Assessing VTS operator situation awareness

Concept

Erik Wiersma
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Chapter 2 Situation awareness

2.1 Introducing situation awareness

In the previous chapter the term situation awareness was presented as a key element in the assessment of performance of VTS operators. Situation awareness has been put forward as an objective measure of the understanding of supervisory situations, such as VTS. It is based upon the notion that the human operator uses available data sources to create and maintain a mental representation of the situation he must supervise. This representation, together with (his personal interpretation of) goals and objectives and his expectations or preconceptions determine his actions.

The construct of situation awareness was developed in military aviation some twenty years ago. Since then, researchers with a background in many scientific disciplines have studied the construct and tested its applicability in various contexts, within different fields of application, ranging from flying helicopters (Smyth et al. 1990) to anaesthesiology (Gaba and Howard, 1995; Small, 1996) to emergency management in fire fighting (Companion, 1994; Schenk, 1994). Several conferences devoted to situation awareness (Gilson et al. 1994; Garland and Endsley, 1996), numerous symposia at recent meetings of the Human Factors and Ergonomics Society and other conferences, and a special issue of Human Factors (**37/1**) are evidence of the fact that situation awareness is a construct which has attracted a lot of attention.

For the scientific community, situation awareness is a rather new construct. Numerous attempts have been made to define it and give it a place among other cognitive constructs such as mental models, workload, attention, working memory, etc.

An annotated bibliography by Vidulich et al. (1994) demonstrates the attempts of the research community (in that bibliography merely from aviation) to get a grip on the construct of situation awareness: out of 233 papers, 61 mention a definition of situation awareness. In the same report, Dominguez (1994) provides a table with fifteen different one-line definitions from this bibliography (p. 6-7), and provides another one herself.

Dominguez (1994, p.5) states: "*When a new construct emerges and gains momentum in the academic and applied communities with such force as has situation awareness, it is only natural that those of us who pursue its meaning and its measurement should seek to define it as well. Unfortunately, the lack of an agreed upon definition of situation awareness has itself been a defining characteristic of situation awareness from the start. As was the case with mental workload, there are many definitions, and although the concept is accepted as important without qualification, nobody is willing to accept anybody else's definition (Wickens, 1992)*". The first version of this chapter was written some ten years ago, in the second half of the 1990's. Out of 170 papers, articles and reports reviewed for this thesis (see appendix 1), 76 provide a definition of situation awareness, or discuss the concept. Overviews of literature have been presented by several authors, see for instance Vidulich et al. (1994), Dennehy (1996) and Jones (1996). At that time there was still a fierce debate going on about situation awareness. The March 1995 issue of the *Human Factors* journal marks the top of that discussion. With eight papers on situation awareness, this issue brings together the different perspectives on situation awareness of that period. The papers show different theoretical approaches to situation awareness, each with their own methodological approach for assessing situation awareness.

The articles in this Human Factors issue 37(1) are the most influential articles on situation awareness ever written. A bibliographic analysis on publications about situation(al) awareness with Scopus[1] was carried out in March 2006 to study the issue. The analysis shows that six out of eight most cited articles on situation awareness are indeed from this issue, including the top three (see Table 2.1). The most influential article is that in which Mica Endsley elaborates on her theory of situation awareness. That article has been cited over 200 times since publication. The other two articles in the issue are still in the top forty of most cited publications, with 19 and 11 citations each.

Table 2.1 Publications on situation(*al*) awareness most cited in the period (1996-2005) according to Scopus database.

Publication	# Citations
Endsley, M.R. Toward a theory of situation awareness in dynamic systems (1995) Human Factors, 37 (1), Pages 32-64.	209
Endsley, M.R. Measurement of situation awareness in dynamic systems (1995) Human Factors, 37 (1), Pages 65-84.	73
Sarter, N.B., Woods, D.D. How in the world did we ever get into that mode? Mode error and awareness in supervisory control (1995) Human Factors, 37 (1), Pages 5-19.	70
Endsley, M.R., Kiris, E.O. The out-of-the-loop performance problem and level of control in automation (1995) Human Factors, 37 (2), Pages 381-394.	57
Brooks Jr., Frederick P., Ming, Ouh-Young, Batter, James J., Kilpatrick, P.Jerome Project GROPE. Haptic displays for scientific visualization (1990) Computer Graphics (ACM), 24 (4), Pages 177-185.	48
Adams, M.J., Tenney, Y.J., Pew, R.W. Situation awareness and the cognitive management of complex systems (1995) Human Factors, 37 (1), Pages 85-104.	44
Gaba, D.M., Howard, S.K., Small, S.D. Situation awareness in anesthesiology (1995) Human Factors, 37 (1), Pages 20-31.	44
Salas, E., Prince, C., Baker, D.P., Shrestha, L. Situation awareness in team performance: Implications for measurement and training (1995) Human Factors, 37 (1), Pages 123-136.	42

Since then the discussion has somewhat faded. Several papers have appeared on situation awareness theory, but they seldom more than a synthesis of ideas expressed earlier, or an explanation of situation awareness for a different audience, such as the paper by Stanton and colleagues in Safety Science in 2001 (Stanton et al., 2001).

Around the turn of the millennium the first books on situation awareness appeared. The most awaited book was that of Mica Endlsey, published in 2000 (Endsley et al, 2000), in which she outlines her approach to situation awareness. This book is a comprehensive overview of the main approaches to situation awareness, both the theory and application. One of the latest

[1] Scopus is a large abstract and citation database of research literature and quality web sources. It offers: 15,000 titles from 4,000 different publishers; Over 12,850 academic journals including coverage of 535 Open Access journals; 750 conference proceedings; 600 trade publications (www.scopus.com).

books on situation awareness is "*A cognitive approach to situation awareness: theory an application*", edited by Banbury and Tremblay (2004). This book does not strictly follow the Endsley line of thought, although most chapter do quote Endsley's main publications. The book does address several issues that are not clearly worked out in Endsley's approach to situation awareness and therefore is a welcome addition to the existing literature on situation awareness.

What then is situation awareness, and how can it be assessed? Most theories on situation awareness have in common that they regard situation awareness as an active part of knowledge that is combined with current information about the task or environment. This forms a representation of the state of the world that can be used to guide behaviour. The exact form of this representation is under discussion. An important issue that researchers do not agree upon is the question whether situation awareness is a process or the product of this process.

This chapter presents a model of situation awareness that can be used in the VTS domain and places it in a framework of decision making and information processing. The model follows from a critical review of the work of Mica Endsley, incorporating the ideas and experience that has been gained in the past ten years.

The interested reader who wants to know more on situation awareness and methods for measuring it, is referred to some of the landmarks of the situation awareness literature: The 1995 March Issue of the *Human Factors* Journal (37:1), which is completely dedicated to situation awareness, the book of Endsley and Garland (2000) *Situation awareness analysis and measurement*, the book of Banbury and Tremblay (2004) *A cognitive approach to situation awareness: theory an application* or can search the literature referred to in appendix 1.

2.2 A model of situation awareness by Mica Endsley

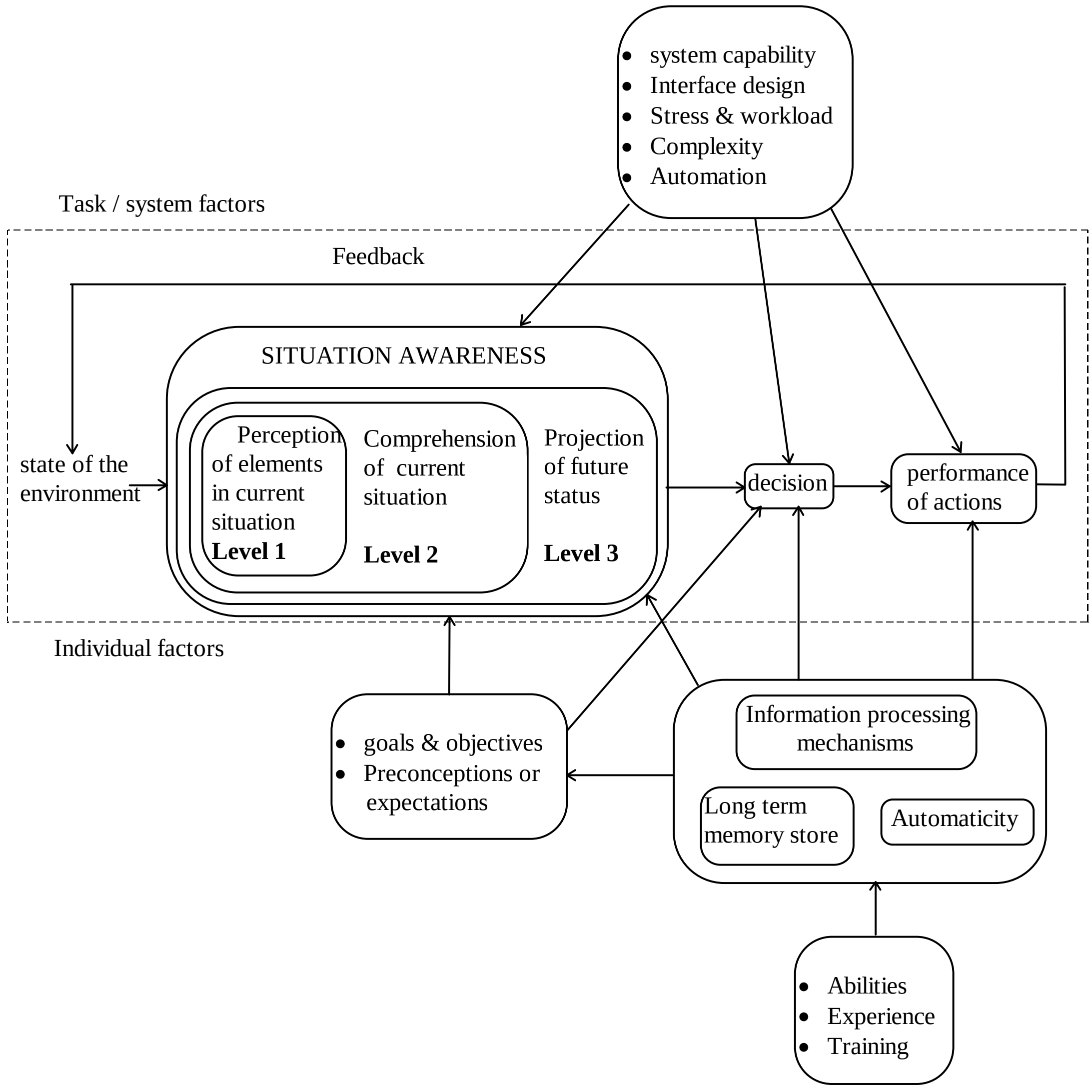
The term situation(al) awareness has been used in the US military aviation since World War I (Press, 1986, as cited in Endsley, 1988). Some of the definitions used by the military are very generic: "*An assessment of the situation based on the best possible information*" (Waddell, 1979, as cited in Jones, 1996). Others are very operational: "*It's simply knowing what's going on so you can figure out what to do!*" (Adam, 1994). A definition that gives a better grip is the one proposed by the United States Air Force's operational community. They defined situation awareness as: "*A pilot's (or aircrew's) continuous perception of self and aircraft in relation to the dynamic environment of flight, threats, and mission, and the ability to forecast, then execute tasks based on that perception.*" (Judge and Bushman. 1992, p. 40)

Situation awareness according to Endsley

Probably the best known framework, and certainly the most quoted one line definition of situation awareness (Bolstad, 1991; Bolstad and Hess, 1996; Carmody, 1993; Charness, 1996; East, 1996; Gaba and Howard, 1995; Hardy and Parasurama, 1997; Kaber, 1996; Vidulich et al. 1995, and many others) has been proposed by Mica Endsley (1988, 1990a, 1990c, 1991, 1995ac; Endsley and Kiris, 1995; Endsley and Robertson, 1996; Jones and Endsley, 1996).

Endsley has developed her framework from research in (military) aviation. The definition of situation awareness was developed with a pilot in mind, but can be easily transferred to other domains. According to Endsley, *"situation awareness can be conceived of as the pilot's internal model of the world around him at any point in time"* (1990c, p. 5). Endsley proposes a model of situation awareness in dynamic decision making as depicted in Figure 2.1.

Figure 2.1 Model of situation awareness in dynamic decision making Endsley 1995c p. 35)



According to this model, a person's perception of the relevant elements in the environment, determined by use of system displays or directly from senses, forms the basis for his or her situation awareness. Selection and performance of actions are separate stages that will proceed directly from situation awareness.

The process is influenced by several factors, both on the individual and on the task/system level.

On the individual level, factors such as abilities, experience and training influence the quality of the information gathering mechanisms. Goals, objectives, and preconceptions

(expectations), on the other hand, provide schemata, that filter the data collection and steer the data interpretation that forms situation awareness.
Situation awareness will also be a function of the system that provides the information. The system design should provide not only the right information, but also this information must be provided in such a way that the operator can use it to maintain or adapt his situation awareness.

To establish a consistent terminology, Endsley (1994) makes a distinction between the process of collecting information to build a model of the situation and the model that results from this data collection. *Situation awareness* refers to the *state of knowledge* at any moment in time. For the process to achieve, acquire or maintain this state of knowledge Endsley proposes the term *situation assessment.* This distinction differs from other efforts to define situation awareness (Dominguez, 1994; Sarter and Woods, 1995), but provides a better model.

Situation awareness forms the critical input to, but is separate from decision making, which is the basis for all subsequent actions. "*Even the best trained and most experienced pilots can make the wrong decisions if they have incomplete or inaccurate situation awareness. Conversely, a pilot may accurately understand what is occurring in the environment, yet not know the correct action to take or be unable to carry out that action*" (Endsley,1990c p. 9).

Situation awareness does not encompass all of a person's knowledge. It refers to only that portion pertaining to the state of a dynamic environment. Similarly, situation awareness is presented as a construct separate from others that may influence it, such as attention, working memory, workload and stress, see Figures 2.1, and 2.2.

Endsley defines situation awareness as:

> *The perception of the elements in the environment within a volume of time and space, the comprehension of their meaning, and the projection of their status in the near future* (Endsley 1990c, p. 12).

According to this definition, this mental picture can be seen to consist of three levels:

Level I SA: Perception of elements in the current situation: the state of the environment, which an operator has to supervise, can be defined as a large collection of different parameters with specific, momentary, values. The completeness of the mental picture of the operator depends in part on the possibility to obtain information on these parameters: personal abilities and supporting equipment determine the subset of obtainable parameters and hence the limits of completeness of the picture.

Level II SA: Comprehension of current situation: numerous state parameters in the environment will be related by causal mechanisms. In any given situation some of these mechanisms are latent and others are active in affecting the way state parameters change over time. Comprehension of the situation can be described in terms of the available repertoire of mental models of these causal mechanisms, the choice of model(s) from this repertoire that the operator is currently applying and the quality (relevancy, accuracy, completeness) of the chosen models with respect to reality.

Level III SA: Projection of future status: apart from an assessment of the current state of the environment, a prediction of how this state will change in the near future is also important for the decisions and actions an operator may take. These predictions are based upon the consequences of external events or actions taken. The quality of these predictions in part determines the quality of the decisions.

Endsley stresses the temporal nature of situation awareness (1995c, p.38). Situation awareness is something that is built up over time and that changes constantly with new information becoming available, taking into account the dynamic nature of the situation.
In many contexts, situation awareness is also very spatial in nature. Often spatial relations also have a temporal dimension. This is the case in for instance ATC, with spatial relations between multiple aircraft that change over time.

Figure 2.2 presents mechanisms affecting and underlying the situation awareness process. In Endsely's terms this is called the *situation assessment*.

Figure 2.2 contains the following elements:

- **Attention** directs whether perceived data are interpreted at all (incorporated into situation awareness) and which data are used in the process of decision making and action guidance.
- A short term sensory store contains all the data that enter the person through sensory perception, that is not yet being processed (perceived)
- Only a part of the **working memory** is defined as being part of the situation awareness process. As stated before, decision making and action guidance are not considered to be part of situation awareness or the situation awareness process.
- In Endsley's model, **schemata**[2] are parts of the long-term memory, used to filter data from the short term sensory store into perception, and to give direction to the interpretation of information. **Scripts**[3] are also part of the long term memory, but they direct more the processes of decision making and action guidance.

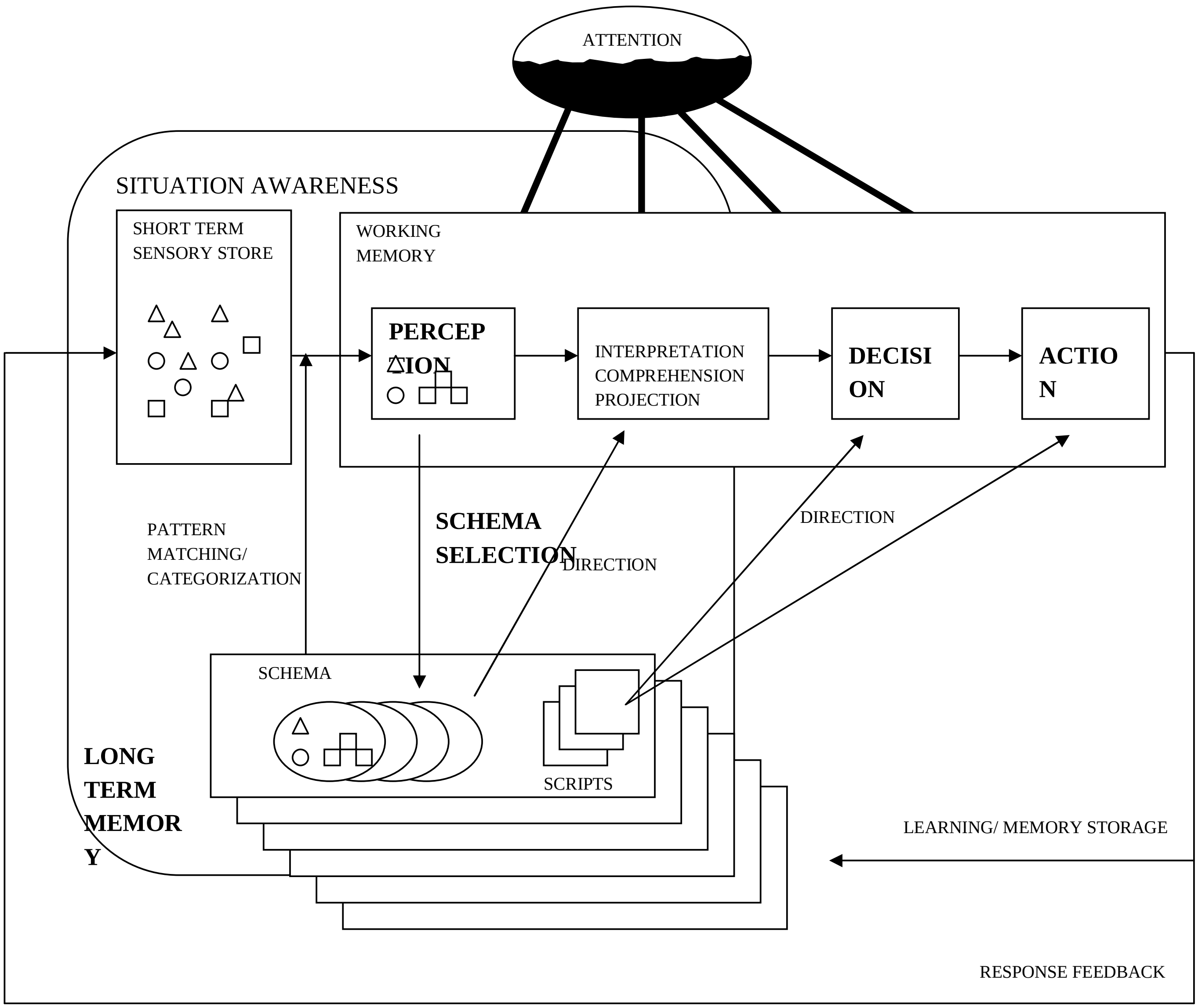
In Figure 2.2 situation awareness can be interpreted as a specific situation model. This model contains more or less fixed elements, such as schemata and scripts and dynamic information in the short-term sensory store and working memory.
Schemata and scripts are the basic elements of the situation model. They are filled with (dynamic) information from the short term sensory store and working memory and in turn provide filters and decision rules to direct the working memory.
If necessary, information from the working memory can lead to a change in the chosen schema or script. If this happens, then situation awareness must be built again: the new schema has to be filled with adequate data.

[2] Schemata are abstract knowledge structures or diagrammatic representations.

[3] Scripts are a memory structure or a form of knowledge representation that organise knowledge about stereotypical situations, such as dining at a restaurant or going to the movies. For further reference see Schank and Abelson (1977).

Attention influences the working memory and learning/memory storage influences the schemata and scripts (on a longer time scale). The action taken in a situation provides a response feedback to the short-term sensory store.

Figure 2.2 Mechanisms of situation awareness (Endsley 1988, 1990c, 1995c)



In summary, Endsley presents a model that describes situation awareness as a state of knowledge of the environment, which uses input both from memory and the environment to understand "*what is going on around you*" (Endsley, 2000, p. 5). Situation awareness is distinct from situation assessment, the process of achieving situation awareness, but the two have a strong interaction.

2.3 Critical review of Endsley's work

Definition of situation and awareness

The term situation awareness consists of two words. A sharp and clear definition of both words seems necessary if we want to establish consensus in what we achieve in using the term situation awareness.

Situation is the first word that needs to be pinned down. Most of Endsley's work is dedicated to the awareness part of the definition, leaving the situation wide open. Her definition of situation awareness as "*The perception of the elements in the environment within a volume of time and space, the comprehension of their meaning, and the projection of their status in the near future*" quoted above leaves far too much room for the inclusion of all kinds of superfluous elements of the situation to become part of the situation awareness model. Endsley has recognised this herself as she states "*Inherent in this definition is a notion of what is important*" (Endsley, 2000, p.5). Since the concept of situation awareness can be applied to the awareness of any (type of) situation, task or activity it seems is necessary to pin down exactly what is meant by it. Therefore I prefer to narrow down the definition of a situation and propose one presented by Pew (1994):

> *A situation is a set of environmental conditions and system states with which the participant is interacting that can be characterized uniquely by a set of information, knowledge and response options.*

Two aspects of the situation are particularly important for situation awareness:

- The *complexity*: The amount of data and interactions present in the situation, and
- The *coherence*. Elements are either independent and need to be treated separately or they are related and can be chunked into larger bits of information. In the latter situation, expertise and training can help.

To better understand the complexity, situations can be regard as "*a nested set of constraints that have the potential to shape performance*" (Flach et al., 2004, p. 44). Rasmussen's abstraction hierarchy (1985), provides a framework for representation of knowledge that can help structure the complexity and coherence. The abstraction hierarchy, generally referred to as AH, is one of the best known representation frameworks that has been proposed for describing complex work environments (Bisantz, A.M. and Vincente, K., 1994), although most papers refer to it, rather than adopting it to solve a particular problem (Bisantz, A.M. and Vincente, K., 1994, p.84).

The second term of the concept situation awareness is *Awareness*. According to the Oxford English Dictionary (2nd ed., 1989):

> *Awareness refers to "The quality or state of being aware; consciousness". Aware is defined as: "(1) Watchful, vigilant, cautious, on one's guard (2) Informed, cognizant, conscious, sensible" (ibid.).*

Awareness is different from knowledge. Laugery and Wogalter (1997, p.1176) compare the difference analogous to a distinction made in cognitive psychology between short-term memory and (sometimes thought of as what is currently in consciousness) and long-term memory (one's permanent knowledge of the world).
Croft et al (2004) devote a chapter to the role of awareness in situation awareness. They state that the focus of Endsley on the explicit conscious knowledge will only provide an incomplete picture of situation awareness, given their failure to take into account the implicit knowledge (2004, p. 82). They advocate an approach that integrates measuring implicit as well as explicit measures of situation awareness.

Product or process

Endsley's model of situation awareness makes a distinction between situation awareness and the assessment of the situation. The two strongly influence each other, but should be considered separately. Not all authors agree with Endsley in this respect. In the literature there is a discussion if situation awareness should only be the *product* or *state*, as Endsley proposes, or that the *process* or *activity* itself should be part of situation awareness. This perspective is taken by Sarter and Woods. They view situation awareness as "*a variety of processing activities*" (1995).

Other authors, such as Adams et al. (1995) argue that although it is possible to make a division of situation awareness in product and process, it is not always useful. The two aspects of situation awareness are interconnected. These authors give examples of aviation accidents to illustrate their point.

Endsley replies that, although there is great benefit in examining the interdependence between the process and the state of knowledge that is a result of this process, it is important to keep the terminology straight (Endsley, 1995c, p. 36).

Situation awareness and Information processing

Endsley places her model of situation awareness in a context of information processing, referring to Wickens (1992) theory of human information processing (Endsley, 1988, 1990c, 1995c, 2000, p12). Her figure on mechanisms of situation awareness (Figure 2.2, this chapter) is an adaptation of Wickens model presented in chapter 1. This figure seems to me unclear and imprecise. It doesn't clarify where situation awareness is to be located; it seems to be part of memory, but Endsley also includes perception, interpretation, decision making, and action guidance in memory. In her last attempt to clarify this subject, Endsley (2000, p. 12-18) introduces new figures that are not much clearer. It seems that Endsley has problems locating situation awareness as a functional block in models. Thus it seems that Endsley too has problems separating the product from the process.

The Wickens (2000) model presented in Figure 2.3 is much clearer. It presents situation awareness as part of long-term and working memory. Wickens stresses (2000, p. 261) that situation awareness is not the same as memory (the structure), it is what is maintained in it (the information contained). In his figure Wickens (2000, p. 295) includes part of the perception block into the situation awareness block. This seems to indicate that he wants to include part of the process into the situation awareness concept. The section above argues, why I don't agree with this. Therefore I have adapted Wickens figure and separated situation awareness and perception. This leaves situation awareness as part of memory.

Levels of situation awareness and decision making

Endsley regards situation awareness as a necessary step in the decision making process. Others, including Wickens, can imagine decision making without proper situation awareness. An everyday example of this provided by Wickens is the experience of driving a car absent-mindedly: "C*onsider, for example, how well we can drive on an uncrowded highway even as our mind drifts away from awareness of the road conditions. Our driving responses are good, but our situation awareness is low.*" (2000, p. 261).

This example by Wickens illustrates the difference between situation awareness and consciousness: Situation awareness may be enough to perform the task, even though the driver is not consciously aware of that.

Although Endsley's model of situation awareness covers the relationship between the levels of situation awareness and decision making, I do not think the model is very clear in that respect. Pritchett and Hansman (2000) present a model that clarifies this relationship better. Their model is depicted in Figure 2.4.

Figure 2.3 Key processes and components involved in an information processing model of decision making. Adapted from Wickens, 2000, p. 295)

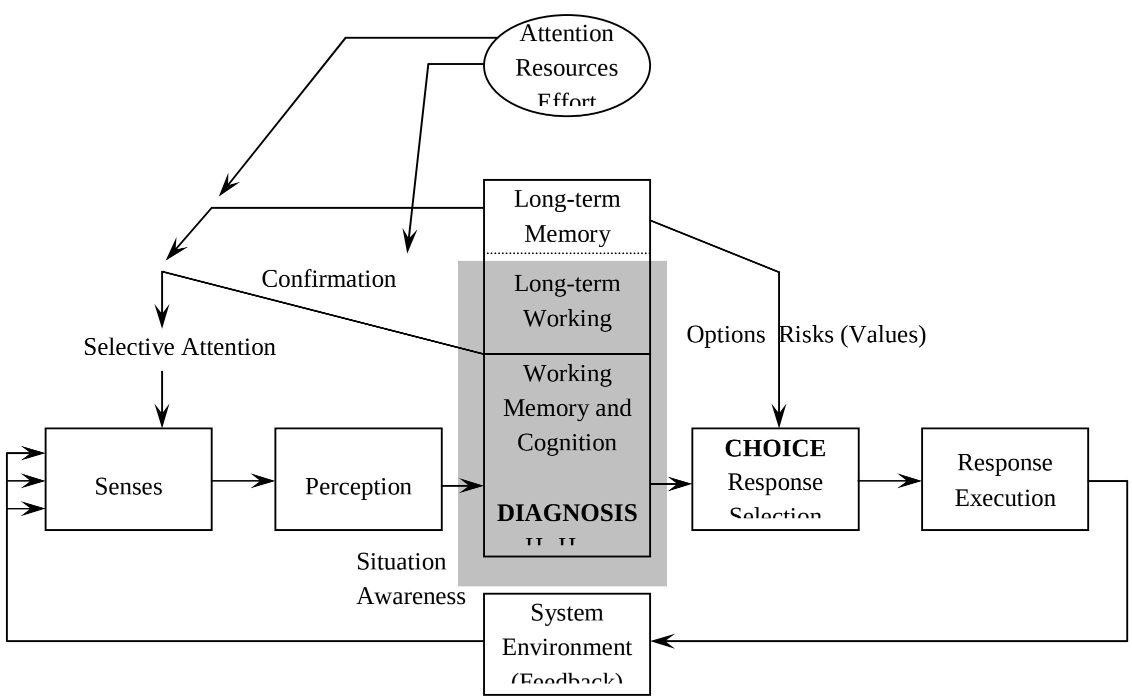
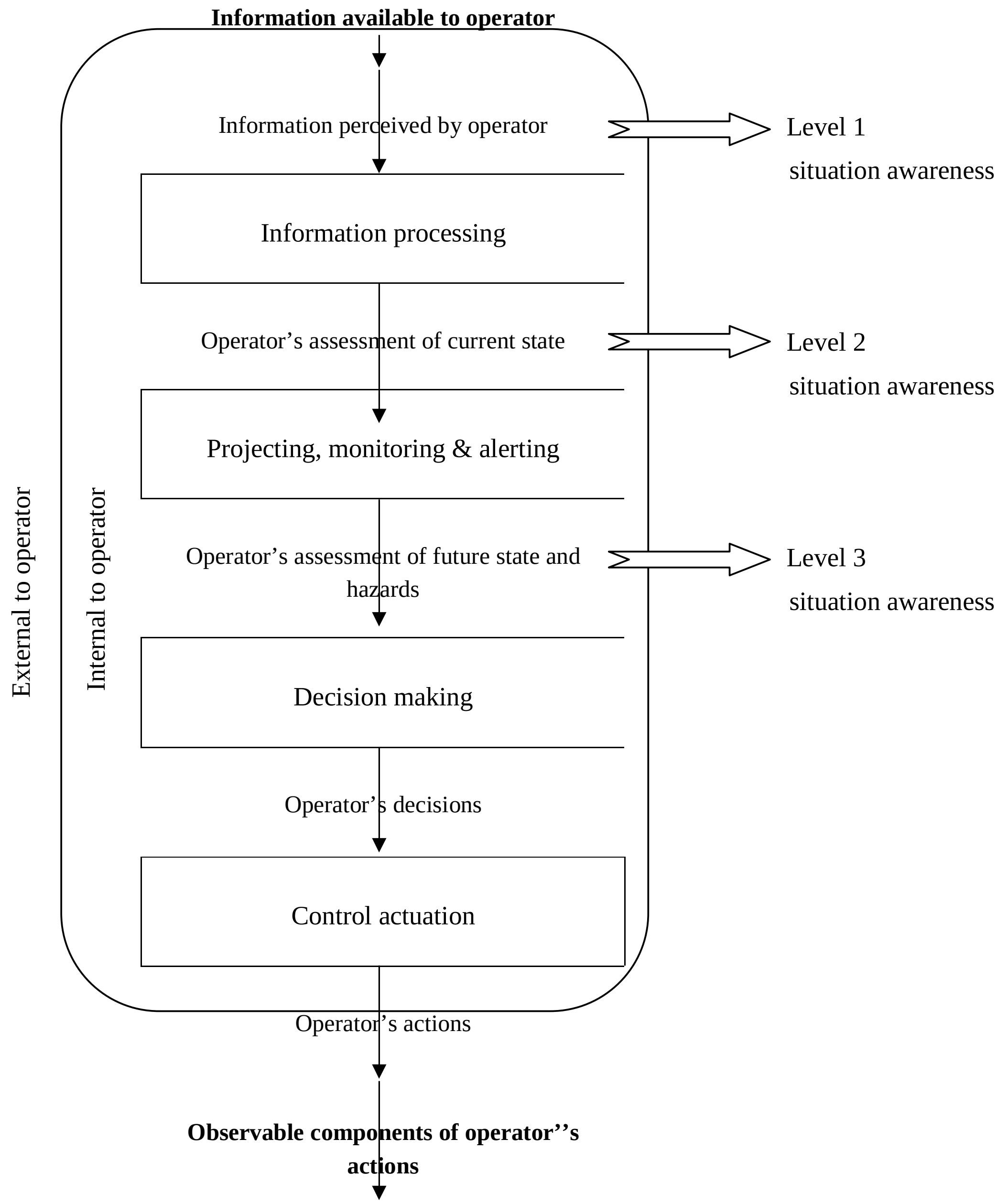


Figure 2.4 Levels of situation awareness and the decision process (adapted from Pritchett and Hansman, 2000, pp. 191, 193)



This model combines the steps from the information processing model with the levels of situation awareness presented by Endsley. Level I, perception of elements correspond to the perception of information; Level II reflects the operator's understanding of the situation and Level III refers to the understanding of the need for action.

In terms of the decision making model of Pritchett and Hansman it can be argued that the example of the car driving presented above describes a situation where situation awareness on the second and third level is low, while situation awareness on the first level is present and is actually guiding behaviour.

In conclusion

Surveying the literature on situation awareness, it can be concluded that there is no complete consensus on what situation awareness is. Most researchers follow the ideas presented by Mica Endsley in the late 1980's, but several issues are still under discussion. The main controversy seems to focus around the question if situation awareness has to be considered a state of knowledge and the product of a process (sometimes called situation assessment) or if the process itself should be part of the concept situation awareness.
Different authors take a different perspective on this issue. However, the discussion on the issue has died down. Most recent literature on situation awareness has stopped discussing the situation awareness concept and its theory. Now most research is trying to develop (experimental) experience with the concept and is leaving the theoretical discussion for what it is.

For the work described in this thesis the whole discussion seems to be of little consequence. I think that there is no theoretical valid argument for making the process part of the situation awareness concept. This is merely a matter of choice. If Endsley's model provides a useful framework, than, in my opinion, there is no need to include the process in the definition.

Situation awareness is a psychological construct, not something that can be localised in the human mind. As such the definition of situation awareness is somewhat arbitrary. A good definition seems to be one that satisfies two objectives:

1. It is in agreement with other currently accepted theories and models, or at least not in disagreement with them;
2. It is useful in describing and explaining phenomena that are being observed; it increases the understanding of the world around us.

The framework presented by Endsley seems to fulfil the first objective. The remaining part of this thesis will address the second topic, starting with a description of methods for assessing situation awareness.

2.4 Situation awareness and Vessel Traffic Services

The previous section of this chapter has shown that there are several definitions of situation awareness. The question remains what the meaning of this is in the context of VTS and the performance of VTS operators. Is situation awareness a good concept to use in this domain?

VTS operator knowledge, skills and situation awareness

The importance of situation awareness for the work of the VTS operator has become well recognised by maritime world in the past decade. At the start of the project the second edition of the IALA VTS manual (1998) was used. This manual does not contain any references to situation awareness. In 2002 the third edition of the IALA VTS manual was published. This edition of the Manual states that one of the considerations to determine a period of duty for a VTS operator/supervisor should be “the ability to develop and maintain situational awareness” (p.67). So not only has the concept been adopted, there also is understanding that it takes time to build situation awareness.

The IALA Recommendation on Standards for training and Certification of VTS Personnel V-103, published in 1998, presents an extensive list of the knowledge and skills a VTS operator needs to have. V-103 also includes methods for demonstrating this competence and criteria for evaluation the competence. (IALA V-103, p.24-31). The document states that tests need to be designed to determine the ability of candidates for VTS to demonstrate spatial and situational awareness [REF IALA V-103, p.15].

Situation awareness is also referred to in the IALA “Guidelines on AIS as a VTS tool” (2001). In these guidelines AIS is proposed to be an important tools to enhance situation awareness [REF IALA-AIS, p.3] .

In earlier research projects on VTS no references are made to the concept situation awareness. The term situation(al) awareness is for example not mentioned in the COST-301 reports (REF) or in the main report of TAIE (REF). Even though the concept *situation awareness* was not widely known when the COST-301 project was finished in 1987, the underlying ideas are present in the COST-301 reports.
The general VTS model presented in Figure 2.5 can be interpreted as a task model of a VTS operator. Situation awareness is then a part of the internal functions of the VTS operator, a mental model that is necessary to carry out the external functions.

The nature of the VTS task is similar to that of Air Traffic Control and pilots with regard to its nature: it is a supervisory control task. In tasks of that nature situation awareness of the process that is being controlled is relevant and thus situation awareness is relevant. The VTS task differs from the other tasks mentioned in the dynamics of the maritime traffic process. These dynamics place special constraints or demands on situation awareness measuring tools.

The VTS model presents three sources of information input:

- Shore-to-shore data exchange/communication
- VTS sensors, and
- Ship-shore communication.

Figure 2.5 General model for Vessel Traffic Services (COST_301, fig 4.2 p.75)

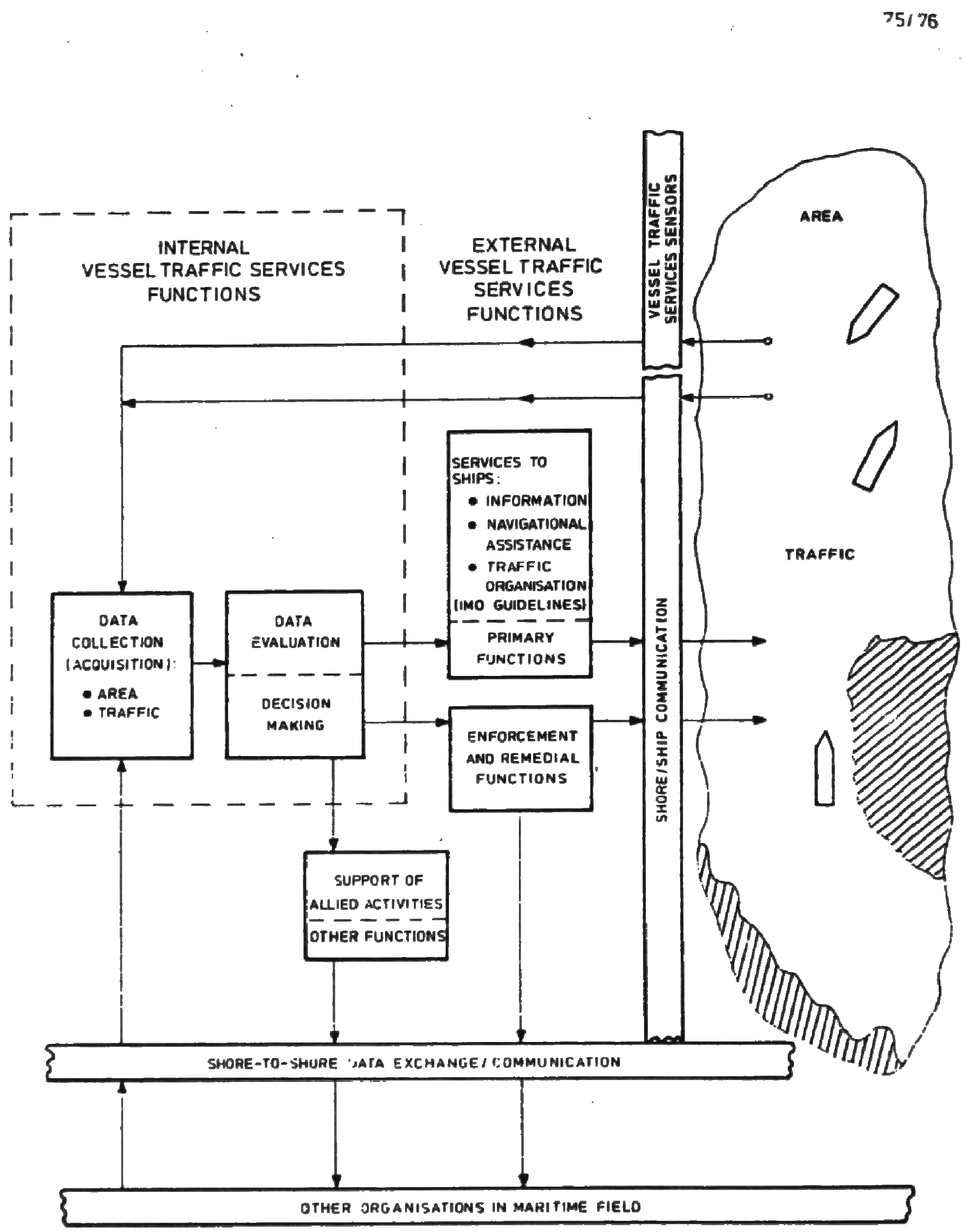


Fig. 4.1 GENERAL MODEL FOR VESSEL TRAFFIC SERVICES

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These three information sources present the dynamic situation information. They provide the information on all aspects mentioned earlier. The knowledge and skills of the operator provide the scripts, schemata that, together with this dynamic information make up the situation awareness. Together they form *Level I situation awareness: perception of elements in the current situation*. This refers to the extent to which the VTS operator is aware of all the information presented to him.

Endsley stresses the *temporal nature* of situation awareness (page 4 of this chapter). Situation awareness is something that is built up over time and changes with new information becoming available, taking into account the dynamic nature of the situation. It is important to notice that the dynamic changes in the situation (and therefore in situation awareness) develop in a different time frame for different aspects. A method for assessing situation awareness must take this into account.

Another element mentioned in Endsley's model that is relevant for VTS is the *spatial nature* of situation awareness. The spatial relations between ships and between ships and shore change over time. This is another aspect that a method for assessing VTS operator situation awareness should consider.

At *Level II situation awareness: Comprehension of current situation* the understanding that the VTS operator has of the traffic situation is defined. Understanding the situation in relation to safety means that the operator knows which ships may have a conflict, either with other ships (risk of collision) or with the infrastructure (risk of stranding). These conflicts may be in the current situation but more likely are further ahead in time (which makes them part of Level III situation awareness). Relevant to this understanding of the situation are not only position and movements of ships, but also other information, such as weather conditions, for instance fog and tidal conditions.

The understanding of the situation of a VTS operator goes beyond the simple extrapolation of current course and speed of ships. This information provides merely a very rough measure of what is going to happen in the next few minutes. More important to the understanding of the situation are the tracks that ships are sailing and deviations from planned tracks. Even more important than the ship information the operator achieves from the VTS displays is the information he gathers through communication with the ships. Ships involved in a potential conflict communicate with each other and the VTS operator about how they plan to solve a situation. If such an agreement is made between the ships, and the ships keep to that agreement, the conflict ceases to exist for the VTS operator.

Track information and understanding of the communication that has taken place, either between ships or between VTS operator and ships, are very important elements in the understanding of the situation the VTS operator has.

Level III situation awareness: Projection of future status builds on the understanding of the situation which has been described in Level II situation awareness. *Projection of future status* contains the prediction of future position of ships, but is not limited to that. To be able to fulfil the external functions of the VTS it is necessary that a VTS knows how a situation will develop. Only then can an operator decide if action needs to be taken. Level III situation awareness involves planning for all situations that have the potential of developing into a conflict, taking into account the circumstances.

Conflicts arise when it is not clear to all ships involved (and to the VTS operator) how a particular situation is going to be solved. As long as such uncertainty exists, the situation is to be regarded as a (potential) conflict. Reduction of traffic uncertainty was mentioned as one of the external functions of a VTS. As long as there has been no or insufficient communication with all parties involved, the situation deserves extra attention. This is the core of the operational work of a VTS operator: predicting where conflicts may develop, and resolving such situations.

2.5 Measurement of situation awareness

As section 2.1 has shown, there are different ways to look at the construct situation awareness. It will be no surprise that there are as many methods for assessing situation awareness, as there are different theoretical points of view. Several authors have provided classifications, along different dimensions. This section will provide an overview of the discussion and methods resulting from it.

As with the definition of situation awareness, researchers from aviation have dominated the discussion on methods and often the methods developed are applicable only there. However, several methods have been designed and applied in other domains, including ATC, car driving, anaesthesiology, but there are none devised specifically for the vessel traffic system.

Many authors have presented a classification of situation awareness methods (Vidulich, 1991; Sarter and Woods, 1994; Dennehy, 1996; Pew, 1996; Endsley, 1995b). In my opinion all of these have one shortcoming in common: they mix up measures and assessment techniques. Pew (1996) for instance categorises the five following measurement categories:

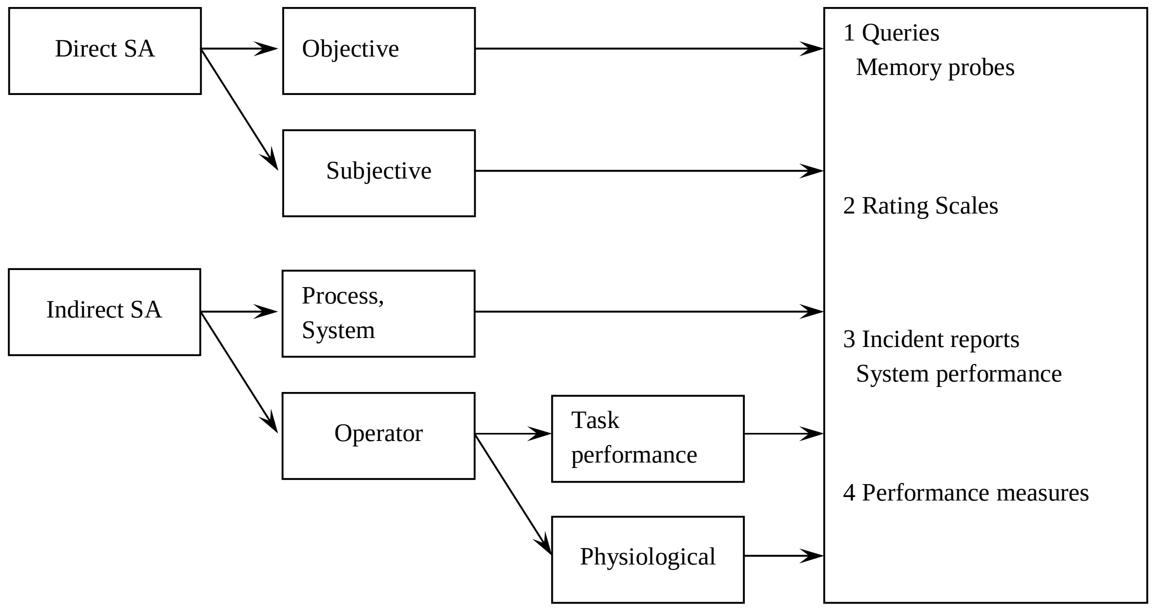
- Direct System performance measures
- Direct experimental measures
- Verbal protocol
- Subjective measures
- Model-referenced performance measurement

The verbal protocol does not fit in this list; it is an assessment method, while the other categories refer to measures. Other categorizations have similar problems. Therefore this chapter presents another classification.

Types of situation awareness measures

Methods differ in the measure of situation awareness they assess. Figure 2.6 gives a schematic diagram of the issues involved.

Figure 2.6 Schematic overview of classification issues in situation awareness measures.



To a researcher who is interested in assessing situation awareness, it seems obvious that methods that use a direct assessment of situation awareness are in principle to be preferred over methods that have to deduce situation awareness from the assessment of something else. Two types of direct situation awareness assessment methods are generally distinguished:

- *Factual queries* are applied to extract information from the subjects about the content of their mental picture of the situation. This type of method is by many considered the most direct and *objective* form of assessing situation awareness. It is usually applied in experimental situations and simulators. The queries can be applied as a separate (secondary) task or can be used in an experimental setting;
- *Rating scales* are applied in several methods as a *subjective* form of assessing situation awareness. They ask subjects to rate their personal assessment of the quality of their situation awareness or of important dimensions of it. As such, rating scales are a self evaluation of the construct situation awareness. Rating scales can also be applied as an *objective* measurement, when observers rate the situation awareness of operators.

In many situations a direct measurement of situation awareness is difficult or even impossible and more indirect measures are used:

- In accident- and incident investigation one has to use *incident reports* to infer the contribution of (the lack of) situation awareness to a particular incident.
- Some situations do not lend themselves very well to additional tasks for direct assessment techniques of situation awareness. This is the case in many real-life situations, where direct situation awareness measurement is too intrusive. *Task performance* is then used as an (indirect) measure of situation awareness.
- Some researchers are interested in the physiological phenomena underlying situation awareness. They use *physiological parameters* that (they think) underlie situation awareness. Most situation awareness researchers are more interested in the mental models

of the situation that their subjects have. Therefore this category of assessment methods is not very popular among researchers of situation awareness.

2.6 Review of assessment techniques

The strengths and weaknesses of the measures presented in the previous section can be assessed in a number of ways.

2.6.1 Factual queries and memory probes

Detailed information on different aspects of situation awareness can be obtained by the use of queries. Probing techniques are especially designed to measure situation awareness in an objective way. The central idea of these techniques is that a subject's memory is unexpectedly probed for certain details of a situation. Usually the methods are applied *on-line*, although *post-hoc* probing is possible.
There are basically two major types of probing techniques (see Figure 2.7):

INSERT FIGURE 2.7 ABOUT HERE

2.6.1.1 On-line probing techniques

On-line probing techniques ask for information relevant to the (situation awareness of) the situation during the simulation run. The probing question is presented as if a colleague or someone else from within the task environment asked it.

STRONG POINTS:

- If the research focuses on a small part of the situation, questions can be asked pertaining to that detail, which enables the researchers to follow that particular aspect over time.
- If the query can be presented in such a way that answering the question is part of normal operation, then this method is an unobtrusive experiment.
- The method can also be applied in real-life situations, providing that the probing does not disturb the main task of the pilot/operator.

WEAK POINTS:

- Only a limited number of questions can be asked at a time, making it difficult to establish a good representation of the subject's total situation awareness.
- This method runs the risk that the question is recognised for what it in fact is: THE thing that the experiment is all about. If this happens, the question becomes very intrusive and can completely destroy the experiment.

2.6.1.2 Freeze technique

The second type of probing uses a *freeze* technique within the scenario. At specified times during these scenarios the system displays are blanked and the simulation is stopped. The operators (e.g.) are requested to answer a number of questions about their perception of the situation at that time, related to their situation awareness. After completion of the query, the simulation continues. The best known technique of this type SAGAT, the Situation Awareness Global Assessment Technique, has been developed in aviation research by Endsley (1990abc; 1991; 1995bc).

SAGAT is a global tool for measurement of situation awareness in military aviation. In SAGAT, pilots run a range of simulator flight scenarios. The questions asked when the screens are blanked pertain to all three levels of situation awareness, Level I (perception of elements); Level II (comprehension of current situation) and Level III (projection of future status). This includes a consideration of the system status as well as relevant aspects of the external environment. The accuracy of the responses is then compared with logged situation data. Thereby a measurement of situation awareness on all three levels is derived.

Endsley's method has been widely used and adapted, both in the aviation domain (Bolstad, 1991; Carmody, 1993), the air combat domain (Chubb, 1996; Endsley, 1996) and in other domains, such as anaesthesiology (Small, 1996); process control (Hogg et al. 1995); team situation awareness for aviation crews (Prince et al. 1996) aviation maintenance (Endsley and Robertson, 1996); chess (Durso et al. 1996) and a laboratory experiment using an experimental task of perceiving moving blocks on a display (Kaber, 1996).

The methods that are adaptations of SAGAT usually consist of the use of the freezing technique in a laboratory experimental setting or simulation. SAGAT-like queries have to be developed in a domain-specific or even task-specific way. Several of the authors have tried to incorporate questions pertaining to Endsley's three levels of SA (perception, comprehension and prediction).

STRONG POINT:

- During the break a number of questions can be asked about the situation. Depending on the type of task, breaks up to five minutes have been applied without causing problems for pilots in getting "back into the scenario". This time is usually considered enough to extract all relevant information.
- This (type of) method has been widely accepted as the standard methodology for the assessment of situation awareness. There is considerable experience with this method and it has been successfully applied in many domains.

WEAK POINT:

- The method can only be used in (simulator) experiments or training sessions that can be stopped. If stopping the simulation is impossible or too disruptive, the method cannot be applied.

2.6.1.3 Post-hoc probing techniques

A post hoc probing method combines some advantages of both methods: Although it is not unobtrusive, debriefing is quite naturalistic and an unlimited amount of questions can be asked. Nevertheless this method is not used much for the following reasons:

WEAK POINTS:

- Post hoc probes assess the memories of the trial run, not the situation awareness.
- They are subject to reinterpretation of the situation, depending on the outcome of a scenario.

2.6.2 Rating scales

Methods using subjective measures of situation awareness can be divided into two very distinct groups:

- Methods that apply the most basic situation awareness scale call on an intuitive understanding of situation awareness. These methods are often used in a preliminary phase of a project.
- The other type of method using subjective measures, is exactly the opposite. These methods apply a very detailed multi-dimensional concept of situation awareness. Scores on the different scales are combined into a situation awareness score. This type of method seems most suitable for researchers whose main interest is a better understanding of situation awareness and the underlying principles and mechanisms.

Both types of methods can be used with self-rating scales and with observer ratings. The simple one-dimensional scale can be applied both on-line and post-hoc. The multi-dimensional rating scales are applied post-hoc only. Figure 2.8 gives a schematic overview of rating scales.

INSERT FIGURE 2.8 ABOUT HERE

2.6.2.1 Holistic, on-line, self-rating scales

This is the simplest technique in which operators are asked to rate their own situation awareness. Such a method of assessing subjective situation awareness is proposed by McGuinness (1995). In his Simple Rating Scale SRC, pilots are asked mid-run to rate their understanding of the situation on a 10-point Likert-scale, thus addressing the pilot's own intuitive understanding of situation awareness.
Another example this type of method is SA-SWORD, a method developed by Vidulich (Vidulich and Hughes, 1991) based on his Subjective WORkload Dominance technique (SWORD). SA-SWORD subjects rate their own situation awareness in different experimental conditions as a one-dimensional concept.

STRONG POINT:

- The method is very simple and can provide basic understanding of a task.

WEAK POINT:

- People are not aware of the things they are not aware of. "Therefore asking people to rate their level of awareness on a scale from 1 to 10 will not provide a terribly valid measure"" (Wickens, 2000, p. 261).

2.6.2.2.1 Multi-dimensional, post-hoc, self-rating scales

Other subjective rating scales have been developed starting with a definition of situation awareness as a multi-dimensional concept. A well-known example of this approach are Selcon and Taylor's Situation Awareness Rating Technique SART (Selcon et al. 1991; Taylor, 1990, 1996; Taylor and Selcon, 1990, 1991; Taylor et al. 1995). SART has been designed as an evaluation tool for aircrew system design (Selcon and Taylor, 1990). The method is based upon a multi-dimensional description of situation awareness of Taylor (1990). It uses the ten dimensions of situation awareness described in Figure 2.9.

Figure 2.9. 10-Dimensional SART Scale (Selcon and Taylor, 1990, p.5-2)

		LOW						HIGH
		1	2	3	4	5	6	7
DEMAND	Instability of situation							
	Variability of situation							
	Complexity of situation							
SUPPLY	Arousal							
	Spare mental capacity							
	Concentration							
	Devision of attention							
UNDERS.	Information quantitiy							
	Information qualitiy							
	Familiarity							

SART applies a seven-point Likert scale for each of ten dimensions. Scores on these ten constructs are grouped together to attain a score on a 3-dimensional scale of situation awareness. These dimensions are:

1. *demand on attentional resources,*
2. *supply of attentional resources*, and
3. *understanding of the situation*.

A rating of SART is carried out post-hoc in experiments. Subjects rate their own situation awareness, after completion of a specific task.

STRONG POINT:

- The method provides a comprehensive set of dimensions to rate situation awareness, covering many relevant aspects of situation awareness.

WEAK POINT:

- It is not clear if the dimensions are empirically based.
- One disadvantage of this is that post-hoc scoring of situation awareness is related to the outcome of the experiment. Subjects tend to rate their situation awareness higher if they are successful in accomplishing their task.
- Another, more fundamental problem of this type of method is that it builds up situation awareness from underlying mechanisms, such as demand on attentional resources. Mental workload also draws on these resources. This makes it difficult to differentiate between the two.

2.6.2.2.2 Multi-dimensional, post-hoc, observer-rating scales

Observer rating is a method, which requires an independent, knowledgeable observer to rate the quality of a subject's situation awareness. A method that applies this type of scoring is the Cranfield-Situation awareness scale, developed by Dennehy (1996, 1997). The Cranfield scale was developed to monitor pilots' progress in developing skills necessary for situation awareness. It is based upon "*pilot actions and knowledge that the aviation community considered important in maintaining situation awareness*" (Dennehy, 1997, p. 1). Overall situation awareness scores are based on the addition of ratings on five subscales:

1. Pilot knowledge
2. Understanding and anticipation of future events
3. Management of stress, effort and commitment
4. Ability to attend, perceive, assimilate and assess information
5. Overall awareness

The Cranfield scale applies a 9-point Likert scale, ranging from unacceptable to excellent. The five dimensions are measured through scores on 22 descriptions. Several of these descriptions are specific for the aviation domain, especially the knowledge questions (e.g. Q.1-3: know the aircraft's systems, such as fuel and hydraulics?). Other questions can more readily be transferred to other domains (Q.2-4: accurately interpret incoming information?).
The method can be applied as an *observer-rating* scale or as a *self-rating* scale.

STRONG POINT:

- The Cranfield scale is a comprehensive method for the aviation domain.

WEAK POINT:

- An observer may have more information on the situation, but he also has less information of what is going on inside the subject performing the task. His observations are based on observable behaviour and are therefore comparable to other performance measurement techniques, and not really a direct situation awareness assessment.

2.6.3 Incident reports

Post hoc assessment of incidents and accidents can be a useful way to determine the importance of situation awareness in accident causation. A wide range of techniques are applied in this type of research, such as statistical analysis of experimental data and databases, video analysis, and in-depth investigation of specific accidents (Strauch, 1996; Klein ,1996).
The fundamental problem with this type of research lies in the first step of the process. Accident data collection of physical objects is certainly possible. But trying to understand the situation awareness of people involved in an accident is almost impossible. In the words of Rodgers *cum suis*: "Occupations requiring interaction with complex, dynamic systems make the post hoc assessment of situation awareness problematic due to the lack of available information that directly relates to the cognitive processes of relevant personnel." (Rodgers et al. 2000, p.73) Still, in depth investigation of accidents can reveal all sorts of underlying causes of accidents. It is possible that this type of research provides a better understanding of situation awareness and situation awareness related issues in accidents.

STRONG POINTS:

- Accident analysis can provide insight into the mechanisms of situation awareness *if* situation awareness is taken into account from the first data collection on.

- To be useful, they have to incorporate other techniques mentioned in this chapter, such as simulation, experiments, etc.

WEAK POINTS:
- If situation awareness has to be reconstructed from statistical analysis based on data where there was no attention to situation awareness during data collection, not much can be expected from it.
- Post hoc analysis of situation awareness suffers from memory reconstruction.

2.6.3 Performance measures

A widely used group of methods for the assessment of situation awareness takes performance as a measure of situation awareness. Many authors use performance measures in some way to measure situation awareness. Since situation awareness research is applied in many different fields of application, very many different performance measures are possible.
Performance measures can be classified in six types (see Figure 2.10).

Figure 2.10 Classification of performance measures.

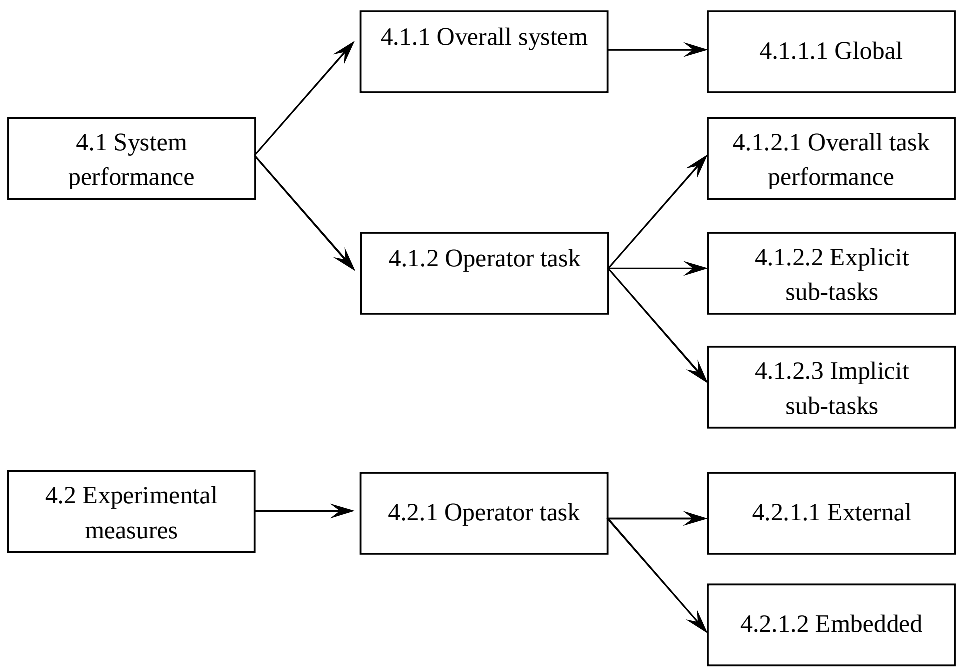


Figure 2.10 Classification of queries

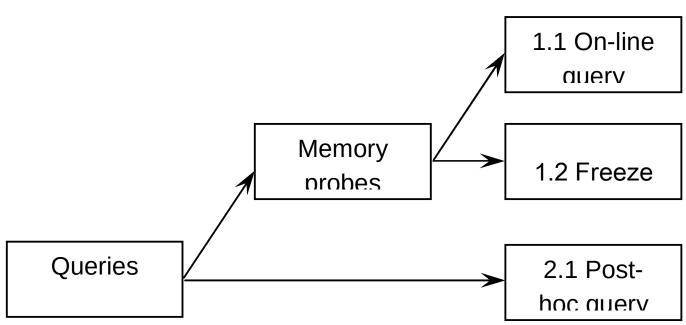
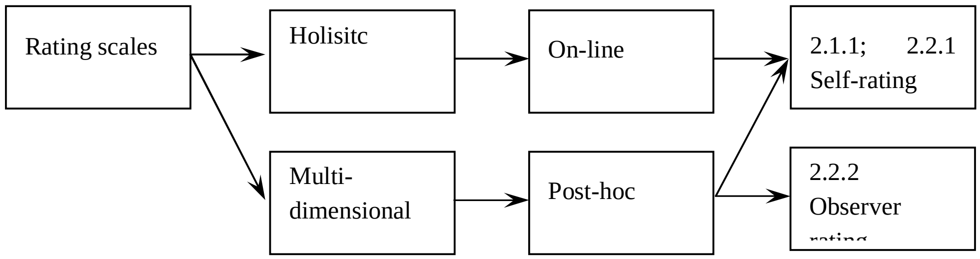


Figure 2.10 Classification of rating scales



Pew (1996) makes a useful basic distinction between methods that use *direct system performance measures* (4.1) and *direct experimental measures* (4.2). The first method uses performance of the total system or performance of the operator on (part of) his normal task as a measure of situation awareness.

2.6.4.1 System performance

In general, direct system performance measures are objective and can be obtained non-intrusively. In general naturalistic test designs provide a good opportunity for assessing “normal” behaviour. However, as a measure of situation awareness they are indirect. Direct overall global system (4.1.1) or overall operator task performance measures (4.1.2) are appropriate only in situations where there is general agreement that the performance in question is driven by situation awareness. This also applies to assessment of performance on specific tasks, implicit and explicit and hence to all subcategories of this type of measure in Figure 2.10.

STRONG POINT:

- System performance can be measured non-intrusively.

WEAK POINT:

- System performance has to be interpreted; it is not a measure of situation awareness.

2.6.4.2 Direct experimental measures

In the second type of performance measures, *direct experimental measures*, the researcher has changed something in the task environment (added a task). Performance on this additional task is taken as a measure of situation awareness. This extra task can be external, for instance an action to be taken by the operator which is not part of normal routine, or embedded in the task (looking up data in a database).

2.6.4.2.1 Direct experimental measures: External tasks (4.2.1)

Adding an extra task, performance on which reflects situation awareness, can be a good method for assessing situation awareness in situations where the relation between the overall task performance and situation awareness is not directly clear. Pritchett et al. (1996) for instance advocate the use of performance measures to assess situation awareness. Their approach is to present subjects with tasks in which the presence of situation awareness leads to certain actions, whereas the lack of situation awareness leads to other actions. An example of such an external task may be answering to a co-pilot who is requesting information or filling in an on-line data display. The disadvantage of this method is that it can distract the operator from his original task, or make him aware that he is in a test situation. Therefore careful design of this task is necessary for minimising intrusiveness of the added task.

2.6.4.2.2 Direct experimental measures: Embedded tasks (4.2.2)

Several authors object to the freezing technique presented earlier in this chapter. Sarter and Woods (1991) for instance find the freeze technique too intrusive, and prefer embedded tasks. One author using embedded task measures, as proposed by Sarter and Woods, is Jones (1996). Jones investigates the effect of specific cue types on situation awareness, such as obtaining information from a display just prior to events where the pilot can be expected to pay attention to them. She states: “A major disadvantage associated with this method is that it can not adequately assess the multidimensional concept of situation awareness. This limitation was not an issue since the aim of this study was to measure the effect of specific cues on situation awareness related to that cue only” (p. 44).

STRONG POINT:

- Performance methods assess final performance of systems and operator’s actions. In many research situations, it is performance that actually counts, and situation awareness is a concept that is brought in to explain or predict certain behaviour. It may very well be that if adequate performance measures are available, the concept of situation awareness is completely unnecessary.

WEAK POINT:

- The strong point is at the same time the weak point of performance methods: they do not provide a direct measurement of operator’s situation awareness. However if these performance measures are used, they can be very useful as supporting measures, helping the experimenter to understand the task and the operator’s situation awareness better.

2.6.3 Physiological measures

Physiological measures provide an assessment of the relationship between operator performance and correlated changes in operator physiology. Research in the field of mental workload measurement has shown that cognitive activity is associated with changes in various physiological systems. Well-known measures in this field include eye blink, heart rate, and respiration. All of these measures are indirect measures of workload; they measure physiological changes and these changes are used to make inferences about workload.

Several authors refer to the physiological aspect of situation awareness. The same measures that are used in the field of workload are used in the field of situation awareness, showing the overlap between the two concepts (Wilson, p. 142). Some authors even simply use workload measures to assess situation awareness, under the assumption that situation awareness varies inversely with workload (Metalis, 1993, p. 116). There is no evidence that this assumption is true, and also from a theoretical perspective there is no clear one-to-one relation between the two concepts (Endsley, 1995c). In a recent study Vidulich (2000) has demonstrated the independence of the two showing how improvement of interface design increases situation awareness, without generally reducing mental workload. Therefore, a physiological measurement of situation awareness cannot be that simple. Van Westrenen in his experimental research in understanding maritime pilots using physiological measures, for instance, rejects situation awareness (1999) because of the unclear link between situation awareness and workload.

Byrne (1996) argues that since maintaining situation awareness is an active process, psychophysiological measures may be useful. Especially EEG and HRV are proposed as useful measures in determining whether an operator is engaged in cognitive activity. Event related potentials (ERP) are used to determine whether an operator receives critical cues from the environment. The P300 amplitude is widely used as a measure of expectancy. However, as a measure of situation awareness as defined in this thesis, it fails, since it does not reflect information content but only the process of retrieving information. Therefore it only refers to part of situation awareness.

Stern et al. (1996) use several physiological measures to assess operator predictions about the future (Level III situation awareness according to Endsley's definition). Specifically they apply assessment of heart rate and several oculometric variables, including the occurrence of saccadic eye movements, eye blinks and changes in the pupil diameter. The authors state that "expectancy leads to a decrease in heart rate, inhibition of blinking, and if one cannot inhibit a blink at a point in time close to an imperative event the blink is of shorter duration than normal" (p. 158).

STRONG POINT:

- The foremost advantage of physiological measures mentioned is the fact that they can be measured without interference with the primary task.

WEAK POINTS:

- Physiological measures applied to assess situation awareness have not been developed especially to measure some aspect of situation awareness; existing methods have been used and their applicability in the situation awareness domain has been investigated. All in all, it seems to me that the authors mentioned have chosen physiological measurements of situation awareness because they are familiar with these measures. The link of physiological parameters with situation awareness is still weak and sometimes even farfetched.
- Physiological measures say nothing about information content. When they refer to the process of achieving or maintaining situation awareness (what we have called situation assessment), they at best assess processes that support (achieving) situation awareness.
- Physiological measures therefore do not provide direct insight into situation awareness, and the best way to use them seems to be as a supporting measure, in combination with other measures of situation awareness.

2.6.4 Conclusion

In this section the following issues have come up which determine whether a particular type of method is applicable in a specific context:

1. *Direct versus indirect situation awareness*. In general direct assessment of situation awareness is preferred over indirect assessment of situation awareness;
2. *Amount of (relevant) information* that can be obtained at one time. In general it is considered preferable to obtain more, or more detailed, information at one time;

3. *Simple* methods are preferred over *complex* methods. However, simple data collection often goes hand in hand with collecting only a small amount of information. I think that the latter is of more importance than the former;
4. Methods that measure situation awareness *on-line* are preferred over methods that only *provide post hoc* information on situation awareness, due to the problems with memory reconstruction of situation awareness. In general, on-line methods are more obtrusive than post-hoc methods;
5. *Unobtrusive* methods are preferred over *obtrusive* methods, since the latter may change operator behaviour. If an obtrusive method is chosen, attention will have to be paid to the extent to which the method disturbs the work of the operator;
6. Some methods can be applied in *real life* only, some in *experimental setting* only and some can be applied in both contexts.

Table 2.2 shows how the methods discussed in the previous sections score on the issues mentioned above.

0Table 2.2 Situation awareness assessment techniques scored on criteria

	Direct SA	Amount of info	On-line	Unobtrusive	Simple	Real life	Experiment	Real life + Exp
On-line probing techniques	+	+/-	+	-	+	-	+	-
Freeze technique	+	+	+	+/-	-	-	+	-
Post-hoc probing techniques	+	+	-	+	-	+	+	+
One-dimensional, on-line, self-rating scales	+	+/-	+	-	+	+	+	+
Multi-dimensional, post-hoc, self-rating scales	+	+	-	+	-	+	+	+
Multi-dimensional, post-hoc, observer-rating scales	+	+	-	+	-	+	+	+
Incident reports	-	+/-	-	+	-	-	-	-
System performance	-	+/-	+	+	-	+	+	+
Direct experimental measures: External tasks	+/-	+	+	-	-	-	+	-
Direct experimental measures: Embedded tasks	+/-	+/-	+/-	+/-	-	-	+	-
Physiological measures	-	+/-	+	+/-	-	+	+	+

Table 2.2 provides understanding of the strong and weak points of the different methodological approaches. It does not yet provide a clear-cut answer, which of the methods mentioned is best suited for application in the field of assessing situation awareness of VTS operators. The constraints of the VTS work in general and the objectives of the research project under study will be essential in providing an answer to the question which approach is optimal. The requirements set by the different research projects will determine the approach. Table 2.2 will be used for selecting an appropriate measure for the different research projects.

2.7 Selecting a method for VTS situation awareness assessment

It can be concluded from section 2.3 that situation awareness plays an important role in the work of a VTS operator. An operator needs to maintain a mental picture of the situation he is monitoring, updating it constantly with new information coming available. Therefore the development of an assessment method for situation awareness for VTS may provide useful understanding of VTS operator performance.

Section 2.6 shows many different approaches towards assessing situation awareness. Table 2.2 shows a number of criteria that may assist in selecting an appropriate method for assessing situation awareness and scores situation awareness assessment approaches on these criteria. None of the methods scores positively on all criteria. Each technique has it strong and weak points. A suitable method has to be selected depending on the objectives of the research, the project definition and constraints.

There have been until the work described in this thesis no previous attempts to assess VTS operator situation awareness. The projects described in this thesis offer the first opportunity to investigate this issue. Therefore it is imperative to develop a method, or methods, that provide us with as much information about VTS operator situation awareness as possible.

To get a better understanding of situation awareness this project has started with the development of a method that provides a *large amount of information* on situation awareness. Therefore a *direct measure* of situation awareness is preferred. In general *on-line methods* provide more understanding than off-line methods, so an on-line method is preferred.
The COMFORTABLE project in which the first method was developed focused on the development of new equipment for VTS stations. These new tools were not yet applied in real-life, but were tested in an experimental situation. Therefore application of the method in *real-life was not necessary*. It would be useful if the method was suited for application in an *experimental setting*.
VTS operators are in their work regularly confronted with disturbances. Therefore it was expected that *obtrusiveness* of the method was not a big issue, although the method had to be tested for it.

Concluding: Important criteria were:

- Direct assessment of situation awareness
- Method provides as much information on situation awareness as possible
- On-line methods are preferred
- Obtrusiveness of method has to be tested
- Method should be suited for experiments

From Table 2.2 there are two categories of methods that score well on these criteria:

- Methods that apply the freeze technique
- Methods that apply multi-dimensional rating scales of situation awareness.

These methods provide the most understanding of situation awareness, while at the same time they fulfil the other requirements. The two methodological approaches are based upon different conceptions of situation awareness. There is a fundamental difference between the two approaches.

Methods that apply the freeze technique try to find situation awareness in the situation presented itself: perceived elements in the situation are built into models that lead to understanding and projection of future developments.
Methods that apply multi-dimensional rating scales of situation awareness try to find situation awareness by breaking down the concept into underlying mechanisms, such as attentional demand. This approach leads to better understanding of cognitive processes, but not necessarily to better understanding of the situation.
The COMFORTABLE project was interested in the work of VTS operators, not in cognitive processes per se. Therefore the freeze paradigm and the SAGAT method were chosen as a template for the development of the first method for the assessment of VTS operator situation awareness.

The next chapter describes the first method that was developed to assess VTS operator situation awareness. This method is a method for direct assessment of situation awareness.