much SA is enough? Is it possible to have *too much* situational awareness? Is having "superior" situational awareness inherently "better" than having "inferior" situational awareness?

Consider a foot race. Who better understands the situation—has superior "situational awareness"—in a foot race, the runner who is about to break the tape at the finish line or the one who is dead last? The one who is dead last certainly knows a lot more about the race than the one who's winning, who knows less about it than anyone else taking part or any of the spectators. This does not prevent the front runner from winning. His situational awareness, although arguably the poorest of anyone present at the race, is sufficient to permit him to carry out his mission, winning the race; he actually knows virtually nothing about the race, but he does know that if he continues as he is he will win. There certainly have been historical precedents for this.

Ancient military commanders from Thutmose III through Belisarius had only the vaguest notions of geographical reality (surely a factor in a commander's "situational awareness"), yet were able to effect extremely complex strategic and operational undertakings.[84] Napoleon, when confronted by conflicting intelligence ("information overload"), often chose to ignore much of what was going on in order to focus on what he believed were the essential elements necessary to the completion of the mission, an effective approach to dealing with this aspect of "the fog of war."[85]

Similarly, years of comradeship coupled with careful training and shared experience, along with a detailed briefing and mission-type orders, provided Nelson's "Band of Brothers" with the shared awareness necessary to win the tactically complicated Battle of Trafalgar though lacking an effective communications system, and despite the fact that the admiral was mortally wounded virtually at the onset of the fighting.[86]

In contrast, excellent situational awareness cannot make up for poor judgment resulting in an inability to accurately predict the outcome. Marcus Tullius Cicero (106- 43 B.C.) was undoubtedly the best informed of any Roman political or military leader of his time. He maintained an extraordinary network of correspondents. It's unknown how many letters Cicero regularly wrote and received. His surviving correspondence includes 835 of his letters to various people. About half of these were to his friend Atticus, a wealthy, astute intellectual, while the rest went to nearly a hundred others, constituting a veritable *Who's Who* of the elite of Roman political and military life, including Julius Caesar, Pompey the Great, Junius Brutus, and others. Many of these people were in regular correspondence with

---

84. Some idea of the Roman notion of a good map can be gained by looking at the Peutinger Table, which apparently was composed in the latter part of the fourth century. It is available online at http://www.lib.utexas.edu/Libs/PCL/Map_collection/historical/Peutingerian_Tables_A.D.393.jpg.

85. Hjelmfelt and Pokrant, p. 5; Pow and Mavor, pp. 302–303, 318.

86. Pow and Mavor, p. 302, cite a modern American admiral's reliance on Nelson's maxim, "know your commanders."

Cicero, based on the 100 or so replies that also survive.[87] These letters contain valuable political and military information, particularly for the bout of civil wars that began in 49 B.C. and continued long after Cicero's death in 43 B.C. The detail is impressive—political machinations, troop movements, personalities, financial transactions, plots and conspiracies, popular opinion, and more. So Cicero's intelligence certainly seems to have been excellent. Indeed it might be said that he had "information dominance." From his letters and speeches we can see that he was receiving information—*perception;* understood the forces at work—*comprehension;* and could consider their implications—*projection.* But his superior perception, comprehension, and projection did not result in superior *prediction;* he managed to choose the wrong side in two successive civil wars, 49–45 B.C. and 44–43 B.C., and lost his head in the process.[88] As Mica Endsley has observed, "While it is assumed that those with better SA will achieve better performance, this may not always be the case."[89]

The question of how to measure situational awareness becomes even more complex when we consider it in terms of a group or team. Discussing comparisons between individual and group SA, Hjelmfelt and Pokrant observed, "The difficulties of measuring individual SA are compounded when trying to measure team SA. At a minimum we

---

87. The Loeb Library editions of Cicero's correspondence are the most accessible in English: *Cicero: Letters to Atticus* (Cambridge, Ma.: Harvard University Press, 1992), in four volumes; *Cicero: Letters to His Brother Quintus, Letters to Brutus, On Elections, Letter to Octavian* (Cambridge, Ma.: Harvard University Press, 1992), and *Cicero: Letters to His Friends* (Cambridge, Ma.: Harvard University Press, 1992), in three volumes.

88. On Cicero, see David Stockton, *Cicero: A Political Biography* (Oxford: Oxford University Press, 1988); Elizabeth Rawson, *Cicero: A Portrait* (Ithaca: Cornell University Press, 1983); J. L. Strachan-Davidson, *Cicero and the Fall of the Roman Republic* (New York: Ayer Reprint, 1972), and Manfred Fuhrmann, *Cicero and the Roman Republic* (London: Blackwell, 1995).

89. Mica R. Endsley and William M. Jones, *Situation Awareness, Information Dominance, and Information Warfare"*(Wright-Patterson Air Force Base: United States Air Force Armstrong Laboratory, Tech Report 97-01, February 1997), p. 27.

must account for individual SA and the coordination process of the team."[90] In this regard Barry McGuinness commented, "At the moment we're in the brainstorming stage, with various plans for experimental work, but we haven't come up with too much beyond developing 'group' versions of our existing individual approaches."[91]

In short, at present there exists no clearly understandable, generally accepted, objective way to measure SA and how it develops, whether for individuals or for groups.

90. Hjelmfelt and Pokrant, p. 17.

91. McGuinness to Nofi, May 5, 2000.

THIS PAGE INTENTIONALLY LEFT BLANK

Degraders of situational awareness

Although the field does not contain much information on what promotes situational awareness, there is a great deal of information regarding things that tend to degrade it, whether for the individual, which is important because individuals can affect the group, or for the group as a whole. This apparent anomaly is rooted in the difficulty of measuring situational awareness except *ex post facto.* All experiments seem to have been based on measuring whether someone or some team has attained situational awareness, based on the *outcomes* of a test, usually measured subjectively. This actually makes it much easier to identify conditions that seem to inhibit the development of a coherent mental model of a situation, rather than those that promote such.

Degraders of individual SA

Quite a number of factors can contribute to degrading individual situational awareness. Most of these seem to be pretty self-evident.[92] All of them require additional study.

Ambiguity. The inability to logically resolve discrepancies between conflicting information from different, but apparently equally reliable, sources.[93]

Fatigue.

Expectations and biases. The effect of *a priori* assumptions on the development of SA

---

92. Adapted and expanded from Hjelmfelt and Pokrant, pp. 11–13.

93. Eric N. Wickfield, "Losing the Big Picture," *For the Record,* September-October 1996. http://www.aviation.org/contents/naa/naa_situation.htm.

Psychological stress

Misperception. "If people aren't perceiving the information properly, they certainly aren't going to be processing it properly."[94]

Task overload. Too much to do, leading to fatigue, stress.

Task underload. Not enough work to be done to keep focused on the primary task, resulting in a lack of concentration.

Information shortage

Information overload

Information interruption

Information irrelevancy

Mission complexity. Too many different tasks, leading to confusion.

Fixation/attention narrowing/information focusing. Excessive focus on particular aspects of the situation, leading to the loss of the "big picture."[95]

Erroneous expectations.

Lack of experience.[96]

Degraders of group SA

Because groups are composed of individuals, we must add to the degraders listed here the factors that degrade individual SA to get an accurate notion of what factors degrade group situational

94. Mica Endsley, SABRE, March 3, 1998. http://users.ox.ac.uk/~pemb0595/wwwboard/5-sa.html

95. Hjelmfelt and Pokrant, p. 12; Wickfield, p. 2; Endsley, "Toward a Theory . . . ," p. 55.

96. *Cf.*, David DuBois, & Renee Stout, "The Role of Expertise in Team Situational Awareness," Klein Associates. http://www.decisionmaking.com/research/abstrt.html

awareness.[97] As with the factors degrading individual SA, these all require further study.

False group mindset. An effective group mindset is important to the development of SSA, but it could just as easily be harmful. The imperceptible socialization of group members could lead them to thinking along the same *wrong* lines.

"Press on regardless" philosophy. Letting the pressure to accomplish the mission warp the development of an objective point-of-view.

Insufficient training/variable skill levels

Poor personal communications skills

Perception conflict. A situation that can result if some members of the team perceive the information differently than others, thereby altering their situational awareness, perhaps caused by individual misperception of the information on the part of some team members, but perhaps also the result of legitimate difference in interpretation.

Personnel turbulence[98]

Degraded operating conditions

"Real time" vs. "virtual time."

Degraders of group SA in a distributed environment

In addition to those degraders already at work, a team working in a distributed environment finds itself affected by additional ones.

Lack of a common environment. This may seem so self-evident as not to merit mention, but in fact there are implications to being in a distributed environment that are quite subtle. Mica Endsley uses the example of two people having a conversation in a car, "that

97. Adapted and expanded from, Ron Davis, SABRE, September 20, 1998. http://users.ox.ac.uk/~pemb0595/wwwboard/19-sa.html

98. Klimoski and Mohammed, p. 424.

conversation will instantly be suspended when a serious traffic problem arises. The passenger is aware of the situation through the fact that the two share a common environment . . . . and modify behavior accordingly. In contrast, a person without this information would continue talking, distracting the driver."[99]

Insufficient/poor communications and collaboration tools. This includes communications problems, computer glitches, and system incompatibility, as well as poor writing and communications skills on the part of individual members of the team.

Absence of non-verbal cues to communication.

99. Endsley and Jones, p. 49.

Thinking about criteria

Despite the uncertainty in the field, it does seem possible to develop situation-specific ways to *estimate* the degree to which situational awareness may exist, whether individually or for a team. By examining the nature of a particular situation, it should be possible to develop a tailor-made set of criteria that can be used to get an approximate idea of the state of individual or group SA as it applies to that specific case. This would enable an observer to elucidate some of the factors affecting the development of situational awareness in individuals and in teams, whether collocated or distributed, to reasonably rigorous statistical standards.

We can identify some criteria that seem to apply to the measurement of situational awareness. These criteria fall into two categories, one substantially subjective and the other more objective.

Subjective criteria

These criteria essentially are helpful in suggesting that the *process* of developing shared awareness is going on. Answering them requires some degree of judgment; hence, responses are essentially subjective. Presumably, each of the criteria would have to be addressed several times during the unfolding of the situation to get a coherent picture of the development of the "common mental model," which would further influence the responses.

We have to ask "How well . . ."

1. *Do members understand the team mission?* Questioning the team members will elicit a reasonable idea of their impression of the mission, which can be compared with the actual mission.
2. *Do members understand their individual roles on the team?* Questioning the participants will elicit a reasonable picture of their

understanding of their individual roles, which can be compared with what the prescribed role is, but would lead to "studied" answers.[100]

3. *Is information flowing into the team?* Essentially, this means trying to determine team members are receiving the information necessary to perform their tasks.

4. *Is information passing among members of the team?* This seems highly subjective, attempting to determine the degree to which the team members are sharing the information to which they have access. And in any case they may be talking up a storm, but may be disseminating little useful information among the team members.

5. *Are decisions being made by the team in a timely fashion?* Although the timeliness of the decision-making process can be measured with fair objectivity, the *appropriateness* of those decisions is likely to be difficult to evaluate; the decisions being made may be wrong.

6. *Are appropriate actions being taken by the members of the team?* We have to attempt to measure whether the participants are acting in accordance with the decisions that were collectively made by the team.

To varying degrees, all of these criteria are highly subjective. Worse, due to their nature, criteria 1 and 2 are likely to yield studied results; questioning the participants will inevitably influence their responses. And, in any case, attempting to secure more precise results than "poor—satisfactory—good" seems unreasonable. These criteria can help us gain some subjective insights into the development of situational awareness in teams. But the results do not lend themselves to rigorously objective mathematical scrutiny.

---

100. It might also have been interesting and useful to question participants as to the roles of the other members of their team.

Objective criteria

There seem to be only two substantially objective questions that would enable us to determine the extent to which the members of a team have successfully developed shared situational awareness.[101]

1. *Does the team understanding of the situation, at any particular moment, conform to reality?* This probably can be determined by comparing the actual "picture" of the situation with that held by the team members, both individually and collectively. However, efforts to elicit team member views on the current picture would probably bring polluted results, since they would be tempted to edit or revise their conclusions.

2. *Is the mission being successfully executed?* This would not seem to be measurable until the mission is completed, but at that point at least we can measure the outcome.

So there are really only two criteria that actually focus on the question of whether a team is developing shared awareness. They can be summarized as *how closely did the team image conform to "reality"?* Most of the research done in situational awareness has been based on this question, deducing the existence of a mental state—SSA—based on outcomes. Essentially this is a phenomenological approach to putting some structure behind Michael Webb's comment about situational awareness, ". . . you know who has it, and who doesn't."

---

101. In earlier versions of this paper, I included as an objective measure, "*How long is it taking the team to make decisions?*" On reflection, however, I do not think it seems reasonable to consider "response latency" as an indicator of the growth of shared awareness. A team might be making decisions at a fast pace based on a false shared picture.

THIS PAGE INTENTIONALLY LEFT BLANK

Questions needing answers

There has been some research into the differences between collocated and distributed teams. Pamela Hinds, of the Center for Work, Technology, and Organization, conducted an experiment using 47 pairs of workers in a distributed environment. She concluded that

> Analyses of their shared mental models suggest that distributed workers have less overlap in their representation of the task than do co-located workers. Distributed workers also have less overlap in their representation of the work context. Further examination indicated that contextual information is rarely discussed among distributed workers.[102]

Dr. Hinds' work is valuable, but tentative and limited. Clearly more work needs to be done. Determining and understanding the possible differences in the ways in which collocated teams and distributed teams operate is of critical importance. Whereas in the past political and military decisions were usually made by teams working in a face-to-face environment, they are now increasingly being made by teams working in a distributed environment using a variety of "teaming tools," often with much tighter time constraints than was the case in the past. Any failure in effectiveness or efficiency has the potential to be catastrophic.

Using "how closely did the team image conform to 'reality'" as our basic criterion should permit us to get a handle on the principal issues regarding differences in shared awareness between collocated and non-collocated teams. There are four basic questions that require answers.

102.Pamela Hinds, "Perspective Taking Among Distributed Workers: The Effect of Distance on Shared Mental Models of Work," *WTO Working Paper* # 7 (Stanford, CA: Center for Work, Technology, and Organization, 1999), p. 2.

1. What differences exist in the process by which collocated and virtual teams develop shared awareness?
2. Is there a difference in the SA developed by virtual teams and that of collocated teams?
3. Are there differences in the factors that foster or impede the development of SA in virtual and collocated teams?
4. What techniques facilitate or impede the development of SA in virtual teams?[103]

This sounds simple. But it's actually pretty ambitious. After all, the very concept of shared awareness is rather squishy. Moreover, as Michael Markowitz of CNA observed, "collocated and virtual teams operate under such radically different conditions of time, space, and interaction; how could we possibly hold everything else constant and vary only the condition of collocation and virtuality?"

103.In this context, consider possible differences among teams using telephone, online chat, or email either solely or in various combinations.

Suggestions for further inquiry

There are a great many factors that almost certainly influence situational awareness, both individual and team, whether collocated or distributed. In some instances the effect may seem obvious, but perhaps it is not. In either case, further investigation seems necessary, not only so that we can understand how the factor effects shared situational awareness, and how its affects may differ in collocated and a distributed environments, but also in order to develop ways to minimize such effects through more sophisticated training, since it seems likely that the influence of virtually all of those differences can be reduced by training.

Age and sex

The differences in the way people of different ages and different sexes behave, cooperate, act and react, and so forth have only recently begun to be explored, and involve considerable debate over "nature *vs.* nurture." Certainly differences do exist. Do teams composed of people of heterogeneous ages perform "better" or "worse" than those composed of people of approximately the same age? Do teams composed of older persons perform differently from those consisting of younger folks?[104] Likewise, do mixed-sex teams have more or less difficulty developing SA than same-sex teams, and are

104.Some work has been done in this area; *Cf.,* Cheryl A. Bolstad and Thomas M. Hess, "Situation Awareness and Aging," *Situation Awareness Analysis and Measurement,* edited by Mica Endsley and Daniel J. Garland (Mahwah, N.J.: Lawrence Erlbaum, 2000), pp. 277–302, which concludes (p. 298–299) that, "Although the literature supports the notion that SA will decline with age, there has been very little research to support or disprove this claim," and suggests that experience may be an important mechanism compensating for the normal decline in physical and mental faculties associated with aging.

there differences in the way teams composed of entirely of one sex develop SA compared with teams composed of the other sex?

Personality and education

What effect will differences in personality have on the development of group cognition? Does the influence of personality differ between collocated and distributed teams? If the members of a team have to work together to merge their individual mental models into a team model, to what extent will personality influence the final picture? Decisive, extroverted, aggressive, or articulate individuals are likely to be able—whether consciously or not—to impose their views of the situation on teammates who may be less decisive, introverted, or passive, or have less facility with words. Will personality tend to influence which team members emerge as leaders? Indeed, will a clear "leader" necessarily emerge? To what extent will "first impressions" influence team member behavior? In addition, given that some personality types are "naturally" more or less compatible, what influence might personality differences have on the process by which a collocated or a distributed team develops shared awareness? Personality will also be of importance in terms of how teams will be able to resolve "perception conflict" among their members.

With this in mind, we also have to ask if working in a virtual environment leads to changes in the personality and behavior of team members? There is considerable anecdotal evidence—though apparently no studies—to suggest that this is the case. People who are quite reasonable and polite in person are often less so when online, sometimes even becoming abrasive, rude, and unreasonable when engaged in chat or posting to bulletin boards. Likewise, at times, people who are shy or retiring in person, often become much more outgoing when online. The opposite phenomenon—that someone abrasive or outgoing in life becomes more polite or shyer online—does not seem to manifest itself. This has important implications if we are seeking to develop shared awareness in a distributed team.

As a corollary to the question of personality, members will come to a team with a wide variety of pre-existing knowledge, tenets, and opinions. Some of these will be resistant to change. How will these

influence team development of shared awareness, particularly given the fact that team members may not be consciously aware that their basic programming is influencing their judgment?[105]

There is some evidence that groups made up of generalists performed better at some tasks than groups made up of specialists. Groups composed of generalists tended to have a "higher level of similar knowledge . . . broadly distributed across group members, while [groups composed of specialists] had non-overlapping or unique information that was concentrated in different group members. Thus, in generalist groups, minimal effort was needed for members to retrieve the knowledge they needed."[106] In addition, in groups made up of generalists "members may be more likely to share conceptualizations of one another's expertise, whereas in groups made up of specialists, group members may be more likely to form different conceptualizations of one another's expertise." Moreover, in groups composed of specialists, members "have difficulty discussing or sharing" the knowledge they do have." [107]

Art vs. science/talent vs. learning/reflex vs. situational awareness?

The very "squishiness" that attends the definition of "situational awareness" suggests that it may be more of an art than a science. Perhaps some people naturally have "better" SA than others.

Dr. Malcolm James Cook raised this question on the SABRE bulletin board, by observing that skilled memory " . . . supports efficient perception, skilled comprehension and effective retrieval of situationally relevant knowledge." To his question as to whether this talent would

---

105.Pow and Mavor, pp. 311ff, have some material on this.

106.Diane L. Rulke and Joseph Galaskiewicz, "Distributed Knowledge, Group Network Structure, and Group Performance, *Management Science*, Vol. 46, No. 5 (May 2000), p. 612, citing research by D.W. Liang.

107.Rulke and Galaskiewicz, p. 613.

lead some people to have better SA than others, he received no reply.[108]

If SA is essentially an art, rooted in the talent of the individual, attempts to train people to develop better SA will have limited results. It will probably be possible through training to enhance a person's inherent ability in the area, much as we can teach most people to draw or to play a musical instrument. But we can't turn everyone into a master of SA, just as no amount of training can turn everyone into a Leonardo or a Heifitz. As Michael Webb observed, SA is something that "comes as a by-product of training and experience, and some never get much of it, while others seem to develop it with ease." We are perhaps here dealing with the "ace" phenomenon.[109] The importance of talent can be seen particularly among fighter pilots. In every air war since World War I, about 5 percent of the pilots have accounted for about 40 percent of the kills. Many "aces" have been indifferent pilots in a technical sense, while some flew numerous missions without a single victory, and then quite suddenly began piling up enormous scores. Asked how he seemed to be able to identify enemy aircraft at great distances, British World War I ace Albert Ball replied, "I smell them." Some people who have the talent and the training will develop the necessary expertise, while others will not.[110] The importance of this question goes beyond the issue of native talent. Since one's life is a continuing learning experience, different people are going to develop different skills that will tend to enhance or reduce their ability to develop SA depending upon the environment. So someone may have excellent SA in a tank battle, but do poorly in a volleyball game. How will these differences influence the development of SSA, and will their e ffect be different for collocated and distributed teams?

108.Malcolm James Cook, SABRE, December 3, 1999. http://users.ox.ac.uk/~pemb0595/wwwboard/37-sa.html

109.On the ace phenomenon, see Mike Spick, *The Ace Factor: Air Combat & the Role of Situational Awareness* (Annapolis: Naval Institute Press, 1988).

110.Spick, p. 54.

A post on the SABRE bulletin board by Valerie Gawron raised another important question about SA—how does it differ from reflex? "I once asked a crusty old marine pilot if SA is all mental. He replied, 'Some is below the brain stem.'" Gawron continued,[111]

> Fire fighters talk about instant olfactory warnings that result in immediate, almost reflexive behavior. For example, first, the odor of a particular combustion by-product is distinctive. Second, the by-product is produced only at high temperatures and only immediately prior to explosion. Third, the fire fighter smells the odor and takes cover. Reflex or incredibly good SA? If you ask fire fighters afterwards, they may not remember why they took the actions they did.[112]

Mica Endsley replied, "I think this instant recognition (e.g., reflex) is at the heart of very good SA in experts. They can very rapidly detect these cues, sometimes at a subconscious level, and from that recognize the situation they are in . . . . It's not an either or question."[113]

So SA is at least partially a matter involving both our senses and our reflexes, albeit senses and reflexes honed by training and experience. Tyro fencers, for example, *think* about the nature of the attack being made, then *decide* on the proper counter stroke, and then *make* the appropriate response, while experienced fencers *react* to the attack by *making* the appropriate counter move without thinking or

---

111. Valerie Gawron, SABRE, March 24, 1999. http://users.ox.ac.uk/~pemb0595/wwwboard/12-sa.html

112. I have a neighbor in Austin who's a firefighter, and recently asked him this very question. He substantially agreed with Gowan, noting that quite often he had taken the "right" course of action without consciously doing so.

113. Mica Endsley, SABRE, March 29, 1999. http://users.ox.ac.uk/~pemb0595/wwwboard/32-sa.html

deciding.[114] This is an example of the difference between the expert and the novice, a matter sometimes referred to as the difference between "muscle knowledge" and "skull knowledge."

This is important for an understanding of SA. To what extent do experience and consequent learned reflexive actions influence the development of SA? And do people who have had the same experiences, both qualitatively and quantitatively, tend to react in same way, and are thus likely to have more uniform SSA than a group with more mixed experiences?

Social complexity and networks

A number of issues can be subsumed under this heading.

Are teams composed of people who are acquainted with each other—or who at least have previously met face-to-face—more effective at developing shared awareness than teams composed of strangers? The answer to this question would seem a given. After all, it's "logical" that acquaintances will work together better, and even more so in a distributed environment, where they have some understanding of each other's strengths and weaknesses. But it's a question that ought to be explored in a systematic fashion.

To what extent does team size affect the development of SA? Certainly greater numbers will increase complexity. This is the case in collocated teams and would seem to be even more of a problem in distributed ones, but it would be useful to have some idea of the extent to which increased size degrades effectiveness.

114.I once watched a veteran medieval re-enactor training a greenhorn in broadsword and shield work, using padded rattan laths. The trainer began quite slowly and called his blow each time ("right low," "left high," etc.), giving the trainee time to use his sword or shield as appropriate. They continued on like this for about an hour, during which the trainer gradually increased the tempo of his blows, though still calling them out. Afterwards the trainer told me that they would do this sort of drill for several sessions. The student would then "graduate" to drill without the trainer calling his blows, though once again starting at a slower pace.

How do formal and informal lines of communication affect the development of team SA in both collocated or distributed environments? All institutions, including armies, usually have both formal and informal lines of communication and authority to overcome some of the complexity resulting from size, organizational hierarchy, and so forth, with the informal ones often the more important of the two.[115] To what extent can—will?—the "collaboration tools" in a distributed system overcome this effect? Or perhaps the members of distributed teams will also evolve informal lines of communication and authority, using the very tools that are supposed to make them work as one.

Cultural differences

This seems to be an important area requiring additional inquiry, particularly given that multi-national operations are becoming more common.[116] To what extent is "situational awareness" subject to cultural factors? A poster on SABRE asked, "How universal are theoretical models of Situational Awareness? Across country, language, and indeed, work environment!!" Providing an example of significant cultural difference in a relatively simple matter, he went on to observe,

> If you ask a Japanese colleague a question in a meeting, they will fall silent and concentrate for just as long as it takes them to think of an appropriate reply; whereas in the U.K. or the U.S.A., the person you asked would be likely to start to talk their way through the problem, thinking as they went along. If you don't know about that difference, you might think your question was being ignored. Worse—if you repeat the question, you're interrupting your Japanese colleague's train of thought! Gestures can be a problem, too: a perfectly harmless gesture in the Japanese context can have

115.See, for example, Pow and Mavor, pp. 304ff.

116.Some work has been done in this area, but it seems to focus on collocated groups, *cf.*, Helen Altman Klein, Anna Pongonis, and Garry Klein, "Cultural Barriers to Multinational C2 Decision Making." http://www.dodccrp.org/ccrp/2000CCRTS/cd/html/pdf_papers/Track_4/101.pdf

> a vulgar or insulting meaning in the Western cultural context.[117]

To make the issue as clear as possible, imagine that the Japanese colleague in question is a member of a virtual team and is operating at the other end of a computer terminal. Perhaps his cultural conditioning will make cooperation even more difficult. Or perhaps not. Perhaps the effect will be to enhance cooperation. If the mode of communication is email, the Japanese may be more easily integrated into the team. But will this be the case if we are using voice- or teleconferencing as our collaborative tool?

Culture also affects our non-verbal modes of communication. In a face-to-face situation, our understanding—or lack of same—can be communicated by expressions, gestures, and body language, tone and hesitation, and the many other clues that regularly supplement conversation. Although these modes of conveying information begin to break down when we are engaged in a cross-cultural conversation, because different cultures often use different expressions, gestures, and body language, they are wholly useless in a distributed environment.

Similarly, considering the question of developing shared awareness in a distributed team, are team members who come from individualistic cultures—such as Americans—more or less likely to form effective teams quickly than those from collectivist cultures—such as Japanese?[118] Likewise, are there differences among team members who come from hierarchical cultures and those from egalitarian cultures?

It seems reasonable to conclude that cultural differences are likely to have an important impact on the development of situational awareness, both individually and in groups, whether collocated or virtual.

117.Sam Joseph, SABRE, January 30, 2000. http://users.ox.ac.uk/~pemb0595/wwwboard/61-sa.html

118. Sirkka L. Jarvenpaa and Dorothy E. Leidener, "Communication and Trust in Global Virtual Teams," *The Journal of Computer-Mediated Communications*, Vol. 3, No. 4 (June 1998), pp. 5–6, deal with this cultural issue in the context of developing trust (http://www.ascusc.org/jcmc/vol3/issue4/jarvenpaa.html).

A number of cultures such as the Australian Aborigines or Papuans value certain aspects of SA much more than we do, due to its importance as a survival skill. As a result, these peoples are much better at fieldcraft than most other peoples—a matter that made them very valuable to Australian and Ameican forces operating in New Guinea during the Second World War.[119]

Consider some simple examples of how a cultural default might affect even a relatively minor task. Both New Yorkers and Londoners have a propensity to cross streets in the middle of the block. Neither city has a particularly high pedestrian casualty rate, since native residents have considerable awareness of traffic movements. But New Yorkers in London and Londoners in New York are unusually prone to being hit by cars when trying to cross two-way streets. Their cultural biases work against them; the New Yorker's SA antennae are attuned to traffic moving on the right, the Londoner's to it moving on the left.[120]

We can demonstrate a simple cultural default experimentally. Say we have a checkerboard on which one bean has been placed in each square, and have asked several people to remove the beans, one-by-one. A Westerner would likely approach the task by starting in the upper left square and at least initially would probably proceed to the right. In contrast, an Arab, an Iranian, or an Israeli will most likely begin the task from the upper right square and proceed to the left, while a Japanese would probably begin from the upper right square and proceed downwards. These patterns reflect the normal writing patterns of these cultures.[121] In the end, all five subjects—the Westerner, the Arab, the Iranian, the Israeli, and the Japanese—do

---

119. See, for example, Thomas Sinclair, *To Find a Path: The Life and Times of the Royal Pacific Islands Regiment* (Brisbane: 1990).

120. The most famous victim of this cultural default was Winston Churchill, who was struck by a car while crossing a street in New York in 1930; he had looked, but it was the wrong way.

121. This was confirmed by Dr. Ahmed S. Hashim of CNA, Dokhi Fassihian, also of CNA, and Ronit Setter, native speakers, respectively, of Arabic, Farsi, and Hebrew, as well as Prof. Theodore F. Cook, of William Patterson University, who has lived and worked in Japan for many years.

complete the task at hand, but their approach to it is radically different.

Presumably, people can develop good situational awareness regardless of culture, but culture probably influences the process by which a person develops individual situational awareness and the process by which they help build team awareness, which is likely to be of considerable importance in attempting to develop a state of shared situational awareness in a culturally mixed team, particularly in a distributed environment.

Although the impact of culture on one's ability to develop situational awareness is most clearly obvious in the case of one's "culture" in the traditional ethno-linguistic-religious sense, it is probably just as true for a "sub-culture," in the sense of "the military culture" or the "corporate culture." What effect can this have on shared cognition in a collocated group? A distributed group?

This is bound to be of considerable importance when operating with allied or associated powers, with government agencies, with diplomats, with NGOs, and so forth. It seems reasonable to attempt to assess the degree by which people from different cultures and sub-cultures function in terms of situational awareness, particularly in group environments and especially in distributed ones. The difference will probably be more important for people working on staffs than for those actually under fire.

Superficially, it would seem reasonable to conclude that "sub-cultural" differences will be more readily overcome than "cultural" ones, but this may not be the case. After all, "cultural" differences in the ethno-religious-linguistic sense may be so readily recognizable that they can tolerated or adjusted for. It's easy to see the overt differences when encountering someone from a different culture; dress, accent, mannerisms, and more will all be obvious. The clues distinguishing someone from a different sub-culture within the broader culture—say a soldier *vs.* a diplomat *vs.* a banker *vs.* a human rights advocate—are likely to be much less overt, because to a great extent, members of these sub-cultures are indistinguishable from the rest of the members of society, but it's the less obvious differences that are likely to create problems. Consider the numerous difficulties that

arise in complex humanitarian emergencies. These have often been beset by cultural conflicts among soldiers, diplomats, relief workers, journalists, and others. At times, they are all supposed to be on the same "team," but they often can't even agree as to what constitutes the primary mission.[122]

Leadership

In a military context, teams—whether collocated or distributed, will be hierarchical; they will have a "leader." To what extent will strong leadership influence the development of effective shared awareness in a team? There are certainly historical examples of strong leadership both promoting and degrading development of an accurate shared awareness of a military situation. In December of 1944, George S. Patton and his staff accurately predicted the German "Ardennes Offensive," which did not even occur in their sector, because Patton actively encouraged his people to develop an awareness of the military situation across the whole front, not merely across that of Third Army. In contrast, in October of 1950, Douglas MacArthur and his staff completely missed increasing evidence of the buildup that led to the massive intervention of Communist Chinese troops into the Korean War, because of the general's firm belief that such was not possible. During the North African Campaign, Erwin Rommel's intelligence picture was never as good as that of his opponents, who had the benefit of ULTRA, which provided them with virtually complete information about the state of his troops and his plans, giving them significant "information superiority." Nevertheless, he had a greater understanding not only of the strengths and weakness of his own forces, but of those who opposed him as well. And he knew the minds of his enemies. Rommel seems to have belonged to that small group of commanders about whom Lawrence

122.See, for example, Hugo Slim, "The Stretcher and the Drum: Civil Military Relations in Peace Support Operations," *International Peacekeeping*, III, 2 (Summer 1996), pp. 131–134.

of Arabia observed their "instinct so nearly approached perfection that . . . they reached the certainty of scientific knowledge."[123]

123.T. E. Lawrence, *Seven Pillars of Wisdom* (Garden City, N.Y.: Doubleday, 1938), p. 192. The actual line is, "men whose [doxa] so nearly approached perfection that by its road they reached the certainty of [epistêmê]." In terms of his Myers-Briggs score, Rommel was probably an "Intuitive," while his opponents were "Sensors." *Cf.* Krueger and Thoresen, *loc. cit.*

Conclusion

The concept of "shared situational awareness," which underlies some recent ideas about the organization of military staffs, is elusive and ill-defined, and does not lend itself easily to traditional scientific evaluation. Nevertheless, it is possible to compose a systematic definition and to develop objective approaches to studying the process by which "shared situational awareness" arises.

Although certainly important, the nature of situational awareness is uncertain. Although there is some confusion in terminology, there is a considerable agreement on *what* situational awareness is: the result of a dynamic process of perceiving and comprehending events in one's environment, leading to reasonable projections as to possible ways that environment may change, and permitting predictions as to what the outcomes will be in terms of performing one's mission. In effect, it is the development of a dynamic mental model of one's environment. There is also a measure of agreement on what constitutes *shared* situational awareness and how it develops by a process of integrating the mission-essential overlapping portions of the situational awareness of individual team members—thus, developing a group dynamic mental model.

However, there is no clearly understandable, generally accepted, objective way to measure situational awareness, whether for individuals or for groups, and little evidence as to the effect of a distributed environment on the development of shared awareness. Nevertheless, despite the enormous uncertainty in the field, it does seem possible to develop situation-specific ways to *estimate* the degree of situational awareness that a person or group may possess, and from that to be able to make rigorous statistical inferences as to factors that enhance or degrade it.

This possibility has considerable importance, particularly for military and political decision-makers. By better understanding the process by

which situational awareness and shared situational awareness develops, we may not only be able to strengthen our ability to develop situational awareness in crisis situations, but may also be able to better understand the enemy's situational awareness, which in turn might permit us to get inside his situational awareness loop to degrade his situational awareness, with potentially important benefits to ourselves.