A System Theoretical Approach to Situation Awareness

A holistic view of purposeful elements

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A System Theoretical Approach to Situation Awareness – A holistic view of purposeful elements

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Abstract

From the theories of Ackoff about system theory and how the management of an organization should perform, the concept of situation awareness is discussed. A short history of the situation awareness concept is given in the light of aviation and human cognition. Motives are given why it is of interest to explore the concept of SA. The Russian Theory of Activity (Activity Theory) is presented with the focus on the orientational activity to give the background for a comparison against the adaptive-learning management system as presented by Ackoff. As result a definition of SA is presented, the result of the comparison of theories is presented, discussed and summarized in a conceptual design and future research is presented.

Keywords: Situation Awareness, Situation Understanding, Automated Systems, System Theory, Management.

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1 Introduction

“The change of change” as Ackoff (1999) puts it, is implicating that change is in a constant change, even change it self is changing. The change is making it harder to make decisions, because the decision-maker does not know what to look for. What was relevant for a decision a time ago have no guarantee to be relevant for decision making now. In the quest of making as good decisions as possible, decision makers often are presented with all known information. Even if the information is not of any known use for the decision, it is presented to the decision maker, in the misbelieve that the more information the decision maker has, the better decision will be made (Ackoff, 1999). As a result of the massive information set, the decision maker has to make filtering of what information might be of importance according to decision to make. Because of the limited time, this work is often delegated to other people of the organization. Computers can be used to help the filtration. The field of data mining and data warehousing is example of computerized information gathering from cooperative and domain data, to make better information for the decision making. This process involves concepts like categorization, grouping, aggregation, summarization, etc. When computers are used as a tool in the filtration someone has to tell the computer what to look for. The computers often use pattern matching in the filtration process, matching is done against some known pattern to find similar patterns in the data store. In the filtration process the computer has no understanding for the situation of the data or the situation of the decision-making. The filtration process is just searching for patterns in the data store or environment to find the data of interest (Cantwell, Schubert & Svensson, 2000).

When the whole process of decision-making is to be automated it is the computers that will be in the position of deciding what to look for. This demands that the computer has an understanding of the nature of the decision and what will effect the decision. It will no longer be sufficient to match patterns, the computer must be able to reason about the situation. For the system to be able to reason, it will not do with knowing the current state of the situation, the computer will have to understand it. There is a difference between pattern matching and reasoning systems (Denoeux & Zouhal, 2001). When pattern matching is used there is often no understanding about the properties and how they affect each other. The properties are just monitored to match a certain pattern. In reasoning systems the elements are understood as goal seeking systems. The properties of the elements are monitored and are used to understand the goal of the element. An understanding about how the different properties of the environment and other elements in the system affect the goal of the element is the main concern (Ackoff, 1999).

According to Ackoff (1999) humans have to be seen as systems with own goals (because of the feature of choice and purposeful systems) not as deterministic machines. This puts a little twist to the understanding of system where humans are involved. A system that at a first glance seems to be totally mechanical and deterministic often involves humans as decision makers, for a part of the system or for the whole system. So to understand the system the goal of the human has to be determined and evaluated in the process.

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Systems that have humans (purposeful system) as parts, are what Ackoff (1999) name social system. Ackoff (1999) further claims that the result often is incorrect when a system is described with models intended to describe other types of system. In other words a social system should be described as a social system with models indented for this description.

This work is assuming the theories and thoughts of Ackoff (1999) for system theory and Situation Awareness (SA). SA is the process to be aware of the current situation. The work compares two system theoretical approaches to SA, orientational activity (Bedny & Meister, 1999) and adaptive-learning management system (Ackoff, 1999). Orientational activity is one of three dominant theories in the field of human cognition for SA (Stanton, Chambers & Piggott, 2001), and adaptive-learning management system is the design by Ackoff (1999) for a management system. Even though both are based on system theory, they are intended for different fields. Orientational activity is intended for describing the internal process that a person is presuming to reach SA, and adaptive-learning management system is intended for the management of an organization to do the same. Both of the theories have parts that cannot be found in the other theory. This is because the theories are to describe SA in different fields. Even thou the difference in fields there are common aspect according to SA that can be compared. The comparison is focusing on these parts that are common for both of the theories (the intersection of the theories).

In this work the focus is on the process to achieve SA. The differences between orientational activity (Bedny & Meister, 1999) (as the most accepted system theoretical theory to describe the process of SA in the cognitive field) and adaptive-learning management system (Ackoff, 1999) (as assumed theory) will be studied. The differences will be analyzed and understood. With contribution from both of the theories, a conceptual design for a computerized SA component will be designed and discussed. The resulting design will be a general SA system. The system is not intended for any specific field. The system that is observed will be assumed to be a social system. The process of understanding the situation, the SA of the system, will be considered in separation from the decision making process. It will be assumed that the reader has basic knowledge about human cognition and perception, and are familiar with the thoughts of system theory.

1.1 Layout

The report is structured as follows:

In chapter 1 an introduction to the problem is given and the thoughts of Ackoff is presented. In chapter 2 the history and current research of SA in the cognition field is presented. The theories of Ackoff and the orientational activity are presented. In chapter 3 the problem is specified and the aims and objectives are given. In chapter 4 the methods of this work is presented. In chapter 5 to 9 the result of the work is presented. In chapter 5 the definition of SA that have evolved from the different theories is presented. In chapter 6 the result of the comparison between orientational activity and adaptive-learning management system is presented. In chapter 7 the result from the comparison in chapter 6 is presented in a conceptual design. In chapter 8 ideas for future research identified during the work is presented. In chapter 9 the results are summarized. In chapter 10 a discussion about the progress of the work and the result is presented.

2 Background

In this part central concepts are described and the scene is set for the report. First the various definitions and names for Situation Awareness (SA) are discussed, followed by a presentation of the different approaches of SA in the cognitive research community. Last in this part the theories of Ackoff for management is presented focusing on the aspects of seeing the holistic view of goal seeking elements of a social system to make good decisions.

2.1 Situation Awareness (SA)

SA is to understand the situation. The understanding can be on different levels like monitoring attributes of the elements in the situation. Like in the control panel of an industrial process. Where, as example, different values of temperature and flows are presented for the operator. An other level of SA is when the cause of the effect is understood. In the case with the control panel, the control panel can present a list of dependencies for the operator. From the dependencies the operator can gain a SA of the cause of the situation. In the example with the control panel the control panel is presenting information for the operator to help the operator to gain SA. This is not always the case. The information do not have to be presented by an automated system, it can also be presented by a person or a organization. Next a short history of SA is given.

SA in the area of aviation can be traced back to the World War 1, when the concept of SA was identified by Oswald Boelke in Gilson (1995);

“the importance of gaining an awareness of the enemy before the enemy gains a similar awareness, and devised methods for accomplishing this.”
(Gilson, 1995)

The area did not receive much attention in technical and academic literature of the western world until the late 1980s (Stanton, Chambers & Piggott, 2001), but there has been a diligent work ever after. In the literature of cognition SA occurs under different names, such as situational awareness, situation assessment and situational measurement, the different names are aimed to describe the same thing, and that is the result of the process that precede decision making (Stanton et al., 2001). How this process is performed in the different theories differentiate. The result of this process may vary from a reflection of the environment to understanding the goal of the elements affecting the situation. This report uses Situation Awareness (SA) as a summarizing name for all these theories. A definition of SA (chapter 5) will be identified as one of the objectives (chapter 3.2) of this work to clarify the concept of SA in the context of this report.

The definition of SA has evolved from just understanding the current situation to understanding the background of the situation and the possible future states. The definition has also gone from just observing elements in the situation (Whitaker & Klein, 1988) to understanding the roll of the element in the situation (Bedny & Meister, 1999). The concept of SA are no longer just used in the aviation domain, but has spread to other domains.

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According to Stanton et al. (2001) it is argued that SA can be extended into other domains such as power generation, petro-chemical, nuclear, command and control, medicine, etc. Stanton et al. (2001) claims that any task that requires people to keep track of events is a potential candidate for SA research and application.

In the management of an organization it is important to understand the current state of the organization and its environment to make the right decision for the organization (Ackoff, 1999). Knowledge about the situation is used to make projections of possible futures, simulating the outcome of different decisions made. This is also SA, where the management has to understand the situation to make the right decision. Ackoff (1999) does not use the name SA for the knowledge of the situation. He refers to it as functions of the management to understand the purposeful parts of the organization.

2.2 Cognition

As the concept of SA did emerge in the field of cognition (chapter 2.1) it is interesting to present the current theories of SA in the cognition field.

In this section the theories of SA in the cognition field is presented. The three presented theories is according to Stanton et al. (2001) the three dominating theories of SA in the field of cognition. The theory to be compared with adaptive-learning management system, orientational activity, is presented comprehensively. As the argumentation behind the theory of orientational activity is highly dependent on the theories of Endsley (1988), the theory of the three-level model also is presented comprehensively. The theory of Smith & Hancock (1995) dose not has any contribution to the work of this report. It is therefore presented briefly. The focus of this section is to present the orientational theory for the reader.

Figure 1. Integrated definition of SA in a systems approach based on Stanton et al. (2001).

According to Stanton et al. (2001) there exist three dominant definitions of SA. A common model as presented in Figure 1 can represent these three definitions. The model shows how real world elements are observed and forms an internal representation, mental models, of the world for the human. From the mental models new knowledge can be extracted. The models are also used to make projections about

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future states of the world. The different definitions have focus on different parts of this model. Endsley (1988) presents the Three-level model, the model has a focus on the product of SA and are mainly concerned with the perception and the mental model of reality. Bedny & Meister (1999) are focusing on the process of how real world things behave and are perceived by the human in their Orientational Activity. Smith & Hancock (1995) are mainly concerned on the interface between the real world and the perception process of the human. These three dominant cognition definitions of SA are discussed below.

2.2.1 Three-level model

According to Stanton et al. (2001) the Three-level model best represents the information processing approach. The Three-level model was first presented by Endsley (1988) and was developed further in Endsley (1995). In Endsley (1988) the construction of systems to support SA for pilots in aircraft is discussed. In the article SA is defined as:

“the perception of elements in the environment within a volume of time and space, the comprehension of their meaning, and the projection of their status in the near future” (p.97)

From this definition it is understood that Endsley (1988) has a wider meaning of SA than only to reflection on the current situation. The understanding of the meaning of the elements in the situation is more complex than to reflect on the current situation. It is by understanding the elements over a space of time it is possible to make assumptions about the future. If the reflection just were made on the current situation it would be harder to make assumptions about the future. The definition also mentions time and space as constraints for perceiving the situation. The perception is done during an interval of time, both backwards and the near future. The constraint in space are mainly concerned by the constraints of physical space and the attention of the individual.

The Three-level model presented in Figure 2 is a bottom-up approach divided into three different levels of situational awareness. The information is passed from one level up to the next where the lower level is necessary, but not sufficient, for the higher level of SA (Endsley, 1988).

Figure 2. Decision model after Endsley (1988).

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Level 1, Perception of the elements in current situation, it is at this level the perception of the environment and its elements is processed. No interpretation of the data is done at this level. Level 1 is mainly about data gathering and the elements are seen as independent in an environment. The perception can affect the schemas, as new features are perceived.

Level 2, Comprehension of current situation, at this level the data from level 1 is parsed to get a comprehension of the situation. Schemas and past experience is used in the process to make an understanding of the data. A holistic view of the environment is produced.

Level 3, Projection of future status, at this level the SA from level 1 & 2 is analyzed and projections of possible futures are made. The quality of the projection is highly dependent on the quality of the lower levels SA. With the projection the time to make decisions and the knowledge about the situation can increase.

Endsley (1988) claims SA as a critical input to, but separated from, the pilot's decision making (see Figure 2). Endsley (1988) sees decision making as the basis for all subsequent pilot actions. Endsley (1988) presents a model (Figure 3) of how SA is obtained. The model contains short-term sensory model, working memory and schemas and scripts. The sensory short-term memory contains reflections on the environment, none interpretation is done at this phase of the process (level 1). The short-term memory can be seen as a data gathering memory.

Figure 3. Mechanisms of SA after Endsley (1988).

In an attention driven process the gathered data is matched against the patterns of the schemas in the long-term memory. The attention driven process is addressed by Endsley (1988) as the conceptual driven attention. The data of elements to receive attention are moved to the working memory for further processing. Presented objects in working memory are directed to an attention process that Endsley (1988) refer to as

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the data driven attention. The working memory has four sub-blocks; perception, interpretation, decision making and action guidance. Data is processed in each of these blocks and passed to the next one. This is a one-way process, and the result of the fourth block is observed by the sensory memory and gives the system a feedback-loop. The result are also stored in the long-term memory, in the schemas and scripts, which are updated with new knowledge. All four of these sub-blocks are dependent on the attention of the person and are directed by the schemas and scripts. During the process in working memory the elements are viewed in a holistic way, and their interpretation and future states in the near future are projected. Based on this projection decisions are made that finally lead to action guidance (Endsley, 1988). Endsley (1988) argues that based on the model;

“the more complex components of SA, the development of a gestalt comprehension of the situation based upon perceived items and formation of projected states of the system, will occur largely in working memory.”
(p.98)

In Endsley (1988), Fracker (1984) hypothesized that working memory is the main bottleneck for SA. To minimize the effect of this bottleneck and to free working memory to deal with unexpected situations, automated process can be used. Automated processes rely on the detailed patterns coded systematically in the long term memory. A risk with using automated processes is that they tend to use a lower level of feedback than the conscious processes (Endsley, 1988). There is also a risk that the automated process is not equally susceptible to data. Attention is also a counteracting factor; under high mental workload a person's attention is concentrated to the information of great importance (Endsley, 1988). According to Endsley (1988) this is what Sheridan (1981) calls “cognitive tunnel vision”.

According to Endsley (1988) SA is highly dependent on the existing schemas, and that these are well developed. These schemas are persistent in the long-term memory and are models of the objects single functions and functions as a group with others as well. The functions are also dependent of the environment they exist in. During the projections of future states of the objects the knowledge from schemas are used. It is the level of these schemas that differentiates the inexperienced from the experienced. The experienced have a greater knowledge about the objects and better knowledge of the functions of the objects and can because of this get a better understanding of the SA and future states of the environment. Endsley (1988) argues that to have a high level of SA the person must have a high level of experience of similar situations. From this definition it is stated that the ability to achieve SA often are highly dependent on training. Other factors that influence the quality of SA are capability, preconceived opinion and objectives (Endsley, 1988). All though Endsley's model where first developed for aviation, it could be used in any task where persons need to keep control over a dynamic and changing environment (Stanton et al. 2001). Endsley (1988) believes that SA will be of greater importance in the future because of the increasing difficulties to achieve SA. Endsley (1988) claims that this is due to increasing complexity of systems, narrower time to make decisions and the high number of elements to attend. To facilitate for the person to keep a high level of SA an understanding about how SA is achieved and what factors counteract SA first have to be understood (Endsley, 1988). Another cognitive view of SA is presented below. It has a different view about what is motivating the person to complement the mental model of reality.

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2.2.2 The perceptual cycle

In the perceptual cycle approach (Smith & Hancock, 1995), SA is seen as the result of the interaction between the person and the world. The approach is based on the human information process; the person has a mental model of the presented situation, this model is not complete and in the ambition to make the model complete the person will search for understanding of the missing parts. During the exploration to get a better understanding of the missing parts the mental model is constantly updated and new holes in the mental model will arise (Smith & Hancock, 1995).

2.2.3 Interactive sub-systems

In this section the orientational activity is presented. The theory is presented extensively as the theory is to be compared against the adaptive-learning management system in chapter 6. In this work orientational activity is presented as one of three dominating theories of SA in the field of cognition. But as the argumentation of chapter 3 orientational activity will be the main cognitive theory of this work.

Bedny & Meister (1999) presents interactive sub-systems as a system theoretical description of SA, it is based on the Russian theory of Activity, known to the western world first in the 90's. To help to understand the interactive sub-system approach some basic concepts of the Activity Theory (AT) are presented. AT try's to explain the human psychological-process in a system theoretical way. According to Bedny & Meister (1999) the activity can be psychological, internal, or they can be practical, external. An activity is directed to achieve a particular goal. The method to reach the goal can be changed during the activity because of the increasing knowledge about the situation and its features. The participator can change his behavior in the activity to achieve an accepted goal. This AT view of self-regulation is not a homeostatic self-regulation, but a goal driven self-regulation process. Within the situation the participators can develop their own goals (Bedny & Meister, 1999). Bedny & Meister (1999) claims that an objectively given goal is interpreted in a subjective way. Where the past experience of the person and the significance of the goal for the person are affecting the interpretation of the given goal. The given goal and the perceived goal are not always synchronized.

Bedny & Meister (1999) presents three levels of activity in AT; orientational, executive and evaluative. In the orientational component the person develops a subjective model of the reality, from which different conclusions is drawn. As a result a dynamic images of reality is developed which results in a meaningful and coherent images of reality and expected future situations. This component includes explorative elements that can be internal (mental) or external (practical), and according to Bedny & Meister (1999) it includes what Endsley (1988) defines as SA (as a part of the function block subjectively relevant tasks condition). The orientational component of activity includes both conscious and unconscious elements and mechanisms that enable the individual to extract both stable and dynamic elements from the situation (Bedny & Meister, 1999). The future state of the situation is not only dependent on the current state of the situation. But also on the goal and significance of the situation for the individual, and how the elements of the situation are manipulated. If there is a disturbance in this level it will affect the two other levels (Bedny & Meister, 1999). According to Bedny & Meister (1999) the executive level brings change to the situation in direction to the desired goal. The executive level includes decision-making and performance of action. The evaluative level brings an evaluation of the action

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through a feedback-loop. The result is then used in decision making for correlation of action, and can affect both the orientational and executive levels. This work will focus on the orientational component of AT which has various mechanisms that provides not only conscious but also unconscious reflections of elements of the situation (Bedny & Meister, 1999). To further examine the orientational component the philosophically important principle of AT, the psychic process of the reflective-orientational component of activity is presented. To describe reflection Bedny & Meister (1999) present the following schema:

Reflected object → Reflected system → Reflected representation

The mental representation of reality, reflection, depends not only on the reflected object but also on the features of the situation. It involves concept like goal, significance, motives, mental and behavior actions, that is the concepts that are of great importance in AT. Bedny & Meister (1999) claims that it is therefore not possible to solely explain the situation from the position of the traditional information processing theory. From the position of AT the individual makes a sequence of explorative action to in a attempt to understand the features of the situation. These actions are called gnostic activity according to Bedny & Meister (1999). In the gnostic activity the individual develops task-problems that aims to get a deeper understanding of the situation. These activities can have separate goals, motives and mental and physical actions. Gnostic activities can be trigged automatically for example in an emergency situation, even when the purpose of the activity is positive, the result may not be. It may result in lower reliability of the performance (Bedny & Meister, 1999).

According to Bedny & Meister (1999) the reflection of the situation in AT is provided not only by memory and attention but also by operative thinking. The individual has a constantly changing internal reflection of the same external situation. This process of continual change of the external situation in the mind (internal process) of the individual is according to Bedny & Meister (1999) the gnostic dynamic. The gnostic dynamic is an important element of the self-regulation process (Bedny & Meister, 1999).

SA is one of the important elements of reflective-orientation activity; the other is cognitive analysis (Bedny & Meister, 1999), which requires a description of the AT definition of information processing. This process is divided into three levels, sensory-perceptual, imaginative, and verbal-logical. At the sensory-perceptual level the data from the sense organs are influencing the imaging process. This results in a sensory-perceptual image during perception. At the imaginative level images are developed from imagery memory. The process provides derivates from old images as result of a compare. The comparison process is not directly influenced by the sense organs. The images at this level are less precise but they have some advantages. During perception common features of a group of different objects in the same category can be identified. As a result incorrect features are filtered out and the more important features are saved in memory. The feature of the perception process to work with images contributes to execute activities on images. The verbal-logical thinking level contributes with the knowledge that is learned from the work with symbols and signs to solve problems, especially the concept that these contain (Bedny & Meister, 1999).

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Bedny & Meister (1999) claims that the three levels of reflection are closely bound and are constantly evolving into each other. All these three levels of reflection involve both conscious and unconscious processes (Bedny & Meister, 1999). The images has an important part in the goal anticipation because of their ability to express not just what is presented to the sense organs at the moment, but also what happened in the past and what can be expected by the future. Which in turn is an important part of the decision maker's function.

The internal process is performed highly with images, the task requirement is often presented in the form of images, and as discussed earlier the manipulation with the situation is preformed mainly with images. The goal is formed in image-goal; future results are represented in the form of images, with less emphasis on the verbal-logical first presented by Lomov (1984) and referred by Bedny & Meister (1999). The activities performed by individuals are a mix of logical and image components, where the image-component is that of higher importance. All tasks include both condition and requirement these are often presented as images (Bedny & Meister, 1999). According to Bedny & Meister (1999) there is a difference between objectively given goals and subjectively given and developed goals. The past experience of the individual is effecting the interpretation of the objectively given goals. The acceptance of the goals by the individual, are of great importance in the process of self-regulation. The goal is not just dependent on the objectively given task requirements, but also on the significance of the goal to the individual. The notion of the mental model as presented by Welford (1962) according to Bedny & Meister (1999) is another widely used notion in AT, it is learned as an internal component of activity. In the mental model the individuals "internal world" is presented, and is separated from the informational model, the objectively presented information. The conceptual model is not dependent of a specific task and can therefore be presented in advance of activity (Bedny & Meister, 1999). The individual may at every moment make conscious what is relevant for the task. To present what is relevant for the moment the operative image is presented, reflecting only the relevant elements of the situation for the individual (for more information about operative images see Oshanin, 1977). This can involve task and situation images. With the task image, regulative functions are preformed and with the situation image, orientational functions are preformed (Bedny & Meister, 1999). The individual is just capable to make a small part of the images conscious. It is the attention that makes what is potentially conscious to conscious (Bedny & Meister, 1999).

The functional structure of the activity preformed during orientational activity by the individual is presented next. The model developed by Bedny & Meister (1999) is presented in Figure 4 (on the next page). Only the activities that precede the execution of action are discussed, to keep the focus on the SA aspects of AT. The functional model is based on the functional analysis, which build models of goal self-regulation that can be seen as dynamic organizations. The psychological concepts such as memory, thinking, etc. are not discussed because these are to be involved in different ways in the function blocks and are not of interest in this stage of analysis.

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Figure 4. The functional model of orientational activity based on Bedny & Meister (1999).

All the function blocks in the diagram are connected either through feed-forward or feedback loops. In the first block the information received by the individual is preceded. According to Bedny & Meister (1999) interpretation of the information is highly dependent on the past experience (block 7) and the conceptual model (block 8). The individual learns to work with symbols and signs, and to do responding activities to these. According to Bedny & Meister (1999) the individual need to have professional experience and knowledge to ensure the proper interpretation of the information. Bedny & Meister (1999) further claims the interpretation is also dependent on the image-goal, the goal (block 2) of activity and the motivation (block 4) connected with it. During the interpretation of the information in block 1, the meaning represents reality in consciousness. Both in cognitive psychology and in AT the objective meaning (logical meaning) are distinguished from the meaning of the individuals experience (psychological meaning (Ausubel, 1968)) (Bedny & Meister, 1999). The meaningful interpretation done in block 1 is reflected in the formation of the goal (block 2). Function block 2, image-goal, is an informational block of activity containing the accepted goal (in the form of images) by the individual. The goal is described as the expected future result of activity. The interrelation between block 2 and 4 (motivation and energy component of activity) is described by Bedny & Meister (1999) as a vector that gives the self-regulation a goal-directed feature. The higher the motivation, the more mental and physical effort the individual uses to direct toward the achievement of the goal. Function block 4, the motivation of activity, is divided in two sub-blocks, sense and motivation. Sense is the cognitive-emotional component of evaluation and is linked with the subjective significance of the goal. According to Bedny & Meister (1999) motivation determines the directedness and energy for the activity to achieving a specific goal. The two sub-blocks are closely interconnected. The factor of significance are influencing the method of interpreting the information, this is represented in the diagram in the interconnection between block 4 and block 1 through block 5.

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Block 3, subjectively relevant task conditions, is another component that according to Bedny & Meister (1999) are important in the function of dynamic reflections of the situation. The block includes both conceptual (SA) and image (operative images) components of activity that overlap and together provides a more dynamic reflection of reality. The SA component of block 3 includes a logical and conceptual subsystem of dynamic reflection, in these subsystems the individual are very conscious of information processing. Bedny & Meister (1999) claims that this is also true for the information processing in the overlapping part of the sub-blocks of block 3. The functions of the SA sub-block are preformed by switching from one feature of the object to another. The result is then compared with the goal of the individual, and if required, it can change the activity. Block 3 has the ability to affect the goal (block 2), through block 5 and 4, and if necessary correct it. Block 3 does not just bring orientation in the situation at any time but also brings the ability to make reflections about future states of the situation. This reflection is done internally, to a large extent unconscious and through the manipulation of internal images. This process can be enriched with additional data from internal and external sources (Bedny & Meister, 1999). According to Bedny & Meister (1999) this manipulation is easily forgotten because of the difficulty of verbalization. The part of the imaginative reflection that doesn't overlap with the SA reflection can be considered preconscious reflection. These reflections can become conscious through a change in the situation, a shift in attention or an increase in will. According to Bedny & Meister (1999) this may be reflected in the individual by "vague feelings", these should also be able to affect conscious components. Bedny & Meister (1999) are referring to research preformed by Pushkin (1978) and Tikhomirov (1984) about solving problems. In the result of this research certain dynamic elements of the situation were discovered, "nonverbalized meaning of the situation" or "situation concept". According to Bedny & Meister (1999) these can be of greater importance than the verbalized components. The individual can from the same situation extract verbalized and nonverbalized meanings in the process of solving a problem. This is most apparent in virtual tasks. Bedny & Meister (1999) claim that it because of this block 3 is involved in the dynamic reflection of the situation and the constant transformation of the information on conscious and unconscious levels according to the goal. The aspects subjectively significant to the individual and represented in the dynamic reflection of the situation are not always objectively important. According to Bedny & Meister (1999) the dynamic reflection of the situation can lead to disturbance of the internal model. The dynamic reflections of the task can also affect the subjective evaluation of the significance of the situation. The mental model of reality is influenced by the conceptual model (block 8), image-goal (block 2) and subjectively relevant tasks condition (block 3). This defines the mental model from an activity point of view as a complicated three-component structure.

Bedny & Meister (1999) claims that in simple situations the unconscious functions can bring a dynamic recognition of the situation. In more complicated situations the direct understanding of the situation may be impossible. The gnostic activity preformed explorative functions of the situation to increase the understanding of the situation. The gnostic activity includes mental transformation, decision-making and so forth.

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According to Bedny & Meister (1999) SA in AT has a wider definition and the definition used by Endsley (1995) is a part of block 3. Some of the differences are the consideration of memory and thinking and the reflection of the schemas. In AT, SA is seen as a goal driven self-regulation process preformed by internal logical and imaginative processes. These processes can be both conscious and unconscious.

There are other fields that also are concerned with the concepts of SA. One of these is the management field. It is of great importance to understand the organization and what is influencing on it, to be able to control it successfully (Ackoff, 1999). The idea of Ackoff (1999) for management is presented below. The focus is on how to keep knowledge about the state of the organization and the environment, and to understand the elements of the organization and how these influences the system.

2.3 Adaptive-learning management system

Adaptive-learning management system as assumed theory of this work is presented in this section. To clarify the meaning of the thoughts behind the theory some key concepts are also presented.

Ackoff (1999) advocate a planning paradigm he calls interactive planning containing five phases; formulation of the mess, ends planning, means planning, resource planning and implementation and control. By the mess Ackoff means the problem of the situation, formulating the mess involves understanding how the problem arises and what is influencing the arise of the problem. During the ends planning an idealized design is developed. Idealized design is a design of the system if it where to be design from scratch today to solve the mess. The gap between the current system and the idealized design of the system is tried to be minimized. The tree final phases of interactive planning are about narrowing the gap. In an organization it is the task of the management to identify the mess and find a solutions for getting rid of the mess. The definition used by Ackoff (1999) for the management of an organization is:

“Management is the control of a purposeful system by a part of that system”
(p.269)

To understand what he means with his definition the concept of purposeful systems and organizations are presented.

A purposeful system is one that has a variable and chosen behavior and an outcome that also is variable and chosen. The system can produce the same outcome in different ways, and can produce different outcomes in the same state. The system can change it's goal under stable conditions, it will select mean and ends. Ackoff takes the human being as an example of the most familiar example of a purposeful system. The purposeful system is not the same as a goal seeking system, because the purposeful have the ability to choose. Table 1 is presented to clarify the relationship.

Background

Table 1. Behavioural Classification of systems after Ackoff (1999).

Behavioral Classification of systems		
Type of System	Behavior of system	Outcome of Behavior
State-maintaining	Variable but determined (reactive)	Fixed
Goal-seeking	Variable and chosen (responsive)	Fixed
Multi-goal-seeking and purposive	Variable and chosen	Variable but determined
Purposeful	Variable and chosen	Variable and chosen

The two first types of system keeps a fixed outcome in a self-regulation way. The first is reactive; an event that happens to the same system or its environment is sufficient for a reaction. And the second is responsive; an event that happens to the same system or its environment is necessary but not sufficient. The system has not to react on the stimulus, but it does have to react on its cause. The behavior presented by the goal-seeking system is responsive not reactive. In the same environment it is not possible for the system to perform different actions for the sufficient state.

Organization can be many different things, in order to clarify what Ackoff (1999) means with an organization the definition is presented next.

“An organization is a purposeful system that contains at least two purposeful elements which have a common purpose relative to which the system has a functional division of labor; its functionally distinct subset can respond to each other’s behavior through observation or communication; and at least one subset has a system-control function” (Ackoff , 1999, p.61)

From this the conclusion that an organization includes at least two human beings (purposeful system) can be drawn. The organization can involve two machines as long as human beings control these. The definition also addresses that the elements must have the same purpose in some way, they all has to have some common aim, and they need to have a executive function, something that is performing work in the direction of the aim. This function can bee responsive to the behavior of the other elements functions. From the definition this can be preformed by communication and observations. The last part of the definition is of great importance as this says that it is not an organization if it does not have the control function, the management. So without management there cannot be an organization.

Models are used to reflect certain aspects of the reality. Ackoff (1999) claims that different types of systems have to be described by different kinds of representations. Ackoff (1999) claims that the consequences of using one type of a model to describe another type of system can be serious. He presents three basic types of systems and models as presented in Table 2, and a meta-model (ecological) that can contain all the

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other three. The three models are deterministic, animated and social. Ackoff (1999) claims that these three systems form a hierarchy where a social system can have animated parts but a animated system cannot have social parts. An animated system can have deterministic systems as parts but not vice versa. The meta-model, ecological system, can contains the three types of systems. The ecological system can have some parts that are purposeful but not the whole.

Table 2. Types systems and models after Ackoff (1999).

Types of systems and models		
Systems and models	Parts	Whole
Deterministic	Not purposeful	Not purposeful
Animated	Not purposeful	Purposeful
Social	Purposeful	Purposeful
Ecological	Purposeful	Not purposeful

The organization contains parts that are purposeful and has a purpose as a whole, from the discussion above it can be concluded that an organization is a social type of system and should be described by social models.

The scene is now set and a short background of the view of Ackoff (1999) for organizations and purposeful systems have been given. It is now time to focus on the adaptive-learning management system. According to Ackoff (1999) a management of an organization has too be adaptive and learning if the organization as a whole is to become adaptive and learning. It is therefore important to ensure that the management is adaptive and learning. The definition of adaptive and learning, and the adaptive-learning management system as described by Ackoff (1999) are discussed below.

2.3.1 Adaptive

Ackoff (1999) gives the following definition of Adaptive:

“A system is adaptive if, when there is a change in its environmental and/or internal state which reduces its efficiency in pursuing one or more of the goals that defines its function(s), it reacts or responds by changing its own state and/or that of its environment so as to increase its efficiency with respect to that goal or goals. Thus adaptiveness is the ability of a system to modify itself or its environment when either has changed to the system’s disadvantage so as to regain at least some of its lost efficiency.” (p.57)

From this definition it can be concluded that to be adaptive the system must be at least purposeful, it must be goal-seeking and it is both reactive and responsive. Adaptive is to be successful in a changing environment.

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The adaptive element can effect both it self and its environment to increase its efficiency, that are degreased due to the change of state. The sum of the changed system state can be negative in a goal-seeking way, but it can also be positive and can lead to new opportunities.

2.3.2 Learning

Ackoff(1999) uses the following definition of learning:

“To learn is to increase one’s efficiency in the pursuit of a goal under unchanging conditions.” (p.58)

According to this definition learning is preformed during unchanging conditions. For an example a person that is trying to hit a tree with a snowball. The person learns how hard he will throw the snowball to hit the tree. If there is a change in condition, internal and/or external, the system is adapting the learning. So if there is a change in wind when the snowball is thrown, the person is adapting the learning. If an organization is repeatedly subject for the same change the organization learns to adapt (Ackoff, 1999). Adaptive-learning is to increase one’s efficiency in the pursuit of a goal under changing condition. So the adaptive-learning management system is the control of a social system with purposeful parts that are learning to increase its ability to reach a goal under changing conditions. From this Ackoff (1999) identifies three functions for the management;

1. Identification of the actual and potential problems.
2. Decision-making and maintenance.
3. Improvement of performance under changing and unchanging conditions.

Next it is presented how the function of adaptive-learning management system is preformed.

2.3.3 Subsystems interaction and role

The three functions presented above ((1) identification of actual and potential problems, (2) decision-making and maintenance and (3) improvement of performance under changing and unchanging conditions) are implemented in the adaptive-learning management system by Ackoff (1999) as subsystems, each responsible for a function. Ackoff (1999) has identified that there is a requirement of continuous supply of information for these function, so a forth sub-system is presented, the management information subsystem. The design of the adaptive-learning management system is presented in Figure 5.

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Figure 5. Adaptive-learning management system based on Ackoff, (1999).

The numbers and letters used in the diagram are the same as in Ackoff (1999), the numbers are kept to help to clarify the flow of data/information. The numbers and letters will be used in the text to reference to the different associations and elements of the system.

To generate data the management has to observe the organization and its environment. In this design this is handled by the information subsystem (C). For the data (1) to be useful for the organization it has to be processed, the processed data Ackoff calls information (2). Data is signs and symbols representing features of elements and events, information is also signs and symbols, but of higher importance for the decision-making. The process of making information from data can be done by filtration, aggregation, summarization, etc. The information is then send from the information subsystem (C) to the decision-maker (D), which makes a valuation of the information (2). The information can be accepted, but needs to be complemented, so the management asks for more information from the information subsystem. The decision-maker may find it hard to understand the information even if it is correct, this can lead to a request (3) for more or new information (revision of information) from the information subsystem. This request of information from the decision-maker to information subsystem makes two requirements on the information subsystem. First it need to be able to examine the organization and it's environment, and second it need to be able to reuse the data and information generated earlier. In other word a data store is required. The information subsystem delivers the new requested information (2) to the decision-maker, who again makes a judgment. This can result in a new

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request (3) of information. The delivery of information and the request for new, results in an information-request cycle. This will finally stop, because the decision-maker is satisfied or because there are no time left. After this a decision is made by the decision-maker, that results in a instruction (5), that are intended to change the behavior of the organization or parts of it.

The focus is now concentrated on how a decision is monitored and controlled. A decision is made to make something occur that should not else occur or to make something not to occur that should else occur. In both cases there is an expected result in a time interval. To be able to monitor the decision it is important that the expected result and the time-interval are accounted for. These are saved in the decision-protocol (6) together with assumptions, information, and the process used to make the decision. The protocol is saved in the inactive memory (E).

To be able to make the evaluation, instructions (7) are sent to the information subsystem to deliver the needed information to the memory (E). Information about the state of the organization and the outcome of the decision (8), according to performance and assumptions, is sent to the memory (E). In the memory the information from the information subsystem about the decision is compared against the decision-protocol (6). If there is no difference noting is done, but if there are this is reported and noted (9). To clarify the difference and why this is, a diagnostic (F) is needed. The diagnostic is to propose corrective and explorative actions.

Threats and opportunities can be reported to the decision maker from external or internal sources (17), but they can also be detected by the management information system (13). First the symptoms have to be identified, and then they are synthesized to a diagnose. Symptoms seldom occur under “normal” states, they often occur when something is wrong or exceptionally right. Symptoms are often associated with something bad, but can as well be something good. To determine what is normal statistical methods are used, the state of the system can then be compared with the normal state to detect the abnormal. Variables for behavior and performance often are used to determine the symptoms. These variables are also used to determine presymptoms or omens. With presymptoms Ackoff (1999) mean something non-random normal behavior, which is something that follows a pattern, a trend or a cycle etc. These are easily identified with statistic testing. It is the responsibility of the information subsystem to obtain and provide the symptoms and presymptoms (11), what Ackoff (1999) referees to as performance indicators. The performance indicators are then sent to the symptom and pre symptom analyzer (G) for further analysis. The performance indicator should be obtained regularly. As a result of the analysis by the symptom and presymptom analyzer (G) symptoms and presymptoms (12) are found. These are sent to the diagnostic function (F) to obtain threats and opportunities (13). When symptoms are obtained by the diagnostic it should be reported to the decision making subsystem (D), in the same manner as with the decision record a diagnostic and prescriptive record (14) should be sent to the memory (E) for comparative actions against the information sent by the information subsystem (15). If derivation are identified these should be sent to the diagnostic and prescriptive subsystem, deviants (9). The diagnostic and prescriptive subsystem (F) are then responsible for making changes to the subsystems (10a-10d) and to itself (16). According to Ackoff (1999) it is from the change of the subsystems and the diagnosis process that the system learns how to learn and adapt.

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In the design described above Ackoff (1999) identifies three levels of control; (1) the system as a whole controls the organization of which it is a part, (2) the diagnostic and prescriptive subsystem controls the management system, (3) the management system controls itself.

2.3.4 Limitations of automation

Ackoff (1999) makes a classification based on model of problem and procedure to conclude a result from the problem model. The problem model is a model that describes the properties of the problem and the information necessary to solve the problem. The procedure aims at a process to generate a solution from the problem model. Ackoff (1999) classifies the decision-making functions in three categories:

1. Both the models to describe the problem and explicit procedures to extract the solution from the models are available.
2. Just the models are available and no procedure to extract the solution.
3. There is no model to describe the problem.

The first category involves repetitive, routine and operations-oriented problems, the human behavior is not important in the solving of these problem. These can be computerized in a high degree. The second category is more difficult to be computerized, but computers can do part of the problem solving so that decision makers time are freed. The last category cannot be computerized according to Ackoff (1999), this involves among other things strategic problem solving.

As models are simplified representations of the reality, which are aimed to reflect certain aspects and to leave others out, the solution derived from these may be faulty and often needs to be adjusted by the decision-maker. The algorithm used to process the model for a solution can only process the information available in the model. Computers seldom request data to make more accurate assumptions.

2.3.5 Misassumptions about Management Information Systems

Ackoff (1999) present five often-occurring misassumptions about management information system that according to Ackoff (1999) has led to that the system have not met the exceptions. These misassumptions need more attention as the computer enters the scene as a tool, so that the good intention is not causes something bad for the organization. The five misassumptions are presented below.

Managers critically need more relevant information, this assumptions is based on the assumption that the managers would perform better if there where given more information. According to Ackoff (1999) this not the case, its the right opposite, managers often are suffering of information overflow. The concern of the manager becomes to filter out the interesting information. The filtration and condensation should be an essential part of the management information system, and the system should be capable of handling unsolicited as well as solicited information.

Managers need the information they want, it is a common assumption that managers know what information they need. For this to be true the manager (1) has to know each type of decision they should make and (2) they must have adequate model of

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each. According to Ackoff (1999) the last if not the first is seldom true. One can not design an adequate information requirement until there is a complete model of the decision making process. When such a model exists the skills of the manager are no longer needed, and a clerk can do the job. The genius of a good manager lies in his ability to handle an organization that he does not fully understand. So to give the manager the information they think they need will most likely result in information overflow or that the managers do the work that someone else would do better.

If managers are given the information they need, their decision-making will improve. In the discussion above the importance of having the right information and knowing how to use it were discussed. The same is still true, if the information needed for solving the problem is given to the manager it is no guarantee that he will solve it. To be able to solve the problem the manager needs to know how to use the information, the process to make information to a decision. If both these things are known, it is just a waste of the manager's time to do the work. It could as well be done by a clerk or a computer. Giving the necessary information to a manager who does not know how to use it will probably result in an increased information overflow. The information system embedded in a management system should be one capable to improve the manager knowledge of what he needs, learn what to need.

More communication means better performance, this would maybe be true if there were no competition between the parts of the organization. According to Ackoff (1999) the internal competition between parts of the organization are often more intense than the external competition. According to this it might not always increase the performance of the organization by increasing the information between managers about what they are doing. As Ackoff (1999) puts it:

“The moral: organizational structure and performance measures should be put right before opening the flood gates and permitting free flow of information between parts of the organisation” (p.286)

In other words information flow should be carefully evaluated before it is executed, and it should be considered how it could affect the performance of the organization as a whole.

A manager does not have to know how the information system works, only how to use it, in the quest of making the management information system easy to use for the manager, the process to determine a result are hidden from the user. The designers of the system often succeed to hide how the system works from the manager. When the process behind the result is hidden for the manager. The manager has no possibility to evaluate the result generated by the system. The manager has delegated the evaluation to the designer of the system. Ackoff (1999) claims that a management information system should not be installed if not the manager who the system should serve fully can evaluate the systems performance. The manager should control the system, not be in control by it.

The orientational activity and the information management system both have the same goal, to present a situation awareness system of a system. The theories are focusing on different parts of the process and the objective of the designs differentiates. An interesting question rises: How do the designs differentiate? This will be discussed in the next chapters.

3 Problem description

The military is familiar with the advantages of having the right data for decision-making. Situation awareness is the common expression used for “seeing the whole picture” (Stanton et al. 2001). The data that is relevant for the military is presented for her/him, so that the military can make the best decisions and be successful in combat. By just presenting the relevant information for the decision maker, the decision maker is not exposed to information overflow.

The area where situation awareness has been used for the longest time is in the cockpit of airplanes. The pilot can be in a stressed situation and the information presented to the pilot must be easy to interpret and difficult to misunderstand. This has led to a high degree of computerization of the situational data presented in the cockpit. The computer does most of the filtration of data, and has a great roll in deciding what data that is relevant for the pilot (Endsley, 1995).

For the least 20 years the military have done a lot of research on how to get situation awareness on other situation than of the pilot in the cockpit. There is research on how to get situation awareness over the whole battlefield in command and control (Stanton et al. 2001). The vision is to have a system that is monitoring all the units of the enemy and can understand the tactic of the enemy. It is by the use of such a system the potential threats and suggestions for action can be identified. (Cantwell, Schubert & Svensson, 2000).

The manager of an organization has the similar problem with information overflow. To manage an organization is to be skilled in the art of adapting the organization to a changing environment (Cao, Clarke & Lehaney, 2003). The manager of an organization is presented with a constant flow of information about internal and external state changes, treats and opportunities. The work of the manager is to see the overall picture and make predictions about the future and how the future will effect the organization (Ackoff, 1999). The manager will then make decisions for how the organization shall meet the future. The work of the manager is in many aspects the same as of the pilot. They both need to see what is coming and react to that scenario; they both need to have the holistic view to identify threats and opportunities, etc.

To achieve situation awareness in computerized systems, a lot of sensor data has to be gathered, filtered and fused. To fusion data is to extract new knowledge from the gathered data. The common approach is to use a bottom up architecture, where data from different sensors are giving different aspects of knowledge of the same object. This way the operator receives more relevant data about the object and its state and less superfluous data (Llinas, Bowman, Rogova, Steinberg, Waltz & White, 2004).

To fusion data mathematics is often used, the process of the fusion is described using formulas and often some kind of artificial intelligence (AI). The aim of the AI research is to imitate the behavior of the human perception process as good as possible. There is a lot of research on how to adapt the knowledge from the artificial intelligence research community to the community of cognition and information fusion (Cantwell, Schubert & Svensson, 2004), but the research of SA in isolation is inferior.

Problem description

The workload on filtration is to increase in the future and so are the demands for intelligent decision system (Endsley, 1995). Dynamic rules are likely to be used due to the rapid changing conditions under which the system is performing. The SA component of an automated decision support system needs to be able to change its process during progress. The SA component should also be able to work with patterns not known at the implementation phase.

3.1 Problem specification

This work will address possible advantages and future research areas of using a system theoretical approach to Situation awareness (SA). The work will assume the theories presented by Ackoff (1999) for system theory and the concept of SA as the main theory. As the concept of SA has emerged from the field of cognition, a cognitive theory will be compared against the adaptive-learning management system theory presented by Ackoff (1999). According to Stanton et al. (2001) there are three dominating theories in the field of cognition. As the only system theoretical approach to SA of the dominating ones, orientational activity will be the main cognitive theory of this work. The comparison of the two theories will be focusing on the common parts of SA. The theories are intended to describe the process of SA in different fields. Because of the difference of intention some parts of the theories cannot be compared. As the first phase in the comparison of theories, a common definition of SA will be discussed that is influenced by both of the theories. To identify the common view of SA by the theories.

As a second phase of the comparison the function of the theories are compared using the knowledge from orientational activity and the adaptive-learning management system. Where data is not just pushed up in the fusion process but requested from the management. The process to achieve SA will be in focus, and contiguous fields like decision-making will be presented, but not analyzed, to achieve a better understanding for the SA process.

A conceptual design for a SA component will be discussed assuming the system as an information system. Requirements of surrounding systems will also be discussed.

3.2 Objectives

The problem specification is resulting in four objectives, these are presented below.

1. Finding a definition of SA.
2. Analyze how the orientational activity of activity theory differentiates from adaptive-learning management system.
3. Discusses a conceptual model that is influenced of orientational activity and adaptive-learning management system.
4. Identify future research areas.

The main objective in the work is objective two, analyze of the differences between orientational activity and adaptive-learning management system. Objective three, discuss a conceptual design of a SA system, is intended to show a possible design of a system that is influenced by orientational activity and adaptive-learning management system.

Problem description

3.3 Expected result

Derived from orientational activity and adaptive-learning management system a conceptual design for a SA component for a system will be presented and discussed. The design will show that the complimentary approach of using bottom-up (fusion), top-down (request) and feedback-loops in the data fusion process is more fruitful than using a bottom-up approach. The SA system has captured the common SA functions from both of the theories and has put these together in a complimentary way.

From the design of the SA component a requirement specification will rise, and requirement of surrounding system will be presented. From this requirement specification a list of future research areas will be presented.

4 Method

This chapter presents the methods by which this work will fulfill the objectives presented in chapter 3.2.

Because of theoretical nature of this work and the comparison of existing theories, all of the objectives are to be performed through literature studies. It would be hard to get the width of information for the comparison with a other method than literature study. A drawback of the literature study is that the theories or parts of the theories can be misunderstood. The misunderstanding can be because of the missing of the thoughts behind the theories, or for the different meanings of key concepts in different domains of the definitions. To minimize the risk for misunderstanding of the theories the literature study could be complemented with interviews with the persons behind the theories. Because of the high workload on these persons it is not likely that they should have the time for the interviews, and because of the limited time of this work it were decided not to make any interviews.

To minimized the risk of misunderstanding the theories. The literature study should be conducted on a wide range of source in the domain of SA, to get the knowledge about the domain specific meaning of the key concepts, so that the risk of misunderstanding will be kept at a minimum.

4.1 Method for objective 1

To be able to reason about a common definition of SA a literature study to inventory and analyze the current research and existing definition of SA will be executed. The study will start by doing searches in the article databases of library at the University of Skövde. The focus will be on the articles in the field of cognition, psychology and management. The articles that are found will be collected and a fast overview of the different articles will be done. The fast overview will result in a wide but not so deep understanding of the SA concept and use. The identified definitions of SA will be analyze deeper, to get a better understanding of their differences. As the theories are intended for different domains and have different purpose they are likely to have parts that cannot be compared. The focus in the analyze will be on the common part of SA. The different views on SA will be discussed and a definition to use in this work will be presented.

4.2 Method for objective 2

To be able to make a comparison of the two system theoretical views of SA (adaptive-learning management system and orientational activity), requires at least two things, (1) the understanding of the system theoretical science, (2) the understanding of the role of the SA concept in both of the views.

My background in system theory is a five-credit course at the University of Skövde. The minimum knowledge about the field calls for a study in the system theory. The study will be conducted by reading some key literature in system theory.

To get a understanding of the role of the SA concept in both of the views a deep going analyze of the proposed designs by the two views will be executed. A literature study will be executed by reading of articles and books about the two different views and designs. The articles will be found by searching the research article databases in the library by keywords. As quality insurance the articles will be discussed with my supervisor. A search for articles that propose criticism against the two views will also

Method

be conducted. The search will be conducted by searching the research article databases at the library of University of Skövde and by discussions with the supervisor. The purpose with the search is to highlight weaknesses of the views. The books to be read are the books written by the persons behind the theories (Ackoff (1999) and Bedny & Meister (1997)). The quality of these books was also discussed with my supervisor, and the result of the discussion was that the books are of high quality. The thought of using other techniques for this objective, as interviews or questionnaires were discussed. But as no big contribution was identified with using these techniques, it was decided not to use any of these.

The comparison will be conducted by understanding the function of one function block. The understanding will involve; the dependency of the function block to other blocks, the contribution of the function to the whole systems, the roll of the function block in the system and the internal function of the function block. When the function block is understood it will be analyzed if similar functions can be found in the other design. If there is a difference, the difference will be discussed and the reason for the difference will be analyzed. In this manner all the function blocks will be analyzed.

The theory of Ackoff (1999) (adaptive-learning management system) will be assumed as the main theory, and the theory of Bedny & Meister (1999) (orientational activity) will be compared against the theory of Ackoff (1999). The aim with this comparison is to identify the common function of the two theories in the light of SA. Both of the theories are likely to have functions that are not possible to compare with the other theory, as the parts are intended for different fields. The field specific functions are not to be discussed deeply, and the focus will be in the common part of the SA process. The result will be an understanding of the differences of the two views of SA.

4.3 Method for objective 3

As a result of the comparison performed during objective 2 an understanding of the differences of the theories and their function will come clear. This understanding will be put together in a list of common functions used in both of the theories. The interaction of these common functions will be analyzed and dependencies will arise. Analyzing the requirement of data/information by each of the functions will identify the interaction of the functions. It will then be analyzed where the required data/information may be found. If a dependency between two functions is identified a association will be presented to clarify the interaction between the functions. From the list of common functions and how these may be interconnected a design of a conceptual model will be presented. A shorter discussion to describe the design and the functions of the design will be presented.

4.4 Method for objective 4

As the analyze of the function block is executed questions that are out of the scope of this work to solve is supposed to appear. These will be listed in the section of future research. It may be so that the questions that are presented in the section of future research are already solved. The aim of doing this listing is to present interesting research topics that are out of the scope of this work to examine further.

Method

4.5 Quality insurance of sources

The author of this work does not have the knowledge about the cognitive and psychological field to determine which sources are of high quality. To assure that the articles are of high quality the acceptance of the article will be examined. If the article is presented at a conference, the acceptance of the conference will be examined. As a last assurance the article will be presented to the supervisor, who has a knowledge in the field of cognition, to determine its quality.

The key references of this work, Bedny & Meister (1999) and Ackoff (1999), have been discussed with the supervisor. The result from the discussion with my supervisor was that these are accepted books and of high quality. The comparison of the two views will be highly dependent on these two sources.

5 Definition of Situation Awareness (SA)

In chapter 5 to 8 the result of the work is presented in order of objectives (see 3.2 Objectives). In this chapter the result of the first objective is presented. The chapters (5 to 8) are highly dependent on each other, and to understand the argumentation behind the result the reader need to be familiar with all of the results. This means that for the reader to be able to fully understand the argumentation, these chapters should be read two times.

The definition of SA as the work started was the adaptive-learning management system presented by Ackoff (1999), minus the decision making block. Most researches agree in the separation of decision-making and SA, the SA process is preceding the decision making process (Stanton et al., 2001). The decider needs to have the understanding about the situation before he can make a decision. From the design presented by Ackoff (1999) of a adaptive-learning management system it can be concluded that the SA are about understanding the elements of the system and the systems environment (information subsystem). The understanding is wider than just to observe the elements of the system. Ackoff (1999) talks about understanding the elements role in the system and how the element is affecting other elements. The system of observation is to be seen as a system of systems. To achieve SA is to understand the interaction and role of the system in the system of observation. The interest in the environment is because of the systems in the environment are influencing the state of system of observation. The system of observation is not to be seen as an isolated island.

Endsley (1988) presents a definition of SA as:

“The perception of the elements in the environment within a volume of time and space, the comprehension of their meaning, and the projection of their status in the near future” (p.97)

Adaptive-learning management system (Ackoff, 1999) is doing the work in the definition presented by Endsley (1988) plus some extras. The perception of the elements is done by the information subsystem and memory (in adaptive-learning management system), where data is processed to make information. Data are put together to describe different aspects of the elements of the situation in the same manner as the perception of a human being. The volume of time is a result of involving history data from the memory block. The volume of space is handled by the decision of the borders of the system of observation. The projection of the near future is a result of having a good understanding of the goals of the elements in the system. When this is clarified it is possible to make simulations of the future to come. The comprehension phase according to Ackoff (1999) has to be preceded by analyzing the type of system of the element. Ackoff (1999) is presenting different types of system, where humans fall into the type of purposeful system, systems that have a variable and chosen outcome and behavior. He claims that different types of system are to be described by different models. There is a great risk of misunderstanding if a system of a certain type is to be described by models intended for another types of system. Depending on the elements type of system, the elements goal has to be understood from the situation and the role in the system.

Both Endsley (1988) and Ackoff (1999) are talking about the importance of the feed-back loop of evaluation of the decision made on the current SA. This feed-back loop is going to increase the quality of the SA. The main difference between the three level

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model (Endsley, 1988) and adaptive-learning management system (Ackoff, 1999) are in the view of the elements and their attributes and in the direction of the feedback loops. Endsley (1988) is mainly interested in observing the attributes of the elements (level 1) and then synthesized them to a comprehension of the situation. In other words Endsley (1988) tries to explain the situation by the attributes of the elements of the situation. Ackoff (1999) claims that this approach is not that fruitful for social systems, if a element is seen not as a system with a goal but as a collection of attributes, it will be hard to have a full understanding of the situation. Ackoff (1999) propose the use of both observation of the attributes and the determination of the goal of the element, which is highly dependent on the system type of the element.

The definition of SA used in AT is the mental image of the situation, this constitutes the conceptual model, the image goal and the subjectively relevant task condition. When compared with adaptive-learning management system no corresponding function boxes are found. This is likely because AT is focusing on the process in a deeper manner than Ackoff. The mental image can be seen as the result used by the decision maker to make a decision. AT have functions that are of interest for the formulation of the definition of SA used in this report. AT is talking about both conscious and unconscious processes, and about dynamic and stable reflection of the situation all of which are putting a extra twist to the definition of SA (the contradiction of all of these concepts to the process of SA are discussed later on in chapter 6.7). So influenced by the theories of Ackoff (1999), Bedny & Meister (1999) and Endsley (1988) the final definition of SA in this work is:

The conscious and unconscious dynamic processes to achieve a reflection of the systems purpose and form, function, system state and future system states.

This definition defines SA as a process, not a product. It involves both conscious and unconscious process. The conscious process is to be seen as the process that is initiated and is in the control of the system. The unconscious processes are doing processing uncontrolled by the system and are trying to get the attention of the system when needed. It is up to the system do decide if the result or request of an unconscious process for attention is to be used or fulfilled. The goal of the processes is to give a reflection of the system so that the systems purpose and form is identified. To understand the interaction of the system and its parts, the system has to identify the functions of the system. To be able to make assumptions about future states of the system. The system has to be familiar with the history of the system, this is done by monitoring the systems state. By dynamic process it is meant that the process of the reflection has to be able to adapt to the changing condition of the system. The process of reflection has to change.

In the next chapter the comparison between the adaptive-learning management system and the orientational activity is presented. The comparison is focusing on the common parts of SA as presented in the definition of SA above.

6 Comparison of Situation Awareness Theories

In this chapter the result of objective two is presented. The intention and the goal with the designs presented by Ackoff (1999) and Bedny & Meister (1999) is to be clarified. The comparison will assume adaptive-learning management system (Ackoff, 1999) as main theory. The comparison will focused on the common SA parts of the theories.

Adaptive-learning management system (Ackoff, 1999) is intended to support the decision maker in the process to understand the consequences of the decision, the nature of the system in which the decision is made and to build the mental image of the problem for the decision maker. The focus of adaptive-learning management system is to make filtration of the data generated by the system (organization and environment). Activity theory (AT) and more precisely the orientational activity (OA) is intended to explain the process of how the decision maker builds and maintains the mental images of the system. OA is describing the internal process of the decision maker and adaptive-learning management system is describing the external interaction. In this work it has not been made any reflection about who or what is to perform the function of the system. The work is focusing on the common parts of the SA process. The domain specific parts of the theories will not be analyzed. The common part of SA is defined by the definition of SA presented in chapter 5. Both of the theories are concerned with the process of understanding the system to make decision about (building a mental image of the system).

The result of this comparison will highlight the key functions of the SA process in both of the theories. It is of great interest to identify what is making the theories fruitful in their specific domain and to use this knowledge to design a SA system that is not domain specific.

Earlier in this work it has been discussed that SA is a process separated from decision making, and that SA precedence the later. Even though this is true, both of the diagrams have a box “decision making”. The result of the decision-making is of great importance to evaluate the SA process. If a decision is made and an unexpected result appears, then something may have been wrong in the understanding of the system. So the “decision making” box presented in the diagram makes it possible to evaluate the SA process. The process of the decision-making is not in the scope of this work.

6.1 Function blocks

In this section the function blocks of adaptive-learning management system (Ackoff, 1999)(Figure 5 in chapter 2.3.3) are compared with the function blocks of OA (Figure 4 in chapter 2.2.3).

6.1.1 Information subsystem

In Figure 6 the information subsystem and the interaction it has with the management information system is presented. The function of the information subsystem is to observe the organization and the environment of the organization. As a result of this observation data is obtained. The information subsystem transforms the data into information. The information is then sent to the decision maker. In OA the same function is preformed by the meaning of input information, the data observed is transformed so it makes sense to the system.

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Figure 6. Information subsystem in adaptive-learning management system after Ackoff (1999).

The decision maker has the possibility to request more information from the information subsystem. According to Ackoff (1999) this puts two requirements on the information subsystem, (1) the information subsystem have to able to generate new data (inquire data from the system and environment), (2) the information subsystem has to be able to reuse old data, this puts a requirement of using a data store. The ability to inquire new information is preformed by the attention of OA. If there is a demand of inquiring more information about some element, the attention is directed to that element. The unconscious processes of the operative image are performing explorative actions that may result in new data about the system. The process can involve both internal and external activity. The second requirement of the information subsystem, to be able to reuse old data, is handled by the paste experience (schemas) and by the conceptual model (reflection) of OA.

The information subsystem has the important function of providing information to the memory and comparator so that the decision can be monitored and evaluated. In OA the instruction of which information to monitor is stored in the criteria of evaluation. This is used by the explorative actions of the subjectively relevant task conditions and the actions of evaluative and inducing components of motivation to monitor the result of the decision. The information needed to monitor the decision is constantly inquired and evaluated in the conscious and unconscious processes, if a deviation is identified the process tries to get the attention of the system.

As explained in the discussion above, the information subsystem does not have an equal function block in OA. The function of the information subsystem is spread over many functions block in the OA, but still the function exists in both of the diagrams.

6.1.2 Decision-making subsystem

As earlier discussed, the decision-making is not a part of the SA system. It is only kept to present the requirements it puts on the SA system. Because of the separation the analyze of the decision-making subsystem is made on the interconnection it has to other function blocks of the design and not on the function of the block. Figure 7 shows the interaction of the decision-making subsystem with the management information system.

Comparison of Situation Awareness Theories

The decision-making subsystem is delivering four products ((1) instruction, (2) decision record, (3) requests and (4) instructions on information required) and is receiving four products ((1 & 2) threats and opportunities, (3) change and (4) information). First the products to deliver, the products the SA system receives, are analyzed.

Figure 7. Decision-making subsystem in adaptive-learning management system after Ackoff (1999).

The decision result in an instruction to the system to change, in AT this is the responsibility of the executive component not the orientational component. So there is no corresponding link between decision-making and system in OA. For the system to be able to monitor the outcome of the decision a decision record is sent to the memory and comparator. It includes assumptions made, the process used, expectations and information. In OA the same information can be found in the criteria of evaluation. The criteria of evaluation is used by the evaluative and inducing components of the motivation block to monitor the decision made. The request and instructions on information required are both about requests of information from the information subsystem, the first is a request for more or other information to the decision-making subsystem, the second is a request to send information required by the decision record to the memory and comparator so that a comparison can be made. The corresponding function in OA is not that explicit, in the model the memory is not show as a box, its a part of all the boxes, every box can make a request of information from the memory. The block meaning of input information is responsible for making data into information, when this transformation is made the information can be accessed by all of the blocks.

The analyze continues with the examination of the delivered products by the SA system to the decision-maker. Threats and opportunities and change are result of the diagnosis and prescription. The first is intended to attract the attention of the decider to a specific threat and opportunity, it is in the deciders interest to request the data needed to make the decision. In OA this function is preformed by the subjectively relevant tasks conditions. The unconscious processes are working to identify what can be a potential threat or opportunity, and when some is found, the unconscious processes tries to attract the attention of the decider. The change is preformed by a loop from the subjectively relevant tasks conditions through the evaluative and inducing components of the motivation that in turn affects the image-goal. This loop is affecting the decision-making by making diagnostics of the process used, and presenting these in the memory, accessible by the decider. The last interconnection

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with another block is the receiving of information from the information subsystem. The information is the respond to an earlier sent request. In the same manner as with request this interconnection is a part of every block.

6.1.3 Memory and comparator

The memory function of the memory and comparator block is to store the decision record and the information past from the information subsystem. According to Ackoff (1999) it is important that the memory is not too active. The human mind is too active for this storage (Ackoff, 1999). The other function of this block is to monitor and compare the assumptions made during the decision-making against the state of the system. If the block identifies any deviants, these are passed to the diagnosis and prescription block for future analysis. The interaction preformed by the memory and comparator function block with the adaptive-learning management system is shown in Figure 8.

Figure 8. Memory and comparator in adaptive-learning management system after Ackoff (1999).

The first function of the block, the memory, is as earlier discussed a part of every block in OA. But as the only storage available in the human is in the mind/brain it has to be accepted that the storage is too active. This is definitely a drawback of the human being, the stored information may be manipulated even during storage. There is no guarantee that information put into storage will remain unchanged. The memory of the adaptive-learning management system has also a wider function than just to store information. It has a monitoring function, which in OA is constituted by the mental image. In the mental images the static parts, the conceptual model and the image-goal, are most suitable for long-term storage of assumptions of the system. The dynamic part of the mental image, the subjectively relevant task conditions, is performing the comparison of the assumption against the state of the system. If deviants are found there will be explorative actions executed (the function of the diagnosis and prescription block in the adaptive-learning management system) and there may be a possible update of the conceptual model.

6.1.4 Diagnosis and prescription

The diagnosis and prescription is providing the regulative function of the system, as shown in Figure 9. The cause of the deviants are explored and understood. This may lead to changing instruction for the function blocks of the diagram. This means that the internal work of every function block has to be able to change. This gives the system the ability to learn and adapt (Ackoff, 1999). In OA the change comes from the

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change of image-goal and motivation. This change results in a change of focus for the system, in the ambition to reach this new goal the system makes an evaluation of how well it is performing, and if a need for change are discovered it may result in a change of process or fact (stored in the conceptual model). The conceptual model of the system is changing over time even though it is static. The knowledge about the system is stored in the conceptual model of the system. The change of the conceptual model may result in a change of the process of the system.

Figure 9. Diagnosis and prescription subsystem in management information subsystem after Ackoff (1999).

The three function blocks, conceptual model, image-goal and subjectively relevant tasks conditions are together making up the mental image (see Figure 11). This is the dynamic representation of the system of observation. In the same manner as diagnosis and prescription is performing explorative actions to find out what has caused the deviants, the subjectively relevant tasks conditions is doing the same. This is what in AT is named gnostic activity. These explorative actions can be conscious and unconscious, the conscious are performed in the subsystem situation awareness and the unconscious in the subsystem operative image. These explorative actions may result in a change of request and has the ability to change the image-goal if needed (through block 4 and 5).

6.1.5 Symptom and presymptom analyzer

The symptom and presymptom analyzer block, presented in Figure 10, aims to detect presymptoms and symptoms in the environment and in the system. If something of interest is found it will be reported to the diagnosis and prescription block for further analysis. The input to this block comes from the information subsystem (performance indicators). According to Ackoff (1999) these symptoms are best detected by statically methods. Ackoff (1999) defines the presymptoms as nonrandom normal behavior, Ackoff (1999) gives two examples, trends and cycles. The information subsystem has to know in advance what the system is looking for.

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Figure 10. Symptom and presymptom analyser subsystem in management information subsystem after Ackoff (1999).

In OA the information is kept in the past experience and in the conceptual model. The evaluative and inducing components of motivation and the image-goal are formulating a vector that adjusts the energy of the explorative actions of the subjectively relevant tasks conditions. If a deviant is detected it may lead to increased energy to the explorative actions about the deviation. The deviation can be mapped against the output of the symptom and presymptom analyzer, symptom and presymptoms, that is directing the explorative actions of the diagnosis and prescription block.

6.2 The mental model

The memory in adaptive-learning management system (Ackoff, 1999) is shared by the inactive memory of the memory and comparator and the active memory of the information subsystem. In OA the memory is a part of every function block or it is accessible from every function block. By memory OA is referring to all the data available for the process. As a contrast to memory OA is talking about the mental model, it is the memory that have the schemas and script, how to react in certain situations. The mental model is a reflection of the current situation and its features. The mental model (presented in Figure 11) of a human in OA is divided into three function blocks, conceptual model, image-goal and the subjectively relevant tasks conditions.

Figure 11. Mental model in functional model of orientational activity after Bedny & Meister (1999).

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Where the first two are static and change little over time, and the last is much more dynamic. The last is also performing unconscious explorative action that tries to find new facts or pattern that may be of interest. These explorative actions may perform simulation of future states and can in this manner identify patterns to observe (schemas and scripts) that the person does not have any earlier experience of.

The ability to find new patterns that the system has no earlier experience about is not supported in the adaptive-learning management system more than in the mind of the decision maker. There is no support for these unconscious explorative actions in his design. The explorative actions of the adaptive-learning management system are about to monitor the assumptions and the information concerned during decision making, to monitor if the knowledge known at decision making may have been wrong or have changed (Ackoff, 1999). The constant exploration performed by the unconscious processes gives the system the ability to not only reflect the actual features of the situation but also the potential ones (Bedny & Meister, 1999), to find more than the system is searching for. How this would be achieved in a computer program is out of the scope of this work.

6.3 Self-regulation

The image-goal gives the mental model a direction of attention. It is the helmsman of the mental model. The image-goal gives the system a goal directed self-regulation behavior. In the same manner as Ackoff (1999), Bedny & Meister (1999) also sees the goal as variable over time, as the situation are better understood the system will change its goal. Every function block should have the ability to influence and change the goal of the system, either direct or indirect through other function blocks. But in the adaptive-learning management system this is not made clear, this is because of the lack of representation of the goal in a function block as in OA. In the adaptive-learning management system the goal is in the “head” of the decision maker. This could be a drawback because important information could be left out and not presented for the decision maker. Because the goal of the system is not communicated to the parts that collects and processes the data into information. Therefore it is important that the goal of the system is accessible by the different function blocks of the system and that they have the ability to change it if it is found to be wrong.

Figure 12 Goal driven self-regulation of orientational activity after Bedny & Meister (1999).

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In OA two separated channels perform the goal driven self-regulation as shown in Figure 12. The first is the vector (association) between the evaluative and inducing component of motivation and the image-goal, and the second is the influence of the image-goal from the subjectively relevant tasks conditions through the block orienting and explorative actions.

6.4 Control

In adaptive-learning management system there are three levels of control (Ackoff, 1999):

1. The management system controls the organization.
2. The diagnosis and prescription are controlling the process of the system.
3. The diagnosis and prescription are controlling and evaluating its own performance.

The first have no corresponding function in OA because of that there is no organization to control, maybe the organization could be mapped against the body, but this is not the same. However if the system is to be used in the management function, it is important to remember that the system is in control of the organization, and is performing a controlling function. The second level of control is not that clear in OA, exportation and motivation of the action performed by the system may result in a change of process. This is not as centralized as in the adaptive-learning management system and is more conducted by every function block privately, even though the image-goal gives a central evaluation behavior. The last control level is very much as the second one. It is performed by an evaluation of the image-goal that results in a regulative function of the evaluation itself.

6.5 View of elements

Ackoff (1999) is talking about the importance of describing the system of observation with the right type of model, where purposeful systems are to be described by models intended for purposeful systems. Further he claims that if it is a goal seeking system that is to be modeled, the goal of the system has to be understood. In OA the view of the elements are described with the reflection. In the reflective-orientational activity the importance of reflecting not only the objects, but also the features of the system are emphasized. The reflection are concerned with the notions of goal, significance, motives, mental and behavior actions (Bedny & Meister, 1999). The reflective-orientational activity and Ackoff (1999) has the same view of how to monitor the elements of the situation. To reflect the elements is to have a wider understanding of the elements than just to monitor their attributes. There has to be a understanding of the features of the elements within the situation, a understanding of the role of the elements and their goal. To be able to make predictions about future states of the system, a understanding of how the elements reflect the system has to be reached. There is a need of two complementing views of the element, the first is concerned about understanding the elements role/goal in the system, and the other is about to understand how the element reflects the system.

6.6 Adapt and learn

In adaptive-learning management system, learning and adaptation is obtained by the management with the process initiated by the preparation of the decision record and that is terminated by a change of the system. The process of validating the information in the decision record to obtain new knowledge about the system is what Ackoff (1999) defines as learning. When the learning is done in a changing environment it is adaptation.

In OA there are two processes that gives the system a learning behavior. First there is the same process of learning as in adaptive-learning management system. Which starts with the preparation of the criteria of evaluation and is terminated with the change of image-goal and/or conceptual model. As a second process of learning the explorative unconscious process of the subjectively relevant tasks condition block is providing the system with a learning process. The unconscious processes are constantly evaluating earlier experience in the light of new. The evaluation is trying to put old information into new context or trying to find new information in the old data. So in OA there are two separated processes that are proving learning to the system.

6.7 Process

Both of the theories that are compared in this work involve different types of processes, transformation of data to data or data to information. Next the different types are presented and there contradiction to the system is discussed.

6.7.1 Unconscious and explorative processes

The unconscious process of the operative image is performing a constant evaluation and exploration of the data and information. The unconscious processes gives the system the ability to identify interesting facts that the system is not looking for. The unconscious processes also bring different views of the same situation, and they can perform simulation of different futures to come in parallel. This is preformed without the knowledge of the conscious process. When something of interest (what is of interest is guided by the goal and significance) is identified by the unconscious processes, the processes have the ability to try to attract the attention of the conscious process (Bedny & Meister, 1999).

6.7.2 Dynamic processes

The change of the adaptive-learning management system that are influencing every of the function blocks gives the processes their dynamic behavior, the ability to change. In OA the dynamic behavior of the processes are given by the change of the mental model. This affects all of the processes and gives them the ability to change. The two ways of providing the dynamic processes to the system are different in many aspects, centralization vs. decentralization, push vs. pull, etc. The analyze of what effect these differences have on the system are out of the scoop of this work.

6.8 What can be automated?

In the discussion about what can be automated Ackoff (1999) talks about a model that describes the data that is available for solving the problem and the process of transforming the data to a solution, a result. If both of these are present for the system, the problem solving can be automated and preformed by a machine. For a problem that does not have the model, automation cannot be performed (Ackoff, 1999). This

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problem is left for the humans to solve. Since they are able to solve the problems it can be assumed that the human has a model of the problem and at least one process to get some sort of solution. So the problem is not the lack of a model of the problem but that the models are not in a form that the computer can use.

The reason why the model is not available in a form that the computer can understand may be explained by:

- The model is too advanced or complex to be translated into a form that can be used by the computer.
- The information needed to understand the model is not present in the system.

Further research about this topic is out of the scope for this work.

6.9 Working with images

Bedny & Meister (1999) are presenting benefits with working with images instead of working with attributes. Images store more information than are requested, and as the system learns new features of the world, the system can go back to the images and extract new knowledge from a old situation. Bedny & Meister (1999) claims that the psychological process is mainly conducted on images and with manipulation of images. The individual makes internal images of the information given by the sense organs. The knowledge is in a high degree stored in the form of images. The use of images as a complement for attributes should be examined closer. Further research about the use of images is out of the scope for this work.

7 Conceptual system of Situation Awareness

In this chapter the result of objective three is presented. From the comparison performed in chapter 6 some key functions have been identified. As a summary of the comparison of the two theories, adaptive-learning management system and orientational activity, the result of the discussion is put together to form a system of function blocks. The function of the blocks could be found in both of the theories. In Table 3 it is shown how the functions of the two theories are divided in the conceptual design.

Table 3. Summarization of the comparison of adaptive-learning management system and orientational activity.

Result of comparison		
Orientalational activity	Management information system	Conceptual system
Meaning of input information	Information subsystem	Data gateway
Evaluative and inducing components of motivation	Memory and comparator	Evaluative system
Conceptual model, past experience	Memory and comparator	Memory
Image-goal	(Decision-making subsystem)	Goal
Making a decision and performance	Decision-making subsystem	Perform
Subjectively relevant tasks conditions	Symptom and presymptom analyzer, Diagnosis and prescription	Diagnostic

In the next coming chapters a discussion to clarify the function and connections of the function blocks in the conceptual design is executed. The chapters are divided by function block. Last in chapter 7 the conceptual design is presented in a diagram (Figure 13) to clarify the relations between the different function blocks of the SA system.

7.1 Data gateway

From the comparison made in chapter 6.1.1 function of the data gateway is identified. The data gateway gives the system a central information system that from past experience makes a translation of the symbols present in the system and its environment. The main function of the data gateway is to observe and inquire data from the environment and the system. This data is then processed in the influence of the past experience of the memory block and the goal block. The influence by the goal

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gives the goal driven interpretation of data. The perform block may require new data, as the data available is not understood or is not sufficient. The request made by the perform block should result in an information loop, inquiring of data, transforming data to information and finally deliver the new information to the perform block. The required data store to keep track of the earlier processed data of the data gateway is kept in the memory block. The data store that is needed by the data gateway to keep track of earlier made processes to process new data. When a decision is made the data gateway should send the required data for the monitoring of the decision to the memory block.

The inquiring of data should be directed by the attention (at least for the conscious process) that is part of the diagnostic function block. The shared attention puts a demand on synchronization and communication between the data gateway block and the diagnostic block.

7.2 Evaluative system

The evaluative block gives the system the regulative behavior discussed in chapter 6.1.3. The decision record should be constantly analyzed by the evaluative system to determine eventual deviants between the assumed result and the actual result. If deviants are found, these should be passed to the diagnostic block for further analyze. The evaluative system should also bring the motivation and sense discussed in chapter 2.2.3 and 6.3 to the system. In the interaction with the goal a vector is formed that brings goal driven self-regulation behavior to the system. The evaluative block should have two subsystems, motivation and sense, these should have the same function as in OA, to bring regulation of the energy to achieve the goal.

7.3 Memory

From the result of chapter 6.1.3 the requirement on the memory block is gathered. The system should have a shared memory that has its own function block to clarify its importance. This memory has both an active part and a passive part. The active part is under constant evaluation by the explorative processes of the diagnostic function block (the memory of subjectively relevant tasks conditions of orientational activity). The passive memory is the passive parts (conceptual model) of what Bedny & Meister (1999) names the mental model that among other things keep the schemas and scripts. Separated from the mental model the informational model exists representing the objectively given information. The information stored in memory should in a high degree be stored in image form (see chapter 6.2 for argumentation).

The memory also stores the past experience of the data gateway block and the assumptions made at decision-making, the decision record produced by the data gateway. The decision record should be constantly analyzed by the evaluative system to determine eventual deviants in assumption against result. If deviants are found, these should be pasted to the diagnostic block for further analyze.

7.4 Goal

From the discussion in chapter 6.3 it is concluded that the goal of the system is variable over time. The goal affects the whole system, and is affected by the motivation of the evaluative system and by the input to goal from the perform block. The goal function block gives the system a goal driven self-regulation behavior. The goal is stored in a form of an image.

7.5 Perform

From the comparison made in chapter 6.1.2, four products of the perform block were identified:

- Instruction of change.
- Affecting of goal.
- Request of information.
- Criteria of evaluation.

The decision made by the perform block results in a instruction to the system to change and a criteria of evaluation (decision record) in the same manner as in the design presented by Ackoff (1999). The criteria of evaluation is used by the evaluative system to control if the instruction gives the expected result. The criteria of evaluation should contain the process by which the instruction where decided, the assumptions made during the process, the information used in the process and the expected result. Even though it is agreed that SA and decision-making should be separated, it is obvious that there should be a close relationship. The decision-making is in control of the SA system in two ways, (1) the information for making a decision is presented by the SA system and (2) the process of the decision-making is guided by change requests of the SA system. The decision will also affect the goal of the system. The affect of the decision may be a change of goal as the decision may result in new rules for the situation. The decision may also give a direction to the goal of which aspects of the situation that is of interest, what to be expected of the future. The request of information may have two reasons (1) the perform block needs more or new information for decision making or (2) to generate the necessary information needed in the criteria of evaluation.

The comparison in chapter 6.1.2 also identified three product to be received by the perform block:

- Threats and opportunities.
- Change.
- Information.

The information delivered from the memory is the result of the request of information sent earlier to the data gateway or the threats and opportunities that were first identified in the data gateway, and then were passed via the memory to the perform block. The memory and data gateway works in close collaboration to generating the requested information. The data gateway is responsible for the inquiring of missing data and the memory is responsible for handling past information and making evaluation of the inquired data. The change gives the decision making its dynamic process, the process of how decisions are made may change. The product of threats and opportunities that should be handled by the perform block come from the diagnostic block.

7.6 Diagnostic

The operative image of OA, with its gnostic activities is a part of the diagnostic function block together with the conscious and unconscious processes (see discussion in chapter 6.7.1). The deviants identified by the evaluative system should direct the explorative processes. The result of the explorative process should result in three things:

- Update of situation understanding.
- Present threats and opportunities for the perform block.
- Influence on the goal.

The first function is mainly concerned with updating of the conceptual model and curious exploration of elements of the situation. As new knowledge is learned the goal of the system may be influenced. The new knowledge may also affect the processes of all of the function blocks of the system. The direction of change should be conducted in the same manner as presented by Ackoff (1999) (see chapter 6.4 for more information). The threats and opportunities presented for the perform block should be investigated (information request cycle) and may result in a decision. As a result of the decision the decision record is stored in the memory and is monitored by the evaluative system.

The decision record should affect the direction of attention of the conscious process. The dynamic and adaptive functions of the system are performed by the change directed from the diagnostic block. This gives the system the ability to adapt & learn (Ackoff, 1999). The change of the diagnostic process makes the system to change its diagnostic process (double loop learning). The process starting with the preparation of the decision record and terminated by the direction of change is according Ackoff (1999) what gives the system the ability to adapt and learn. See chapter 6.6 for a deeper discussion about adaptation and learning.

7.7 Conceptual design

From the discussion of chapter 7.1 to 7.6 requirements on the conceptual design have been presented. In Figure 13 the function blocks presented in Table 3 are shown. The association between the function blocks is identified in the discussions of chapter 6 and 7.

Figure 13. The conceptual design of situation awareness.

The system of interest is representing the system that is controlled by the SA system. The SA system should also be seen as a part of the system of interest as it is affected by and affects this system. The data gateway is the interface between the SA system and the rest of the system. The data gathered by the data gateway is interpreted with the help of the past experience stored in the memory. The memory block has a central function of the design and has several sub parts (active memory, passive memory, decision records, past experience, conceptual model, etc) used by many of the function blocks of the design. The goal gives the system a goal driven self-regulation behavior through the affecting of all the function blocks. The perform block, which is not a part of the SA system, instructs the system how to change to best achieve the goal. The SA system can instruct the perform block through changing of the decision process and through the information given as foundation for decision-making. The evaluative system has the function to identify deviants from the expected and normal and present these to the diagnostic block for further analyzes. The evaluative system also is responsible for determining of the significance (sense) of the goal and how much energy the system is using to reach the goal (motivation). The diagnostic block

Conceptual system of Situation Awareness

involves the attention of the system and the conscious and unconscious processes. The unconscious processes are performing undirected explorative actions to find new knowledge. The conscious process is performing directed exploration. The direction is the attention of the system.

The diagram is to show how the result of the work could be used in a computerized system of the future and are in need of deeper analyzes. These analyzes are out of the scope of this work.

8 Future research

In this section the result of objective four, future research that have been identified in the work with this report, is presented. Some of these may already have been examined earlier and a solution for the problem may exist. It is out of the scope of this work to make an inventory of these areas. The future research topics are presented in no specific order.

8.1 Realization

It should be analyzed if, and how, the design presented in this work could be realized in a computerized system. There are some big concerns that are especially interesting in the computerization of the system. A list of identified topics is presented below.

- **Memory.** It should be analyzed how a shared memory could be used for a decision making system. The memory should be the same for the SA component and the decision maker. This could be a problem if the decision maker is not a part of the computerized system, for example a human being. The separated memory could result in that the information given by the SA component to the decision maker, mismatches with the memory of the decision maker. This mismatch could have unfortunate effects, for the decision-making and the use of the system.

It should also be analyzed how the memory could have both active properties (dynamic) and stable properties (static), and still be able to make comparison between the types. The use of images as a storing type should also be examined. There are, according to Bedny & Meister (1999), some benefits with using images. How images could be used in a SA system should be analyzed (storage, indexing, searching, updating, etc.). It should also be examined how to handle common distribution issues like synchronization, replication and conflict handling.

- **Unconscious process.** The use of unconscious processes is one of the contributions of orientational activity. The explorative action preformed by the unconscious process is a simulation of possible futures, testing how things are working, finding new dependencies, identifying goals of elements, etc. The work of the unconscious process is performed by simulations and testing of hypotheses. It should be analyzed how this type of process could be realized in a computerized system.
- **Requiring data.** One of the drawbacks of a computerized system is, according to Ackoff (1999), that a computer cannot request information not presented in the model describing the problem. The human being can request data not present in the current model of the problem, to find new features of the problem. It should be analyzed how a computer could request data not presented in the model of the problem.
- **Curiosity.** A human that do not have a problem is not becoming apathetic. The person is curios and makes explorations of the environment to learn more about its features. The computer should not stop to execute just because there are no instructions to execute. There should be a curiosity to learn more about the situation. It should be analyzed how this behavior could be realized in a computerized system.

Future research

- Motivation and sense. Motivation and sense as presented by Bedny & Meister (1999) together with the image-goal gives the system its regulative features. Motivation is regulating the energy provided to achieve the goal, and sense is responsible for determining the priority (significance) of the goal for the system. This evaluation of the goal is bringing a function of choice to the system. How the concept of motivation and sense could be computerized should be analyzed.

8.2 Human aspects

As the system is taking over functions performed by humans, it is raising questions about how and if computers can imitate and fill the space of humans. Below some of the identified concepts are discussed.

- Authority of decision. When a computer will give orders to humans, the authority of the decision will be questioned. This will be a problem for the organization to solve. How the authority of automated decision can be kept at a high level should be analyzed.
- Moral. If an automated decision will result in damage to individuals or organization, who will be responsible for the result? Is it more accepted if a human makes an incorrect decision than if they were made by a computer? These moral aspects of using automated systems in decision-making should be analyzed.
- Keeping the semantics. Where the SA system is to present a representation of the situation for the decision maker, there will be a problem of keeping the semantic of the information given. Even though the operator of the system is trying to make an objective interpretation of the information given it is hard. The operator is influenced by his earlier experience and is making the interpretation of the information in a subjective way. It should be analyzed how information given by computerized systems can be delivered in an objective way to the operator.

8.3 Loops and feedback

In the designs of the different theories, loops of regulation and feedback exist. The result and contribution given by these should be analyzed further, it should also be analyzed how and if it would be possible to realize the loops in an automated system. Some of the loops are of special importance and are presented below.

- Goal-driven. The loop of goal driven regulation is complicated. The goal is constantly evaluated and changing. This change of goal also gives the effect that the process of the different functions of the system is changing. It should be analyzed how a computerized system should be designed to support changing processes that change to best reach a changing goal.
- Sensor feedback. The data gathering of the system should get a feedback of the importance and how the data is used. From this information the sensors should be able to change their behavior to better match the requirements of the system. It should be analyzed how this information could be given to the sensors and how the sensors should be designed to support the given feedback of the gathered data.

Future research

8.4 Activity theory

Activity theory should be analyzed closer to identify several interesting areas of application such as decision-making, evaluation of decisions, situation understanding. The ideas of gnostic activity and gnostic dynamic should be closer examined.

8.5 Simulation

The design presented in this paper is highly dependent on simulations to build the domain knowledge. As systems are getting more complex and getting higher level of self-learning, the demand for adequate simulations rises. It should be analyzed how simulation should be performed to learn automated systems.

9 Conclusion

In this chapter the result is summarized. The result is presented in the order of objective starting with objective one, finding a definition of SA (influenced by orientational activity and adaptive-learning management system). Followed by objective two, comparison of orientational activity and adaptive-learning management system, objective three, discussion about a conceptual model for a SA component of a system, and finally objective four, presenting future research.

9.1 Definition of Situation Awareness (SA)

From the argumentation of chapter 5 the following definition of SA emerged:

The conscious and unconscious dynamic processes to achieve a reflection of the systems purpose and form, function, system state and future system states.

This definition of SA is influenced by the orientational activity presented by Bedny & Meister (1999) and the adaptive-learning management system presented by Ackoff (1999). The definition is the result of objective 1, finding a definition of SA, with this definition the objective is considered fulfilled.

9.2 Result of comparison

In the comparison performed in chapter 6 some strong contributions of both of the theories were identified. These are presented below.

Strong contributions identified in adaptive-learning management system:

- Decision-record (chapter 6.1.2).
- Definition of adaptive and learning (chapter 2.3).
- Dynamic process through “diagnosis and prescription” and change (chapter 6.1.4).
- Separation of memory (chapter 6.1.3).
- Discussion of active and passive memory (chapter 6.1.3).

Strong contributions identified in orientational activity:

- Dynamic goal-drive self-regulation (chapter 6.3).
- Unconscious processes through operative image (chapter 6.7.1).
- Direction of attention through motivation and goal (6.3).
- Motivation and significance (chapter 2.2.3).
- Function of sensory memory (chapter 6.9).

With the comparison and analyze of chapter 6 and with summarization above. Objective 2, comparison of orientational activity and adaptive-learning management system, is considered fulfilled.

Conclusion

9.3 Conceptual design

As a result of the comparison of chapter 6 some key concepts and strong contributions were identified (summarized in chapter 9.2). These are put together in a conceptual design of a SA component (presented in Figure 13). The figure is discussed in chapter 7 and the function of each function block is presented. With the presented design of Figure 13 and the discussion of chapter 7 objective 3, discussion about a conceptual model for a SA component of a system, is considered fulfilled.

9.4 Future research

During the work, topics for future research has been identified, these are presented in chapter 9.4. With the presentation of future research topics of chapter 9.4 objective 4, presenting future research, is considered fulfilled.

10 Discussion

In this chapter the finishing discussion about the work and result is presented. The chapter is divided into to parts, discussion about the result and discussion about the process.

10.1 Discussion about the result

The theories that have been analyzed during the work have given interesting input to the design of the situation awareness (SA) system. The cognitive theories presented by Endsley (1995), how to support the operator of the SA system to keep attention on the things with the highest priority and to fast get an understanding of the properties of the situation. The theories of Bedny & Meister (1999), that presents an interesting view of how humans analyses and gets an understanding of the situation. And at last, the ideas presented by Ackoff (1999), the misassumptions about the usage of management information systems and the adaptive-learning management system. Ackoff also has given some definitions of key concepts of the SA domain.

I think that the design presented in this report have a big potential to be fruitful in the mission to give systems an understanding of the situation. The main strengths of the design are the ability to change the internal processes, the active and passive memory, the explorative unconscious processes and the work with images instead of attributes. Many of the designs for SA systems review in this work are focusing on putting together known technology instead of first analyzing the goal and requirements of the system. This work presents a analyze of the goal and requirement for a SA system.

The use of a complementary theory of both using a bottom-up and a top-down design to understand the situation should be more fruitful than just to use one of the designs. As the system is “born” information from the sensory organs have to be pushed up in a process to form a first knowledge. When this first knowledge of the situation has emerged, the system should start to explore interesting features of the situation, as a curious child. This should be conduced as a top-down process, the control system should tell the data gathering systems what is of interest to be analyzed further. In parallel with the explorative process the data gathering system should continue to push data up to the control system. This divided process of pushing and pulling data, is important so that no interesting features of the system are missed.

How the attention should be directed is also an important subsystem of the SA system. The strength of the presented design (Figure 13) is that the attention is influenced by the changing image-goal of the system. The explorative processes are presenting concepts for the conscious process of the system. If the unconscious process presents something that is of interest for the image-goal, the unconscious can be made conscious.

The system of SA should not be seen as a system that always makes the correct reflections of the situation. The level of accuracy must be analyzed based on the domain of use. When a SA system have been fully tested and is ready to used, new problem will rise. In a domain where computers have automatically analyzed the situation and made decision, the authority of the system will be questioned.

Discussion

The design presented in this work could be used in various of fields, from automated steering in cars and airplanes to the command and control of national armies. The learning and adapting features of the SA system should guarantee for the system to be fruitful in the understanding of situations. The applications based on the ideas presented in this work should give new possible of using automated processes to determine opportunities and threats of a social system. To give systems a situation awareness.

10.2 Discussion about the process

When the work with this report started there were a curiosity to find a design that were a reasoning system. A system that understands the features of the observed system. In the design presented in Figure 13 such a system is presented. If the design is used in a way that highlights the misassumptions about how to use a management information system presented by Ackoff (1999) the system should be a success in many domains.

The comparison of the theories were much more difficult than expected. To be able to make the comparison of the theories, the theories needed to be understood. To gain this understanding a lot of material needed to be read and understood. This was a time consuming work. As a deeper understanding of the theories arise it became clear that the comparison would be a hard knot to solve. To make a good comparison the functions of the design needed to be fully understood. This in turn required gaining an understanding of new concepts. Again a lot of time was spent in reading and analyzing the material. The decision to compare adaptive-learning management system against orientational activity has been questioned during the work. With the result presented, it seems like the decision has given new ideas for the design of a SA system. This was in the beginning the desired result of the process.

As all the objectives of this work are fulfilled the use of literature study must be seen as a good choice. The result should be even more interesting if it where discussed with the persons behind the analyzed theories. This has not been done because of the limited time. To test if the ideas presented in this report are fruitful a realization of the system could be implemented. This has not been done because of the limited time. The difference between the expected result and the actual is that the requirement specification has not been formulated. Instead some key functions have been identified and presented. These key functions should need to be analyzed more deeply to generate the requirement specification. This was not done because of the lake of time.

References

- Ackoff, R.L. (1999). *Ackoff's best: his classic writings on management*. New York: John Wiley & Sons.
- Adams, M.J., Tenney, Y.J., Pew, R.W., (1995). Situation awareness and the cognitive management of complex-systems. *Human Factors*, 37, 85–104.
- Ausubel, D. P. (1968). *Educational psychology: A cognitive view*. New York: Holt, Rinehart & Winston
- Bedny, G., & Meister, D. (1997). *The Russian theory of activity: Current Applications to design and learning*. Mahwah, NJ: Lawrence Erlbaum Associates, Inc.
- Bedny, G., Meister, D., (1999). Theory of activity and situation awareness. *Int. J. Cognitive Ergonomics* 3(1), 63–72.
- Cantwell, J., Schubert, J., & Svensson, P.(2000). *Informationsfusion – Förslag till "strategisk forskningskärna" år 2001-2005*. Linköping: Försvarets forskningsanstalt, Avdelningen för Ledningssystemteknik.
- Cao, G., Clarke, S., Lehaney, B. (2003). The Need for a Systemic Approach to Change Management – A Case Study. *Systemic Practice and Action Research*, vol 17.
- Denoeux, T. & Zouhal, L. M. (2001). Handling possibilistic labels in pattern classification using evidential reasoning. *Fuzzy Sets and Systems*, 122(3), 47-62.
- Endsley, M. R., (1988). Design and evaluation for situational awareness enhancement. In *Proceedings of the Human Factors Society 32nd Annual Meeting*. (pp. 97–101). HFES, Santa Monica.
- Endsley, M. R., (1995). Towards a Theory of Situation Awareness in Dynamic Systems. *Human Factors*, 37, 32-64.
- Fracker M.L, (1988). A theory situation assessment: Implications for measuring situation awareness. In *Proceedings of the Human Factors Society 32nd Annual Meeting*. (pp. 102–105). HFES, Santa Monica.
- Gilson, R.D., (1995). Situation awareness — special issue preface. *Human Factors*, 37, 3–4.
- Kaber, D.B., Endsley, M.R., (1997). Out-of-the-loop performance problems and the use of intermediate levels of automation for improved control system functioning and safety. *Process Saf. Prog.* 16 (3),126–131.
- Llinas, J., Bowman, C., Rogova, G., Steinberg, A., Waltz, E., White, F. (2004). Revisiting the JDL Data Fusion Model II, In *Proceedings of the 7th International Conference on Information Fusion* (pp. 1218-1230). Stockholm, Sweden.
- Lomov, B. F. (1984) *Philosophical and theoretical problems of psychology*. Moskow: Science Publisher.

References

- Oshanin, V. A. (1977). Concept of operative image in engineering and general psychology. In B. F. Lomov, V. F. Rubakhin, & V. F. Venda (Eds.), *Engineering psychology*. Moscow: Science Publisher.
- Pushkin, V. V (1978). Formation of situational concepts in structure of activity. In A. A. Simirov (Ed.), *Problem of general and educational psychology* (pp. 106-120). Moskow: Pedegogy.
- Stanton NA, Chambers PRG, Piggott J. (2001) Situational awareness and safety. *Safety Sci*, 39, 189-204.
- Smith, K., Hancock, P.A., 1995. Situation awareness is adaptive, externally directed consciousness. *Human Factors* 37, 137–148.
- Tikhomirov, O. K. (1984) *Psychology of thinking*. Moscow: Moscow University Publisher.
- Welford, A. T. (1962). On the human demands of automation: Mental work conceptual models, satisfaction and training. *Industrial and business psychology* (pp. 182-184). Copenhagen: Munksgaard.
- Whitaker, L. A., & Klein, G. A. (1988). Situation awareness in the virtual world: Situation assessment report. In *Proceedings of the 11th symposium of psychology in the Department of Defense*, USA.