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Team Situation Awareness in Practice

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Team Situation Awareness in Practice

This project will investigate how large screen solutions can potentially support team situation awareness. Situation awareness is the perception and understanding of a current situation and its elements and history with respect to time and/or space in order to make good decisions when needed. In this thesis, situation awareness relates to large and complex dynamic systems such as the process industry and oil and gas. Team situation awareness concerns the situation awareness of people working together in a team, for example a shift team in a control room. When a situation appears that needs interaction, the basic understanding of the current situation ought to be equal, however that may not be the case. Making a decision based on different premises can cause critical consequences and even result in catastrophic outcomes. The main focus of this project is to perform an evaluation of different solutions for large information visualisation systems in control rooms with respect to team situation awareness.

Tasks

This project will have a major focus on evaluating various solutions for presenting overview information in a control room setting with respect to team situation awareness. The outline of the project will be:

- Perform a literature study of situation awareness, team situation awareness and team collaboration in process industries
- Review various large information presentation solutions (large screens, giga mapping, 360 degree control room)
- Evaluate these solutions with respect to the ability to support team situation awareness. Identify which factors are relevant for team situation awareness.
- Write M.Sc. thesis

Preface

This is a Master Thesis written at the department of Engineering Cybernetics at the Norwegian University of Science and Technology (NTNU) in Trondheim, Norway, during the spring semester of 2015. The master thesis concerns team situation awareness in control rooms for the oil and gas industry.

The master thesis was given by ABB, who wanted to find better solutions and factors that could improve the situation awareness for the operators.

Acknowledgements

I want to thank my supervisor at the department of Engeneering Cybernetics, Professor Kristin Y. Pettersen. I also want to thank my two supervisors at ABB, Charlotte Skourup and David Romero for all guidance and support during my work.

A big thanks to the operators from Statoil for letting me join the operator training at Statoil Stjørdal, and for letting me observe and interview them. Also, thanks to Statoil for allowing me to use screen shots from the process. Thanks to the the operator working at Draugen for giving me insight in the working life on the platform. I also want to thank the people working at the simulation park at Høyskolen in Buskerud and Vestfold for being helpful and sharing information about SimSam.

I would also like to thank my classmates and office partners, Thomas, Sveinung and Bjørn-Olav, for good company and help during this year. Thanks also goes out to all my friends and family for all support during my studies.

Last, but not least, I would like to thank my friends Nina F. Lillemoen and Runa Lie Søberg for helping me proof reading my thesis.

Stine Nicolaysen Raaen,
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Abstract

To work in a team of operators in a control room can be both stressful and challenging. When a situation occurs that needs interaction, the basic understanding of the current situation ought to be equal for all involved parties - even though that may not be the case. Making a decision based on different premises can cause critical consequences and even end up in catastrophic outcomes. A high degree of common understanding in the team, a high team situation awareness, is therefore important in a team.

There are several factors influencing the teams situation awareness, one of them is how the information is presented. The aim of this thesis was to perform an evaluation of different solutions for large information visualisation displays in control rooms with respect to how they support team situation awareness. The solutions evaluated was large screen displays, GIGA-maps and 360 degree control rooms.

After performing a literature review on situation awareness and other relevant factors, the current situation in control rooms had to be investigated. This was done by observations and interviews with control room operators and people with knowledge on this theme.

Based on brief technology analysis and input collected from interviews it seemed that the main focus in order to increase the situation awareness should be a good training program. The training program should focus on *why* things happen and *what* really happens in the process, not just how to fix the problem. After a high awareness is gained, informative and readily understood interfaces should be designed on the best suited information presentation solution. As for now, the best solution, with respect to the ability to support situation awareness, is the large screen displays. This is because this solution provides the operators with an appropriate amount of information. The two other solutions investigated, GIGA-maps and 360 degree displays, might be more beneficial in the case of training the operators. The applicability of these above mentioned technologies is still open for question and current topic of investigation by the human factors community in Norway.

Sammendrag

This is the abstract in Norwegian

Å jobbe i et operatørteam i et kontrollrom kan være både stressende og utfordrende. Når det oppstår en situasjon som trenger interaksjon, er det viktig at den grunnleggende forståelsen for denne situasjonen er lik hos de som er involvert. Dette er ikke alltid tilfelle. Å gjøre beslutninger basert på ulike premisser kan gi kritiske konsekvenser, som igjen kan gi katastrofale utfall. Derfor er det viktig at teamet har en høy grad av felles forståelse, også kjent som situasjonsbevissthet.

Det er flere faktorer som påvirker situasjonsbevisstheten. En av faktorene er hvordan informasjonen i kontrollrommet blir presentert. Formålet med denne oppgaven var å evaluere forskjellige informasjonsløsninger i kontrollrom med tanke på hvordan de støtter situasjonsbevisstheten hos operatørene. Løsningene som ble evaluert var storskjermer, GIGA-kart og 360 graders kontrollrom.

Etter å ha gjort et litteraturstudie på situasjonsbevissthet og andre relevante faktorer, ble det undersøkt hvordan kontrollromsituasjonen var i dag. Dette ble gjort ved observasjoner og intervjuer med kontrollromoperatører og andre som hadde kunnskap på dette feltet.

Basert på en kort teknologianalyse, observasjoner og innspill fra intervjuer virket det som om hovedfokuset for å forbedre situasjonsbevisstheten bør ligge i å bedre opplæringsprogrammet for operatørene. Opplæringsprogrammet bør fokusere på hvorfor ting skjer og hva som egentlig skjer i prosessen, ikke bare på hvordan man skal løse problemer. Etter at man har klart å oppnå en høy grad av forståelse hos operatørene, må informative og lett forståelige grensesnitt designes for den løsningen som er best egnet i kontrollrommet. Per i dag, er den beste løsningen for å støtte situasjonsbevissthet i kontrollrom storskjermer, fordi disse gir operatørene en passende mengde informasjon. De andre løsningene som ble undersøkt, GIGA-kart og 360 graders kontrollrom, er trolig bedre å bruke i en opplæringssituasjon. Anvendelsen av disse tre løsningene er fortsatt åpen for diskusjon og for å undersøkes videre.

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List of Abbreviations

HMI - Human-Machine Interface
SA - Situation Awareness
SOD - System Oriented Design

Chapter 1

Introduction

1.1 Background and Motivation

Imagine that a control room operator notices that the flow decreases through a pump. The operator starts to search for a failure in the pump and asks the outdoor operator to go to the pump to verify the decreasing flow, which he confirms. He also checks the valve, which is located before the pump. This valve is 70 % open. He decides to increase the speed of the pump. Shortly after the pump stops because it is overheated. The real reason to this problem is a leakage in the connection between two pipes between the valve and the pump. The operator did not have a complete overview of the situation.

When a situation occurs that needs interaction from the operators in the control room, the basic understanding of the current situation ought to be equal for everyone involved, but that may not always be the case. Making a decision based on different premises can cause critical consequences for the process and even end up in catastrophic outcomes. Team situation awareness concerns this situation awareness of people working together in a team, for example shift teams in a control room - which is the focus in this thesis.

The focus of this project is to perform an evaluation of different solutions for large information visualisation systems in control rooms with respect to team situation awareness.

1.2 Objective and Purpose

The objective of this thesis is to examine team situation awareness in control rooms in the oil and gas industry. One of the factors that has in impact on the situation awareness is how information is presented to the operators. Three different solutions for information presentation will therefore be evaluated in light of how they support the team situation awareness in control rooms. These three solutions are large screen displays, GIGA-mapping and 360 degree control rooms. Other factors that are important for a good situation awareness in this type industry will also be discussed.

Based on brief technology analysis and input collected from interviews it seemed that the main focus in order to increase the situation awareness should be a good training program before making new information presentation solutions. The large screen displays are the best suited solution at this point of time, while the two other solutions are probably better for use in a training programme. However, the applicability of these above mentioned technologies is still open for question.

1.2.1 Limitations

The initial plan for the field studies was to visit several control rooms to observe how the teams worked together, but this turned out to be difficult. One possible explanation to the lack of access to users is the current low level of activities and uncertainty in the oil and gas business in general. Therefore, it was decided that the observations are mostly based on interviews with control room operators, and thereby more based on their opinions than on external observations. This may limit the research results as they are based on subjective opinions, not objective observations.

It is also important to remember that a method working well for one team in a control room may not work well for another. Teams and situations will always be different, so there are no solution that will fit perfect to everyone and everything.

1.3 Approach

The work started with a literature study on situation awareness and other relevant fields such as mental models and solutions for control rooms. After completing the literature study questions to ask the operators were made and a simulator for a control room was visited, which included conducting interviews. Later, another operator, from another company, was interviewed. This time without observations in the control room. At last an engineer was interviewed in order to get another perspective on the theme.

To finish the work, the current control room solutions were evaluated in light of the theory to find factors that worked well and what could be improved to support team situation awareness. The conclusion is based on the factors that generally improve the situation awareness for the operators.

1.4 Structure

This thesis consists of nine chapters, a reference list and an appendix, which are organized as follows. Chapter 1 gives an introduction to the thesis where the context and objective are presented along with some limitations. Chapter 2 contains the background information on the work environment and tasks for a process operator. Chapter 3 presents the theoretical background needed to understand situation awareness, mental models, human processing and how a good interface design can support this. Endsley's model for situation awareness is explained in Chapter 4.

In Chapter 5 the three information presentation solutions are presented, along with how they could support situation awareness. The observations and interviews are gathered in Chapter 6 and an evaluation on situation awareness in light of the earlier chapters is presented in Chapter 7. Chapter 8 is a discussion, while Chapter 9 presents conclusions and further work. An appendix with the questions asked are attached at the end.

Chapter 2

Background

This chapter aims to provide the reader with information on the work environment and tasks performed by an operator in a control room.

2.1 Control Room

Any industrial process needs to be supervised and controlled by personnel on site (operators). Whenever the supervision and control tasks take place in a room, this is called a control room. A control room is thereby a room where tasks such as monitoring, evaluation and operational planning is performed by members of a team of operators. This thesis will focus on the control rooms in process industry, and how teams are working together.

Aune (2000) stated that teams working in a control room have complex tasks that may have many different factors affecting them. The degree of automation defines how much of the task is allocated to the human workers and the system. A low degree of automation requires the humans in the systems to perform most of the tasks, and high degree of automation requires the systems to perform most of the tasks. In the case of high degree of automation, the human will only monitor the system.

The work in a control room is affected by many factors such as the different persons working there, the communication at the plant and how the workers collaborate. The systems are often large and complex and in order to do a good job the operators need good knowledge of the system and the process it controls.

2.1.1 The Development of Control Rooms

Commentators back in year 2000 already observed significant changes in control room design and use over the previous four decades, according to Aune (2000). In the very beginning there were local surveillance in the plants, later (about 1950) there was a service room with an analogue board for remote monitoring and in 1960 computers were introduced as an extra facility in the control room. Today's control rooms are equipped with automation systems consisting of several computers, color screens and several operator desks.

When designing and developing a control room one of the most important things is to have information about the team working there - how many operators they are, what kind of work tasks they perform, how the operators communicate and what the technical equipment required in the control room is. The new design is supposed to help the operators do a better job, not to complicate it.

2.1.2 Work Tasks In a Control Room

The operators in a control room must have an overview of the processes on the plant. Typical activities for them are for instance to start, stop and maintain different systems on the plant. Other important task are monitoring, evaluating and deciding on actions, plans, optimizing the operations, reporting on actions and situations, direct and perform procedures, communicate with the process control crew and company management.

These tasks may be performed in different ways, and to make the process as efficient and safe as possible, operator training is required. Different situations, such as critical situations and alarms, may occur and this affects how the operators perform their tasks. Other factors, like personal and external factors, affects the way the operators work as well.

2.2 The Operator

In the process industry, where the system contains automation, the tasks are shared between the operator and the automation system. Usually, under stable operation, the operators task are mostly monitoring of the process, adjusting variables and parameters.

Bråthen et al. (2001) suggests that one can see the whole process of the control process as a closed loop, with the operator (the user) in the end of it - as seen in Figure 2.1. It is important to keep the operator in the loop, especially when having autonomy in the process.

The operators working in a control room have many different tasks to perform and much responsibility for the plant operations. One little mistake might do much damage or cause high financial losses. It is important that the operator understands the process and that he or she can "simulate" the results of an action in their head. There are also a lot of system parameters and values that needs to be remembered, and the cognitive workload in this type of work is huge.

The systems the operators operate are mostly dynamic systems (real time systems that are constantly in change), and it is not only important that the operator takes the right decision - it must be taken at the right time as well. A process might have a long duration, and depending on the kind of process, the operator may not see the outcome of an action before hours or days later. For that reason, it is important that the operator understands the process, and that they can predict the results of an action before performing it.

The operators would normally work in teams, and it is important that they are able to cooperate. It is also an advantage that the operator communicates easily with others, as the operators have to collaborate closely to make the process easier. Recommended personal qualifications for a control operator is therefore to be structured, efficient, good at working in a team and good at following plans and procedures. The operator must also have knowledge of the process in order to make the right decisions and actions.

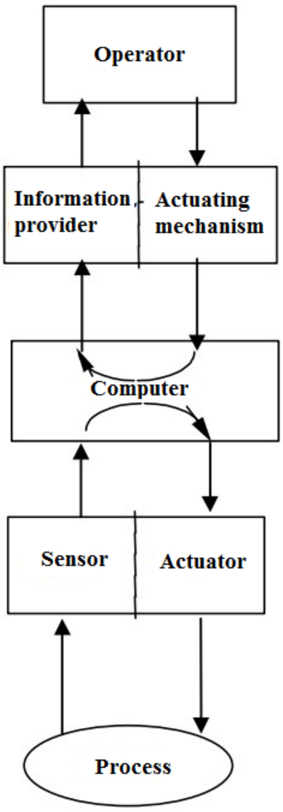

Figure 2.1: The monitoring process, adapted from (Bråthen et al., 2001)

2.3 Process Industries

2.3.1 Process Manufacturing

One can distinguish between process manufacturing and discrete manufacturing. The first is the type of manufacturing this thesis will focus on, which is production where the products are undifferentiated - like oil, natural gas and salt. The latter type of manufacturing is where the products are easily identified, and it is a production of distinct items such as cars, toys and computers.

Process manufacturing is production of goods that are typically produced in bulk quantities, and includes chemicals, food, gasoline and pharmaceutical. This type of industry focuses on the ingredients, formulas and bulk materials, while discrete manufacturing is associated with parts, material bills and units.

2.3.2 Team Collaboration in Process Industries

A team working on a platform will be a intra team (explained further in Chapter 3.7) where the persons work closely and are available for questions and collaboration. A shared mental model will often be developed during a training period, where the new operators learn from the experienced operators.

Communication is very important when working in a control room - always inform your co-workers about your actions in order to avoid misunderstandings or that both operators are trying to fix the same problem on two different computers.

As the operators have to cooperate, the control room has to be designed in a way that allows them to. The operators have to be placed near the information presentation solution and eachother, in order to communicate easily. The location of the control room is also important, it has to be placed where there noise is kept at an excepted level in order to be able to concentrate and cooperate.

Other factors that may have an impact on the collaboration in a control room are the sense of responsibility, hierarchy between the operators, their personalities, the boss and the divisions of power.

Chapter 3

Theoretical Background

This chapter presents relevant theory for the thesis. This theory is needed in order to understand an operator's and a team's situation awareness (SA), how they think and perceive and factors that can improve the SA.

3.1 Situation Awareness

Endsley (1995b) (p. 36) gives a definition as follows "Situation awareness is 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." In other words, SA is an individual's awareness in a situation - one person's understanding of "what is going on" in that exact situation.

3.1.1 What Affects Situation Awareness

Endsley's model for SA is presented in Figure 4.4 and shows the concept of one way to think of SA. The model will be described in more detail later in Chapter 4. It shows that SA is a product of perceptions of elements in the environment, and that it is affected by the operators feedback. The operators' personal factors does also have an impact on SA, like the operators system experience and training. Other personal factors may be preconceived knowledge of how a system should function, the objectives of interacting with the system and innate abilities (Kaber and Endsley, 1998). Endsley and Robertson (1996) also suggest that the cognitive workload has an impact on the SA, because this affects the decision making process and the subsequent actions performed by the operator.

The SA is different from person to person even it people have the same information available and the same working conditions. That is because the cognitive factors such as experience, mental models, schemata and qualifications differ between individuals.

3.2 Team Situation Awareness

A team can be characterized as a group of people with a shared goal. Working in a team may give several advantages over single operators, such as sharing the workload between operators, contributing with expertise on subtasks and there may be an advantage in safety considering that the operators can check each others work (Hauland, 2008).

Salas et al. (1992) defined a team as "a distinguishable set of two or more people who interact dynamically, interdependently, and adaptively toward a common and valued goal/objective/mission, who have each been assigned specific roles or functions to perform, and who have a limited life-span of membership". Taking this definition, Hauland (2008) writes that associated with the goal the operators may have a sub-goal that is supportive of the teams goal. This sub goal can show what elements in SA the team member focuses on, which can be the team members responsibility within the team. Endsley (1995a) presents the team SA in Figure 3.1. There will be some overlap in the team members' SA. This information constitutes much of the team coordination, such as coordination may be communication, displayed information or something else.

Endsley (1995a) states that team SA can be defined at the degree of each team member's SA required for his or her responsibilities, not included the overlapping SA. Each team member has to know a piece of information, it is not sufficient that one knows everything and the other nothing if the team consists of two members. It is important to know ones required part, in order to not become the weakest link in the team.

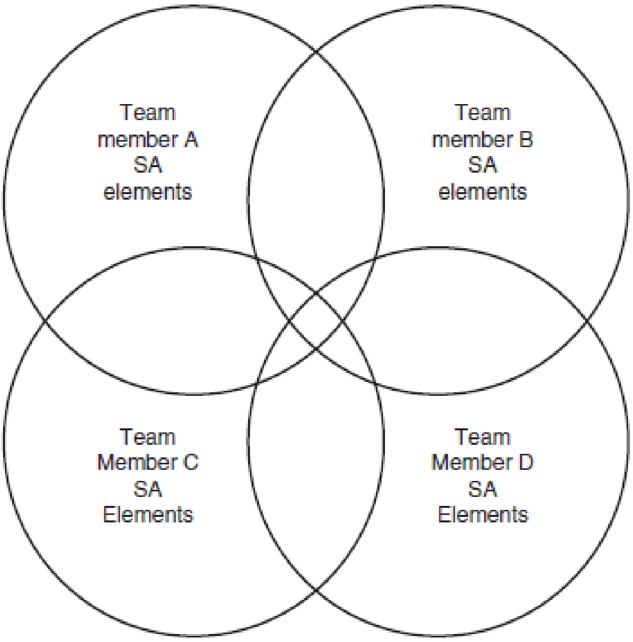

Figure 3.1: SA feedback loop, from (Salmon et al., 2008)

A related concept, *shared situation awareness*, is sometimes defined the same as team situation awareness, and sometimes not. There is still not an agreement about what is what, but in this thesis both these concepts are treated as the same. An example of an article where these concepts are treated separately is (Javed and Norris, 2012).

3.3 Automation and Situation Awareness

Automation is when functions previously performed by humans are replaced by a machine. The degree of automation in systems may vary, and Parasuraman et al. (2000) presented Table 3.1 to show the different levels. A higher degree of automation requires higher cognitive demands.

Table 3.1: Levels of automation, from (Parasuraman et al., 2000)

High	10.	The computer decides everything, acts autonomously, ignoring the human.
	9.	Informs the human only if it, the computer, decides to
	8.	Informs the human only if asked, or
	7.	Executes automatically, then necissarily informs the human, and
	6.	Allows the human a restricted time to veto before automatic execution, or
Low	5.	Executes that suggestion if the human approves, or
	4.	Suggests one alternative
	3.	Narrows the selection down to a few, or
	2.	The computer offers a complete set of decision/ action alternatives, or
	1.	The computer offers no assistance: human must take all decisions and actions.

A high degree of decentralized automation is quite common in today's systems, and have both positive and negative influence on the SA. The increased level of autonomy has distanced the human from direct control of the system, but it is believed that automation gives better reliability, performance and that the cost can be reduced for many functions. With more automation, the humans original role has been changed to not being that involved in operating the system, but rather monitor it. Endsley (1996) writes that people are slow at detecting problems that needs interaction, and that it takes additional time after that in order to understand what has happened to take the correct actions. To act correctly requires a high SA. Endsley presents three mechanisms that have an impact on SA, these are as follows (Endsley, 1996):

1. "Changes in vigilance and complacency associated with monitoring
2. Assumption of a passive role instead of an active role in controlling the system
3. Changes in quality or form of feedback provided to the human operator "

All these mechanisms can contribute to an out-of-the-loop problem in performance of the tasks, and the fact that automation requires higher levels of SA makes it harder as well. The out-of-the-loop problem was presented in Endsley and Kiris (1995), which stated that this could result in loss of skills and problems for the SA. Out of the loop performance is seen as one of the most substantial negative consequences from automation, and it may be diffuicult for the operators to do manually work in case of an failure in the automation (Endsley and Kiris, 1995).

The design of automation systems is very important for SA, because problems such as monitoring, passive decision making, poor feedback and poor mental models are closely related to the bad design of the system. The automation itself may not be the problem, however the way it has been implemented in the system can be.

Poor feedback in automated systems is also a problem, and Norman (1990) stated that "Without appropriate feedback, people are indeed out of the loop: they may not know if their requests have been received, if the actions are being performed properly, or if problems are occurring" (Norman, 1990). The designers of the system must remember to give the user of a system feedback, in case of poor feedback the operators lose some of their SA, which again can lead to accidents.

As mentioned, automation has some positive impact as well - the problems listed does not always happen, most of the time the automation works as desired. Regarding the SA, automation helps by reducing the operators workload, but the workload does only have a negative impact on SA at high levels of workload.

3.4 Human Information Processing

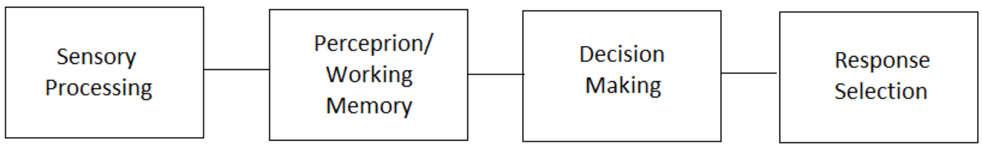

Figure 3.2: Human information processing, from (Parasuraman et al., 2000)

Parasuraman et al. (2000) presented a four staged view of how humans process information, and the model in Figure 3.2 shows a simplification of the many elements that are involved in the processing of information. The first stage is where the human register sources of information, while the second is the conscious perception of elements and retrieving information in the working memory. The third stage is where the cognitive processing is used for making informed decisions in a specific situation, while the fourth and last stage is the action performed based in the decision made in the third stage.

Wickens (1991) also presented a model for information processing, and based on that model it is concluded that not all information can be processed at once. That is because the elements might depend on the same resources, such as writing and seeing. From this one can conclude that the number of elements a person can observe at one point at a time is limited, and thereby how much information a person can process is also limited.

3.4.1 Cognitive Processes

Cognitive psychology deals with how humans perceive, think, learn and remember. In other words, the focus is on how humans process information - how the information is treated and how this leads to a response. Processes affecting the SA, that is attached to cognitive psychology, are attention, formation of concepts, judgement and decision making, learning, memory, perception, problem solving and reasoning.

The above mentioned human processes are the essence of SA - a human's knowledge and integrated understanding in situations. McLeod (2007) writes that the cognitive psychology was needed when the humans started to use the computer - it was needed to investigate the human mind.

In complex situation humans use schemata. Schemata are sets of expectations one has of a situation. Mandler and Johnson (1977) says that the schemata is developed from two sources - the first is stories they have heard and the sequence of them and the second are from experiences and knowledge about actions. These two sources will form a schemata which only contains perceptions, actions, feelings and events that are relevant for that situation. An example of a schema is a doctors schema of how a person with a flu looks like, and the doctor will have a different schema for a person with a stroke.

3.4.2 Working Memory

Baddeley (2000) defines working memory in cognitive psychology as "a limited capacity system allowing the temporary storage and manipulation of information necessary for such complex task as comprehension, learning and reasoning".

A model for working memory with three components are presented in Figure 3.3. The model consists of three parts - the central executive, which is an attentional controller and two subsidiary systems. These two systems are the phonological loop, which holds speech-based information, and the visuospatial sketchpad which holds visual information. The two systems are capable of both storing information themselves, and combine this information from either sensory input or the central executive.

Figure 3.3: Working memory, from (Baddeley, 2000)

Figure 3.4 is developed from the model in Figure 3.3, where the shaded areas represents "crystallized"-cognitive systems capable of accumulating long-term memory, such as semantic knowledge and language. The others represent "fluid" capabilities. These are the capacities that are unchanged by learning, like attention and temporary storage.

3.5 Rasmussen's Model For Human Behaviour

People have different ways of process information around them, different ways of acting and make decisions in different situations. Rasmussen developed a model for the different levels of behaviour that humans can face situations in, Figure 3.5 shows the three different levels and a description for the different levels is given here (Rasmussen, 1983):

Knowledge-based behaviour is when the operators have to analyse and evaluate

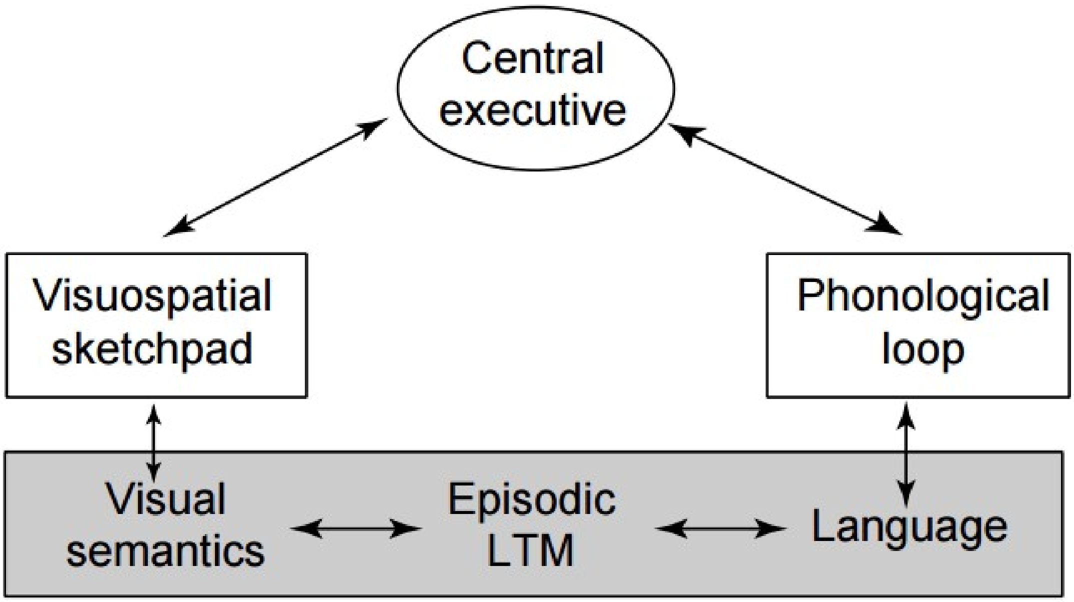

Figure 3.4: Working memory, from (Baddeley, 2000)

what to do in a process situation. This result in a slower process because it requires a lot of thinking, and is therefore more demanding than the other behaviours. This is the kind of behaviour used when solving an unknown and new problem.

Rule-based behaviour is when the operators follow certain rules to perform the task. The coupling between a pattern and actions are quite quick and does not require a lot of thinking. This kind of behaviour is based on training, and is developed through performing the tasks.

Skill-based behaviour is when the operators actions are a direct action from sensing to taking action. The action is subconscious and may not be explained explicitly. Such behaviour require a lot of practice, and because it is subconscious it is easily performed, and doesn't require a lot of thinking before the action is performed.

By training and performing a task several times one can move between these levels of behaviour. A person may also be at different levels for different tasks, one can have skill-based behaviour in one situation and knowledge-based behaviour in another.

The boundary between skill-based behaviour and rule-based behaviour or between

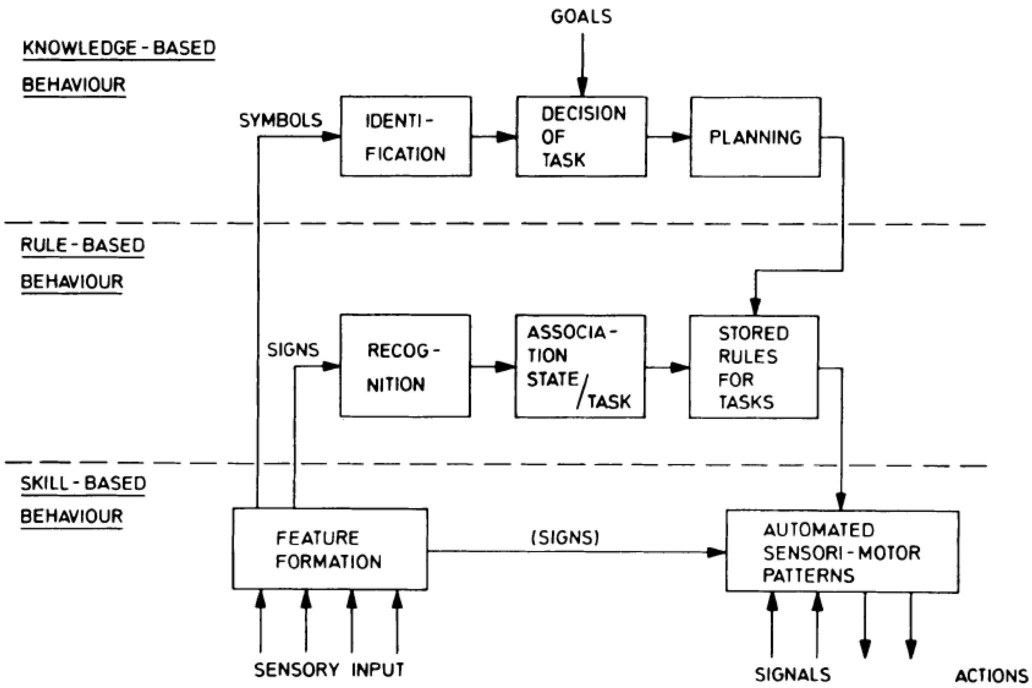

Figure 3.5: Rasmussens model, from (Rasmussen, 1983)

rule-based behaviour and knowledge-based behaviour is floating. According to Bråthen et al. (2001) humans keep the processing of information on the lowest level possible for carrying out the given task.

In most industries a higher degree of automation is introduced, which result in the operators' work tasks being focused on monitoring and creating solutions. This kind of work requires a higher cognitive workload - such as memory, knowledge, imagination, assessment ability and perception (Bråthen et al., 2001).

Bråthen et al. (2001) presents a figure of the steps in a decision making process given by Rasmussen. The process starts with the operator detecting a situation, that might need an action from the operator. After the detection the operator will be on the alert for new observations of relevant data. The operator identifies the systems current state, and interprets possible consequences and goals. After the interpretation, the operator will evaluate the possible goals, and after choosing the best, the operator will define the tasks that leads to the desired state and formulate a procedure based on this definition. Finally, the operator will execute the task.

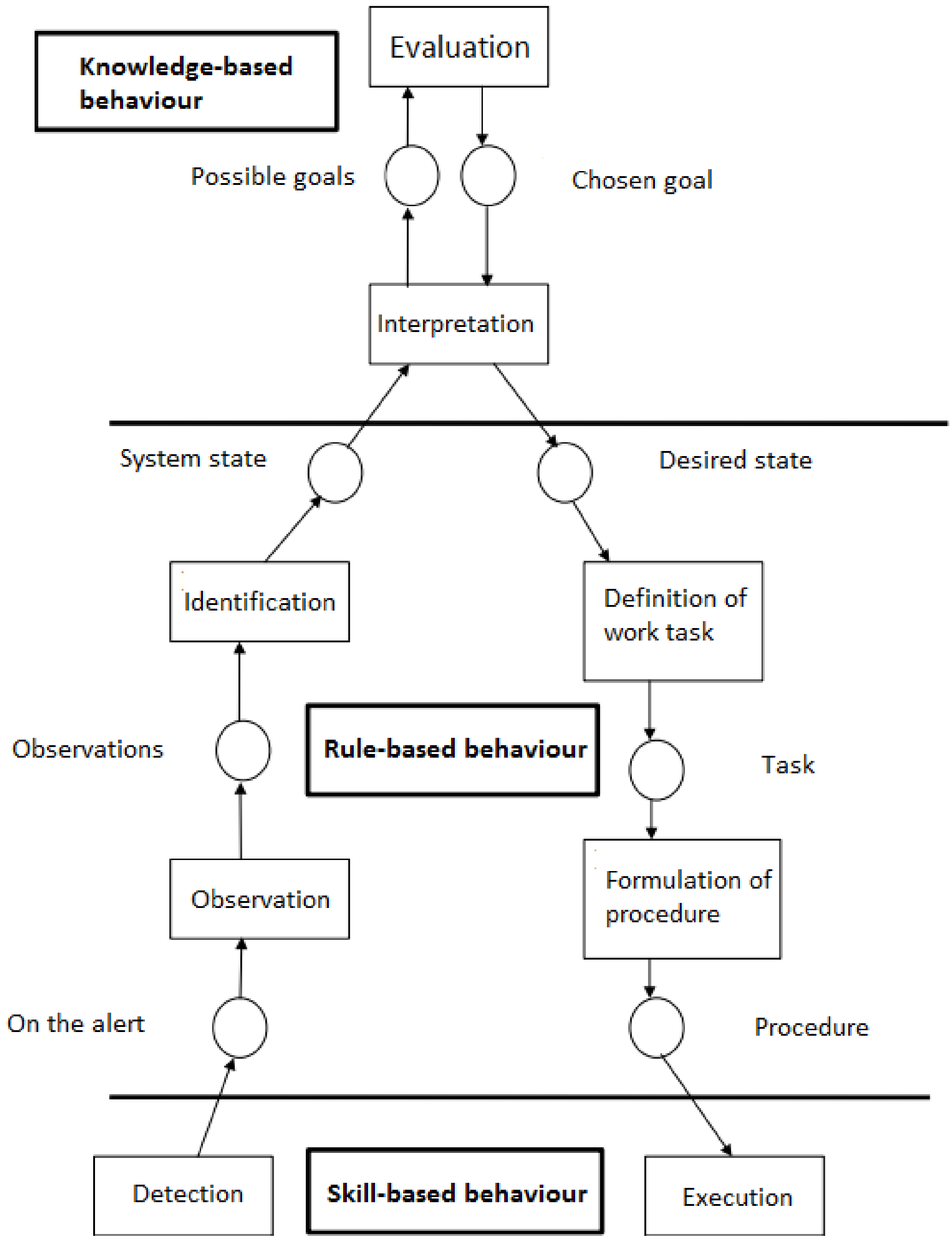

Figure 3.6: Rasmussens steps in a decision making process, translated and adapted from (Bråthen et al., 2001)

3.6 Mental Models

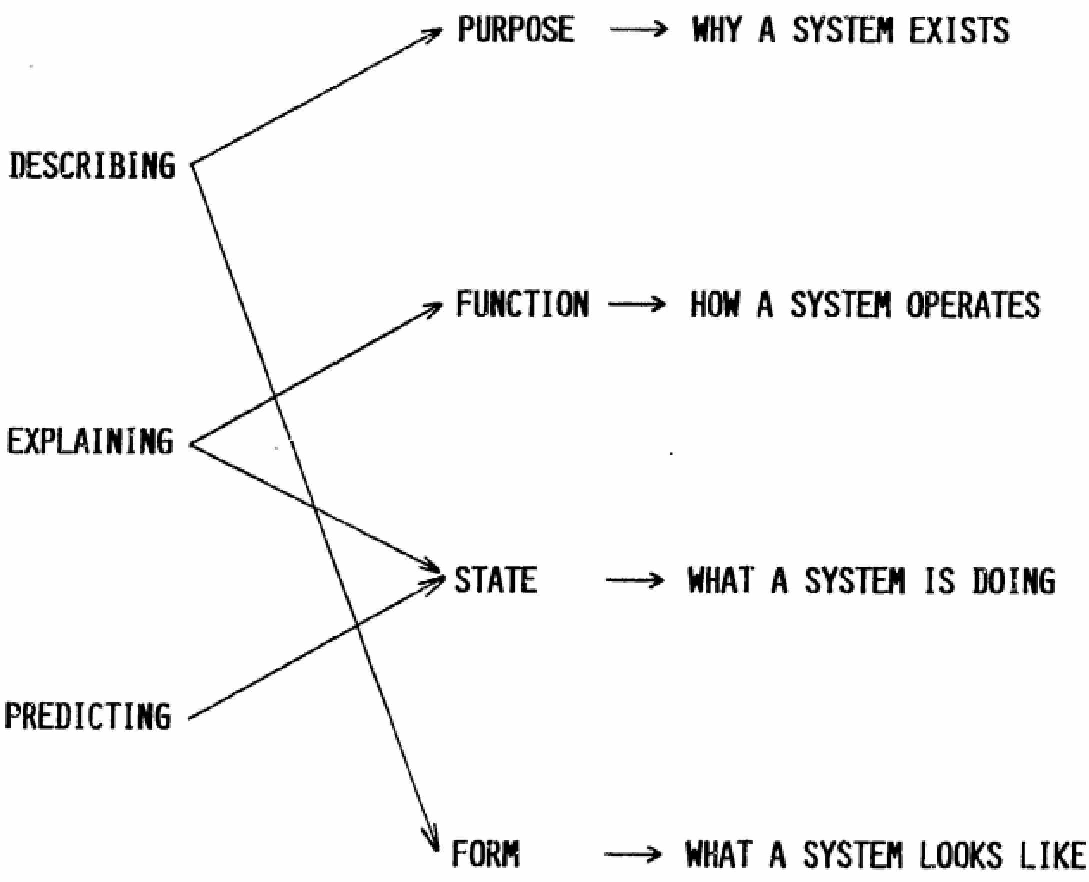

Figure 3.7: Mental model, from (Rouse and Morris, 1986)

Rouse and Morris defined mental models as follows: "Mental models are the mechanisms whereby humans are able to generate description of system purpose and form, explenations of system functioning and observed system states, and predictions of system functioning" (Rouse and Morris, 1986). Rouse and Morris (1986) also presented the purpose of mental models in Figure 3.7, where they presented three common themes combined with Ramussen's model to show the purpose of mental models.

Endsley (2000) states that mental models are used for describing a persons representation of a system - for instance how a computer works. The mental models contains information about this system that is stored in the long-term memory and can be used in a situation where this kind of problem is met. If one meets an unknown, but similar, situation, the stored information from a known situation can be used in this situation to solve the new problem.

Mental models are developed all the time and grow with experience and new knowledge. Endsley writes that "Mental models, although they may grow, evolve with experience, largely represent static knowledge about the system: its significant features, how it functions, how different components affect others, and how its components will behave when confronted with various factors and influences" (Endsley, 2000).

3.6.1 Situation Models

A mental model represents a persons generic knowledge about a system. Situation models are related to mental models, but they are dynamic and represent the human knowledge and understanding of the *present state* of the system.

The situation model may consists of both the value of different systems parameters and an understanding of the dynamics of the system developed from the changes in the situation model over time (Endsley, 2000). The relationship between the mental model and SA model is given in Figure 3.8.

3.6.2 Shared Mental Models

Endsley (2000) defines shared mental models as the degree of commonality among the mental models of two or more people and shared SA is the degree of commonality among the situation models of two or more people. A shared mental model is one of the factor that has an influence on SA - it is needed to gain a

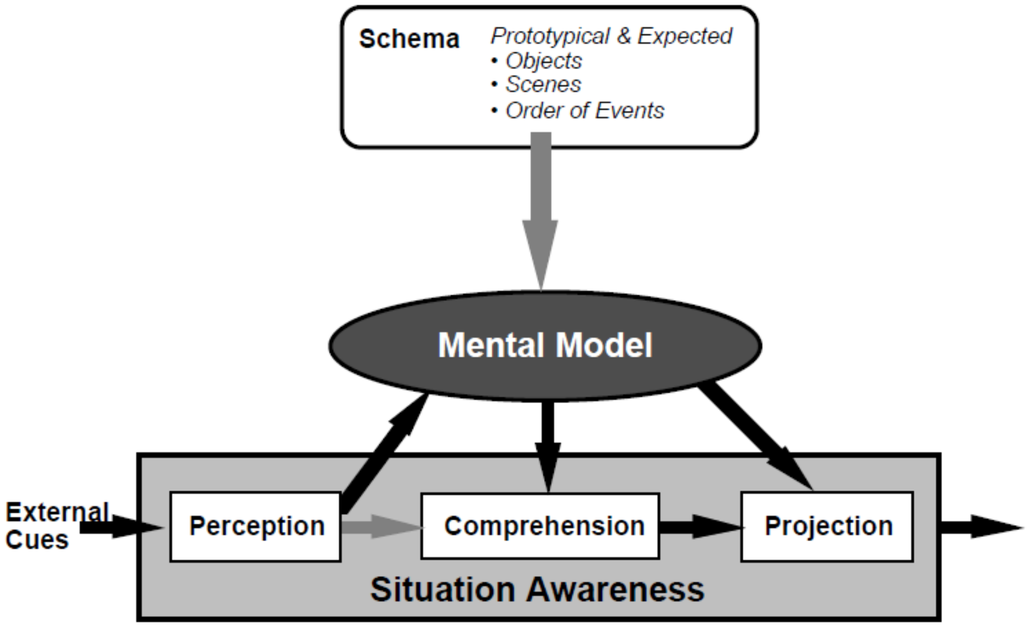

Figure 3.8: Relationship between the mental model and situation awareness, from (Endsley, 2000)

common understanding.

Mathieu et al. (2000) states that a shared mental model will not be that important in situations where workers discuss and communicate what to do, because they discuss their moves and the actions do not rely on already existing knowledge. Having a shared mental model is important in situations where the communication is hard, either because of time pressure, excessive workload or in situations that needs a quick reaction (Mathieu et al., 2000).

On the other hand, it is important to have shared knowledge and a shared mental model in order to discuss problems and situations. For instance, take two people discussing cars - a person that only thinks about a car as a mean of transport will answer a question on what happens when you hit the gas pedal differently than if one ask a person who are very interested in how a car works.

Table 3.2: Different types of shared mental models in teams, from (Mathieu et al., 2000)

Type of model	**Knowledge content**	**Comment**
Technology/equipment	Equipment functioning Operating procedures System limitations Likely failures	Likely to be the most stable model in terms of content. Probably requires less to be shared across team members.
Job/task	Task procedures Likely contingencies Likely scenarios Task strategies Environmental constraints Task component relationships	In highly proceduralized tasks, members will have shared task models. When tasks are more unpredictable, the value of shared task knowledge becomes more crucial.
Team interaction	Roles/responsibilities Information sources Interaction patterns Communication channels Role interdependencies Information flow	Shared knowledge about team interaction drives how team members behave by crating expectations. Adaptable teams are those who understand well and can predict the nature of team interactions.
Team	Teammates' knowledge Teammates' skills Teammates' attitudes Teammates' preferences teammates' tendencies	Team-specific knowledge of teammates helps members to better tailor their behavior to what they expect from teammates.

Mathieu et al. (2000) states that there are several mental models among team members, for instance models of task, technology and teams work as seen in the Table 3.2.

It is important to obtain shared mental models in a team's training. Making all members share knowledge and information about tasks and background for both what to do and what happens will improve the teams work.

3.7 Inter- and Intra-Team Situation Awareness

An inter-team is a team where the persons do not work in the same building, the people do not meet often and one persons role is complete before the others starts their role. Intra teams on the other hand are teams where the people see each other on a regular basis, have regular meetings and work together with overlapping tasks.

Most of the SA theory is equal for both type of teams. The difference is that the distributed teams do not share a common environment and things such as non-verbal communication can not be used.

Intra team feedback improves the development of a shared mental model. It is improved because by giving each other feedback, the team members can get a better understanding of how the other members think, and thereby better insight on how to better coordinate tasks to gain higher efficiency.

Rasker et al. (2000) presents the Figure 3.9 to explain how shared mental models are gained by intra team feedback. The task is central in this figure - a task can be decomposed in several activities. Team member must share information in order to complete these activities. The team members can give each other feedback on activities that are executed, and monitor the performance. The task can than be adjusted to the next time it is dealt with. And the team members get a shared mental model from developing strategies together. The feedback can be either activity based or task-related. The first is communication where members of the team inform each other on what they do, giving advise on tasks and feedback on the others performance. Task-related communication is when the members look back on their performance to find out what could be done differently to optimize the performance in the future.

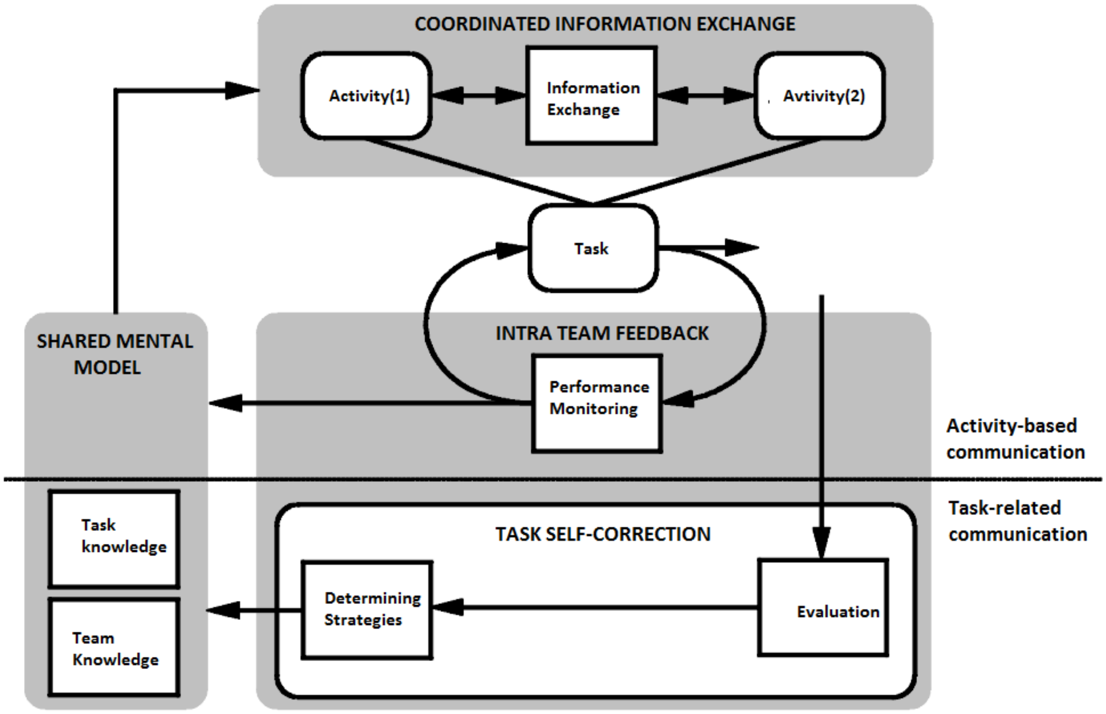

Figure 3.9: How intra team feedback can help gaining a shared mental model, from (Rasker et al., 2000)

3.8 Human Machine Interface Design to Improve Situation Awareness

The human machine interface (HMI) design in a control room is important - applicability, efficiency and to fulfill the given requirements. A successful design is a design that helps the operators by making the operator do his or her job faster and better and simplifies rather than complicate the operators work.

In order to achieve a successful design it is important to understand how the human perception works. General best practices have been gathered in form of usability heuristics and gestalt principles, which will be described in the next sections.

3.8.1 Ten Usability Heuristics

Jacob Nielsen made a list of ten principles for a good interface design. The reason why it is called heuristics is that the points are broad rules, and not strictly specified guidelines. The list following is adapted from (Nielsen, 2005).

1. *Visibility of system status*, always keep the user informed on what is happening in the machine.
2. *Match between system and the real world*, use the users language. Use words and notion known to the user.
3. *User control and freedom*, always let the user be in control, and let the user have the ability to go back.
4. *Consistency and standards*, let the interface be consistent, follow guidlines for the platform.
5. *Error prevention*, make a flexible design to prevent errors.
6. *Recognition rather than recall*, it should not be necessary for the user to remember information between dialogues, make instructions visible when needed.
7. *Flexibility and efficiency of use*, make shortcuts for experienced users.
8. *Aesthetic and minimalist design*, remove everything that does not have a function for the user.
9. *Help users recognize, diagnose and recover from errors*, help function if errors should occur.
10. *Help and documentation*, make a good system for helping the user.

This list of ten points is developed from identifying problems associated with user interface design, to prevent bad designing, and should be taken into consideration for a good and understandable design. When working in a complex process, the user should not have to spend time thinking of how to use the system.

There are more lists and thoughts on how an interface should be designed, and Shneiderman's Eight Golden Rules are one of them, these are presented in (Shneiderman and Ben, 2003) (p. 74-75).

3.8.2 Gestalt Principles

The gestalt principles are from perception psychology, which explains how we sense and organize the visual impressions. The principles have its basis from the perception study which says that we look at things as a whole, not part by part. When listening to music, we hear a melody, not just a set of tones (Leksikon, 2012).

These principles are based on how a person sense and organize the different visual impressions. The human eye is good at seeing patterns and things that deviate from the pattern. It is about how we get parts of objects and form them to a whole based on these parts.

The gestalt principles are:

1. *Similarity* - objects that looks the same are often seen as one object.
2. *Continuation* - when looking at one object leads to looking at another object.
3. *Closure* - if an object is missing a part, the user will fill in that part for observing the whole object.
4. *Proximity* - objects located close to each other are often seen as one object.
5. *Figure and Ground* - the eye differs between what is in front of and in the back of the object.

The gestalt principles are presented in figures in Figure 3.10 to Figure 3.12.

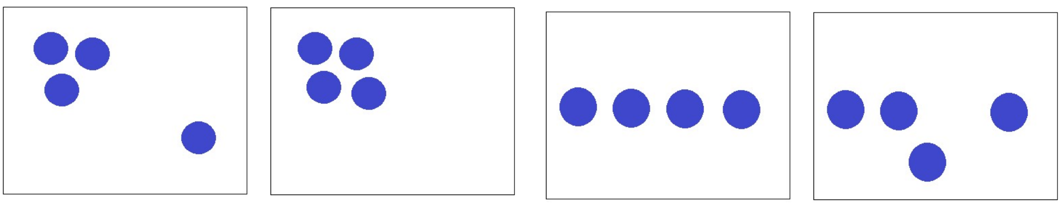

Figure 3.10: Left: Proximity Right: Continuation

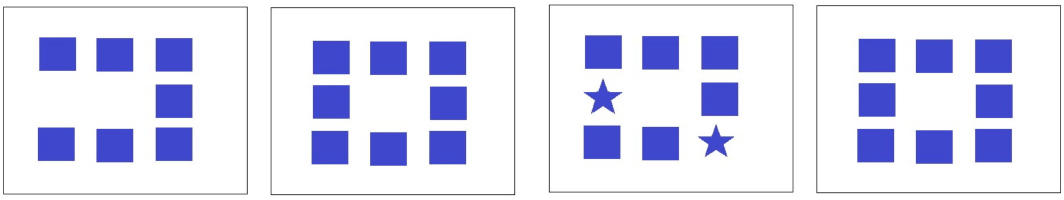

Figure 3.11: Left: Closure Right: Similarity in shape

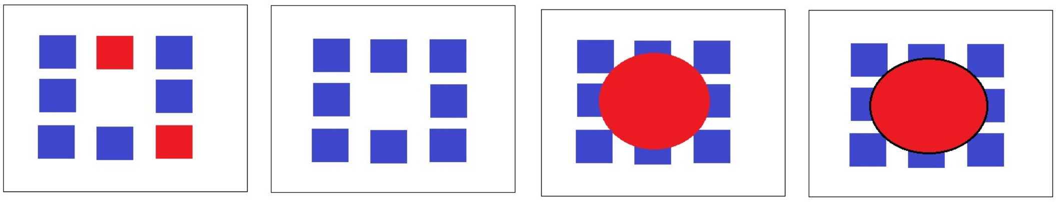

Figure 3.12: Left: Similarity in color Right: Figure and Ground

3.8.3 How Does Good Human Machine Interface Support Situation Awareness

Since SA is the principle of understanding what is going on. The design of the interface is therefore an important matter, because ones vision is one of the biggest influences of how you understand a situation, and it will either help or complicate your decision on your action.

A well designed HMI can improve the operators mental model and a team's shared mental model. By using common rules like *red for danger* and *green for "everything is ok"* will help the common understanding in the team.

If the interface design is based on common rules, the principles of the design is more likely known by the operators and the operators can use already achieved knowledge (mental model) to perform an action.

3.9 Challenges when designing Human-Machine Interaction Interfaces

A good human machine interaction interface is important in order to maintain a good SA. Braseth et al. (2009) present some known challenges when making computerized HMI. The first one is known as *the key-hole effect* (originally presented by Endsley), which means that the operator looses overview of the complete process. This happens because the HMI fails at giving the operator the opportunity to step back and view the big picture. The interface only focuses on small parts of the system at a time, which gives the effect of looking through a key hole.

Second Braseth et al. (2009) presents the problem where *the operators get lost* because the interface is distributed over many interfaces. The operator has to navigate through these to get the information they are looking for and choose the display on each screen themselves. This is what may lead an operator to "get lost" and finding it hard to find the information they are looking for. This problem reduces the operators performance.

The third challenge presented in Braseth et al. (2009) is called *visual pattern disappear* and is a consequence from going off the analogue control room to a modern control room with screens. In earlier days one had arrows pointing and alarms lightening up different places in the control room. This is now replaced by numbers and lines on a screen, which may not support a fast recognition of the overall process as well as the old analogue control room did.

The forth, and last challenge presented by Braseth et al. (2009) is the *teamwork transparency*, which concerns the fact that it is difficult for the operators to see what the other operators are doing. As the operators are located at desks and it is hard to see each others displays the team members awareness of the others actions are reduced. This makes coordination more difficult, and it requires the operators to have good communication in order to improve the SA.

These four points are important to have in mind when designing a system to ensure a high SA.

Chapter 4

Endsley's Model for Situation Awareness

As mentioned in Chapter 3, Endsley's model for SA is a cognitive model, and is therefore based on what a person perceive, think, learn and remember. A definition of SA is given in Chapter 4.1, and this chapter will give a presentation of Endsley's model for SA.

The model is presented visually in Figure 4.4 and the three levels presented in the box named "Situation Awareness" is presented as explained in (Endsley, 1995b).

Level 1 SA: *Perception of elements in the environment.* In order to achieve SA, the first step is to perceive status, attributes and dynamics of relevant elements in the environment. The operator has to be aware of the present elements.

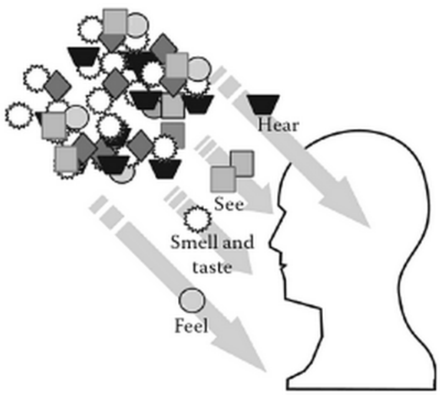

Figure 4.1: Level 1: Perception of elements in the environment,from (Endsley, 2011)

Level 2 SA: *Comprehension of the current situation.* Not only being aware of the present elements, but also understand the significance of those elements in light of pertinent operator goals. Based on Level 1 elements, particularly when put together to form patterns with the other elements, the decision maker forms a holistic picture of the environment, comprehending the significance of objects and events.

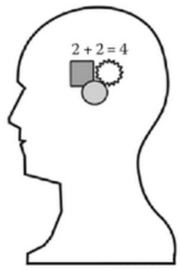

Figure 4.2: Level 2: Comprehension of the current situation, from (Endsley, 2011)

Level 3 SA: *Projection of future status.* The ability to project the future actions of the elements in the environment - at least in the very near time. This is achieved through knowledge of the status and dynamics of the elements and comprehension of the situation (both Level 1 and 2 SA).

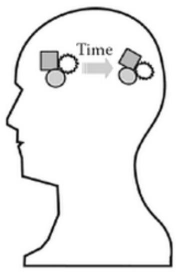

Figure 4.3: Level 3: Projection of future status, from (Endsley, 2011)

From Figure 4.4, one can see SA as a closed loop with different factors influencing it - both personal factors and system factors. As people change, learn new things, meets people with different meanings and uses new systems these factors change. So, as Endsley (1995b) also mentions - SA is something you build up over time, not something you acquire instantaneously.

A closer look on the feedback loop is given in Figure 4.5, which shows the importance of the relationship between environment, SA, decision making and performance. Under the SA box there are three elements, these represent each of the three levels in the SA process. The first level is to perceive the relevant

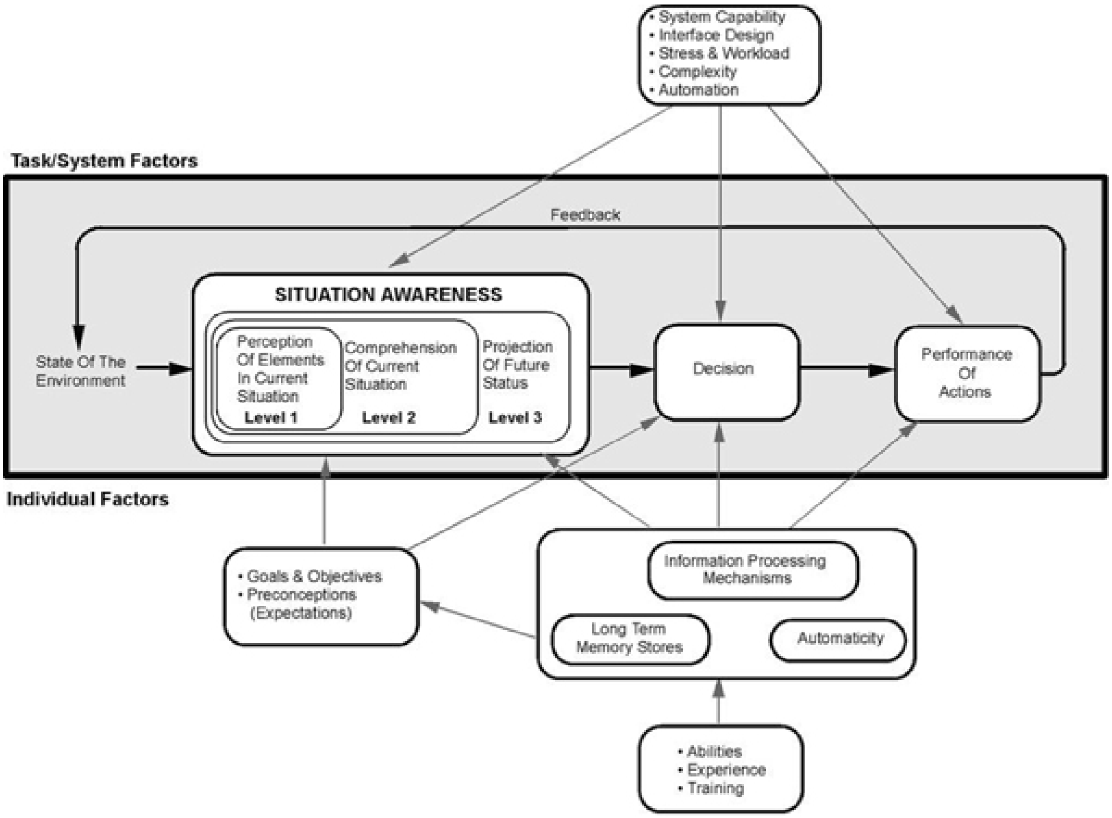

Figure 4.4: Endsley's model, from (Gheisari and Irizarry, 2011)

information for the situation, the second level is to integrate the information with the goal of the task and then, the third level is to predict the future events using your own understanding of the situation.

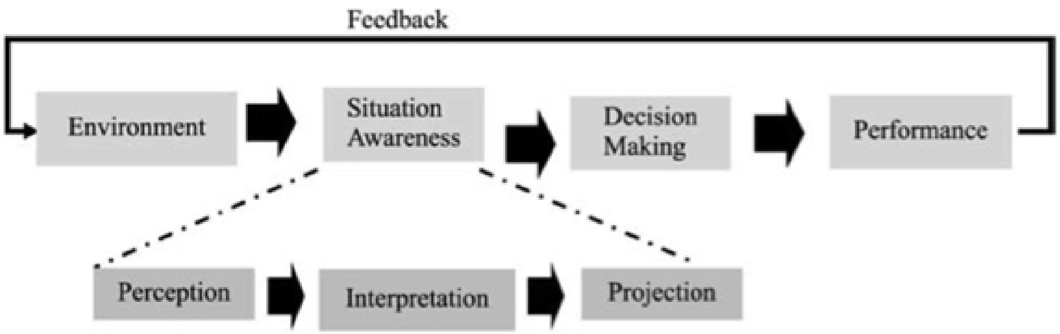

Figure 4.5: SA feedback loop, from (Gheisari and Irizarry, 2011)

Figure 4.6 shows the human properties that are affecting and underlying SA. The

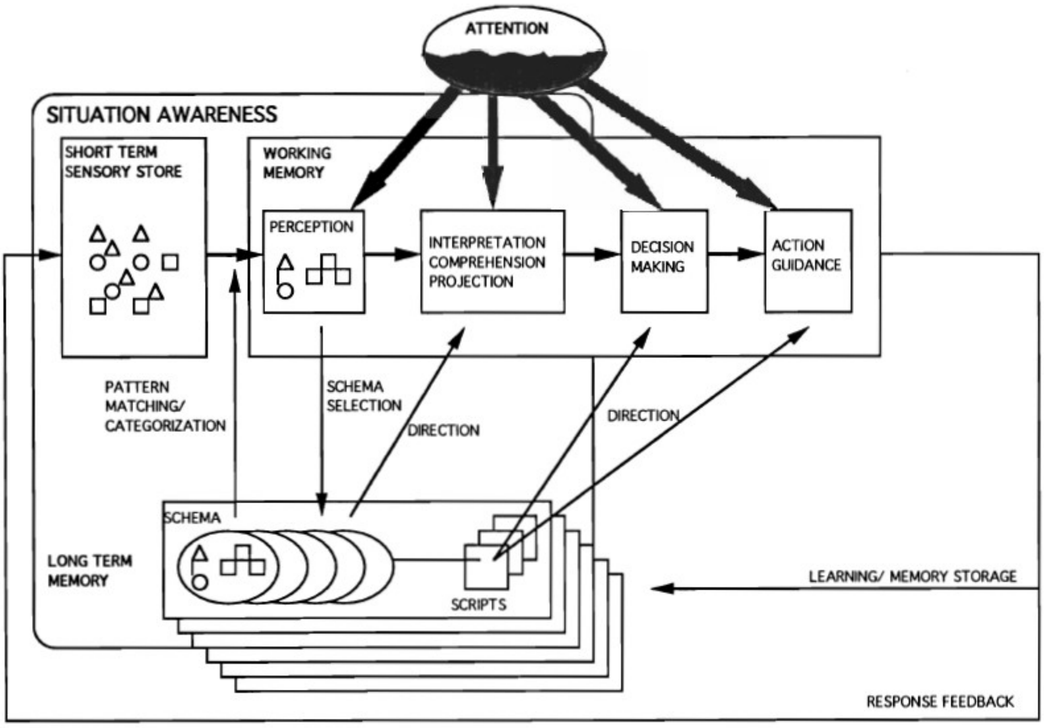

Figure 4.6: Human properties, from (Endsley, 1995b)

factors that are presented in the figure are the short term sensory memory, perception, working memory and long term memory. Endsley (1995b) mentiones other factors such as preattentive processing, attention, level of automation and the users goals as important factors as well.

Endsley (1995b) states that the key features of SA is that a persons SA is restricted by limited attention and working memory capacity. The memory is stored as mental models and schemata - and how an operator uses these models depends on pattern matching between elements in their models and elements in the environment. A person's goals and expectations will have a major impact on the SA as well, because this decides where the attention of the operator is focused, how it is perceived and interpreted. The use of automation will help operators overcoming attention limits, but it may also make the operators miss novel stimuli that again may have a negative effect on the operators SA.

The fact that the mental models and schemata are developed over time and with experience can explain why novice users need more mental processing time to sort out what is happening, which again can lead to overloading the working memory and give gaps in SA (Endsley, 2011).

4.1 Errors in Situation Awareness

A poor SA and shortcomings in information processing might increase the probability of undesired performance. Endsley (1995b) looks at what can lead to breakdown in the SA portion in the decision making process. The breakdown can come from lack of SA, either incomplete knowledge or inaccurate knowledge.

Endsley (1995b) looked into some of the errors that may occur, that are not human errors, and she found:

At the lowest level (level 1) of SA, the operator may have an incomplete SA in the way that he or she fails to perceive the information needed for the task that should be performed. That the information is not perceived may have several different reasons - lack of detectability because of physical characteristics or from a failure in the system design that makes the information unavailable for the operator.

In the second level the errors may be that the operator fails to properly integrate or comprehend the information in light of the goals. A new operator may not have the right mental model, and will fail at which of the cues are relevant for the task. Another error that may occur on this level is that the operator has the mental model necessary for the task, but chooses wrong model from memory. Even when the operator have chosen the right model, mistakes may be made if pieces of data are mismatched with the model or not matched at all.

Level three, is the last and most advanced level in Endsley's model for SA. On this level the operator may have clearly understood the situation, but he or she can still fail on projecting the future dynamics. The operator may fail on this because the mental models are not developed enough.

The automation system might also be an error source for the operators, as the operator may to not be up to date on what is happening in a process. Habitual schemata may be a problem, as the operator will automatically activate it based on the environmental cues. When a change need to be made, which does not follow this schemata, a problem may occur. Endsley (1995b) uses an example of a person driving home from work, and as usual activates the driving home schemata. If that person one day decides to stop by the store, this the person needs to change his or her schemata. Often the person will be back home before he or she realizes that the detour was forgotten.

The operators are also dependent on switching their attention between several sources of information, but sometimes the attention can get trapped in what is called attentional tunnelling (Endsley, 2011). The phenomenon, which is illustrated in Figure 4.7, shows that the person concentrates on a special feature. This leads to factors outside the feature is neglected, which again leads to an outdated SA outside the area focused on.

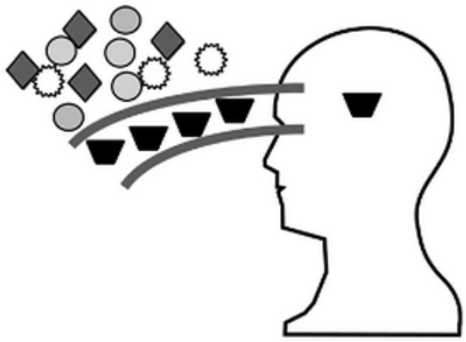

Figure 4.7: Attention tunnelling, from (Endsley, 2011)

Fatigue and stressful factors can also affect the SA negatively, factors like poor lightning, either too high or low temperature and noise. Operators at platform work long durations and at night. These stress factors may reduce the working memory, and one is less capable to collect information when one is stressed (Endsley, 2011).

Endsley (2011) also mentions data overload and misplaced salience. Data overload is when the operator gets too much information for the cognitive system to process. Keeping in mind that humans can only process a limited amount of information at a time, this will lead to holes in the SA. Misplaced salience occur when the use of elements that draws the operators attention are too high. The use of red lights, high noises and flashing lights are sometimes overused - making it hard for the operator to put focus on the right factors. With a lot of items demanding attention, it is also hard to process the information well. This is important to think of for the designers of a system, because it is important for the operators SA. The humans perceptions are also more sensitive to some physical signs than other."The color red, movement, and flashing lights are much more likely to catch one's attention than other features. Similarly, loud noises, larger shapes, and things that are physically nearer have the advantage in cathing a person's attention" Endsley (2011).

How do the operators detect errors in SA? This is not easy, and operators may not know how much they do not know. One clue might be that the operators perceives new information that does not fit with the expected information and by that understands that something is wrong.

4.1.1 Where Has This Theory Been Applied?

Endsley's theory on SA has been applied to aircraft aviation and Endsley (1995b) presents the following example of what elements should be included in the levels for air-to-air fighter:

" Level 1: location, altitude and heading of ownship and other aircraft; current target; detections; system status; location of ground threats and obstacles.

Level 2: mission timing and status; impact of system degrades; time and distance available on fuel; tactical status of threat aircraft (offensive/defensive/neutral)

Level 3: projected aircraft tactics and manoeuvres, firing position and timing " (Endsley, 1995b)

Aircraft aviation and process control are both industries where there are operators in a "room" monitoring and controlling a process. The operators of both of these processes have a major responsibility and the importance of the operators understanding and making the right decisions during the process is very important. Mistakes might have major consequences for both environment and humans. In both situations a lot of procedures has to be followed, lists have to be followed in order to be allowed to start the process, take of from the airport e.g.

As aircraft aviation and process control have many similar characteristics, Endsley's theory is well suited for being applied to control room work in process control as well.

A similar example for an oil and gas control room operator of the levels when applying the theory to control rooms instead of aircraft aviation could be like this:

Level 1: observe process, values and alarms. Identification of abnormal even on HMI, alarm annunciation by pop-ups, audible or ambiance light changes, call from field operators, observation from CCTV.

Level 2: check piping and instrumentation diagrams (P& IDs) in order to understand the location of elements, check instrument datasheets, request support from field operator, check last events and process data associated with item of interest.

Level 3: Imply from cause and effect tables to see where the abnormal situation might propagate, understand which alarms downstream in the process will be triggered and why, establish a plan for tuning parameters which will bring the process back to normal.

4.2 Other Models For Situation Awareness

Several models for kinds of SA has been outlined. To mention one, the 3-question model has been developed for clinical decision making (Sibold and Geisler, 2012). None of the other theories suited the situation in a control room as good as Endsley's model. In the rest of this thesis Endsley's theory for SA will be used in the evaluation of the control room solutions. The reason for choosing Endsley's model is that this theory is tested on aircraft aviation, which, as discussed in Chapter 4.1.1 in many ways have similar characteristics as process control.

Chapter 5

Information Presentation Solutions

A control room is a room for the operators controlling the process where significant data and information are gathered. A large amount of information is needed and there are different solutions for making such information available for the operators. In this chapter an overview of some of these solutions for information presentation are demonstrated. The solutions presented will be evaluated on their ability to improve the operators SA.

5.1 What Is a Good Solution?

A good solution will be a solution where both the human and the machine can do what they do the best. The focus should be on keeping the human in the loop, and design the interface such that humans can perform at their best. The solution should make it easy for the operator to perform rapid actions whenever a critical situation occurs or when the automation fails.

The system must aim at giving the operator the highest SA possible, which is required for the humans to make the best decisions in a process. It is important to design a system, which contributes to a good SA, and hinders failures that may cause incidents or injuries to humans or damages to the process or surroundings.

Often, several alarms go of at the same time, and there can be a lot of information for the operators to handle. The operators have to choose the right alarm to do the right actions. Because of this, the presentation solution in a control room has to present the alarms in a way that makes it easier for the operators to choose the right one.

To help the operator gain a good understanding of the situation it is essential to present the information clearly and intuitively. Because the systems are automated and the operators are not a part of every action, the information should be precise and accurate to make the operator able to react quick and take the correct actions in both normal and emergency situations.

To conclude, a good solution should contain just enough information for the operator to understand the situation and what is going on. The information should be precise and presented when it is needed allowing the operators sufficient response time to handle the event correctly. The way the screens are laid out, as well as their contents are some of the factors that have an impact in gaining SA. A lot of training is required too get knowledge and a good mental model of the process and different situations that can occur in that particular system.

In the next sections three information presentation solutions that might help the operators gain better SA are presented and analysed.

5.2 Large Screen Displays

Control rooms often use large screens to share the information needed by the operators. The large screens makes all the information available to the operators by collecting, visualising and distributing it. A large screen display may also provide the operators with relevant indicators, KPIs or charts results in faster and more efficient decisions without having to spend too much time looking at the displays. The possibility for the screens to provide *too much* information are also there. Too much information at one screen may confuse the operators, and that is not desired.

Different industries needs different information, and the requirements for the large screen display may therefore be different as well. How many large screens needed will also be different from one control room to another, depending on industry, the size of the room and process needs.

Eyevis (2013) presents reasons for installing a large-screen display in a control room and what conditions that should be taken into account before installing a large-screen display.

The reasons for using large screen display are according to Eyevis (2013): "precise survey of all information (and therefore short response times and fast troubleshooting in emergency situations), advanced control possibilities, intelligent display solutions with control features (such as alarm management, presets, etc.), task sharing, multiple possibilities of display and a large number of different signals / information/scenarios" (Eyevis, 2013).

There are several factors one have consider when installing large screen display. The space and location of the room, the life-time, budget, how many operators, the cost of maintaining the screens, quality of the display and the environment and ergonomic factors (Eyevis, 2013).

Figure 5.1: Large screen solution, from (Eyevis, 2015)

5.2.1 How Can Large Screens Support Situation Awareness

The large screens, which are placed in front of the operators, are meant to provide the operators with a common overview. The content and their distribution on the large screen displays are usually a predefined standard, and will be the same for all the different teams working in the control room. The concept of large screens gives the operators a shared information overview, which can help the interaction and coordination between the operators. Better coordination between the operators also requires the operators to communicate and that they update each other on actions - but the large screens help the SA because they can look at the same screen while discussing situations or problems.

The information displayed on the large screen should contain enough information to make sure that even the operators without experience in that specific process understand what is going on, but not so much information that it is confusing.

One of the drawbacks with large screens are as mentioned in Chapter 3.7 *the key hole effect*. The pictures displayed on the screen does only show the operator a small part of the process, and the cause for an abnormal situation may be outside that process view that is displayed. As the operators do have their own desk in addition to these large screen they can decide to either go deeper into a process on their own screen or to zoom out to get an better overview, which can help the SA.

5.3 GIGA-Mapping

GIGA-mapping is a System Oriented Design tool developed at Oslo School of Architecture. It was developed by Sevaldson (2011) who describes GIGA-mapping as a super extensive mapping across multiple layers and scales, investigating relations between seemingly separated categories. The concept is tailored both by and for designers.

In a formal definition "GIGA-mapping is super extensive mapping across multiple layers and scales, investigating relations between seemingly separated categories and so implementing boundary critique to the conception and framing of systems" (Sevaldson, 2012).

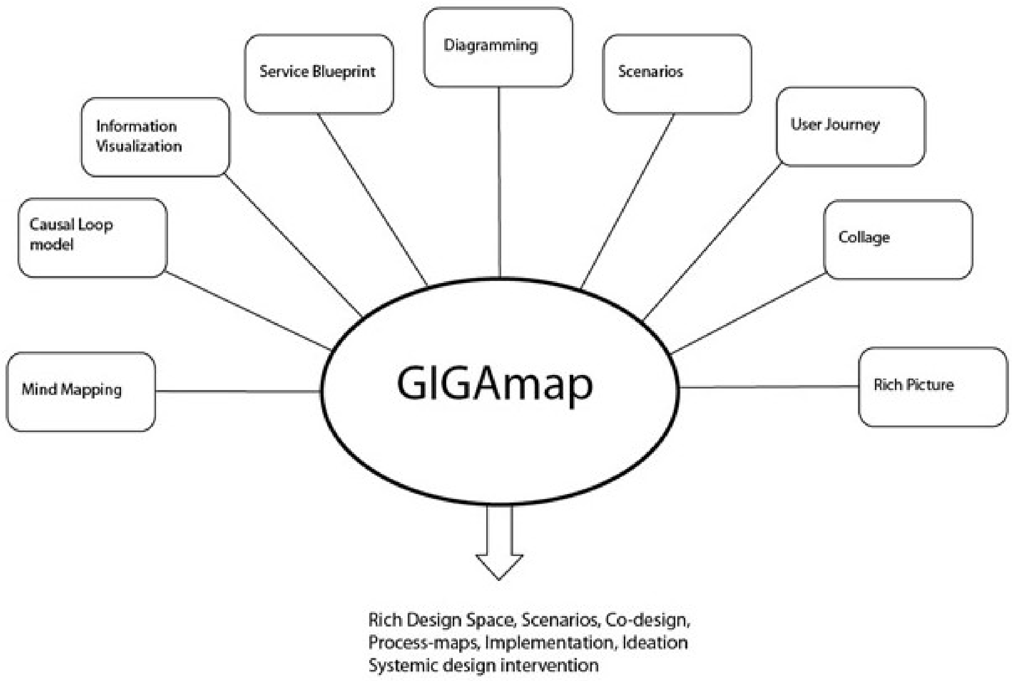

Figure 5.2: GIGA mapping, from (Sevaldson, 2013a)

System oriented design (SOD) is an upcoming practice that use system thinking in order to capture the complexity of systems addressed in design practice.

In practice GIGA-maps collect and gather all information on an enormous sheet of paper. This brings knowledge and insight to the workers. In this way everyone working on a project has information to share, discuss and get knowledge from.

"GIGA-maps try to grasp, embrace and mirror the complexity and wickedness of real life problems. Hence they are not resolved logically nor is the designerly urge for order and resolved logic allowed to take over too much and hence bias the interpretation of reality" (Sevaldson, 2013b).

An example of a GIGA-map is shown in Figure 5.3, which shows a map with a lot of information about a system. Sevaldson (2013b) states that GIGA-mapping are meant for design situations, and not situations that needs communication and simplifications. A GIGA-map consists of a lot of information, and sometimes the map can get so complex that it is hard to understand it if one has not been a part of the design process. The GIGA-maps help to keep track of connections, details and to internalize all the parts of the system.

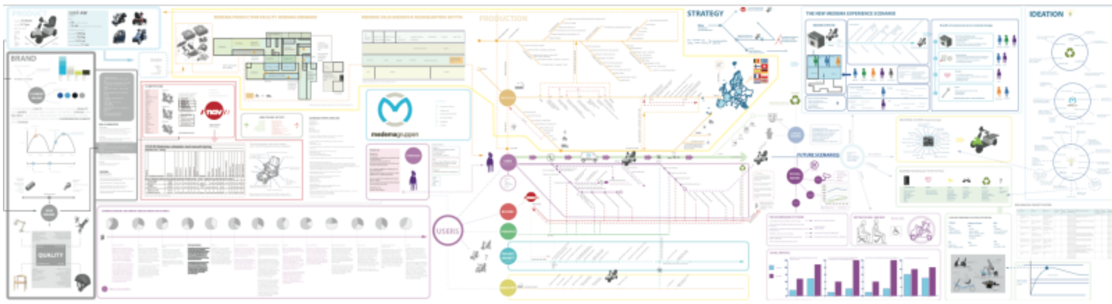

Figure 5.3: GIGA mapping, from (Sevaldson, 2013a)

5.3.1 How Can GIGA-Mapping Support SA

GIGA-mapping is tailored for designers, and it would be beneficial to involve a control room worker in the design process to get the users needs and thoughts as well - not just the designers.

Students at Oslo School of Architecture and Design have used GIGA-mapping in their master thesis work, and Sevaldson (2012) presents some of their thoughts about the benefits of GIGA-mapping. The benefits mentioned are the shared overview - the people working in the team will get a synchronized overview.

Another benefit mentioned is that GIGA-maps are easily comprehensible - it is easy to point out and find opportunities. The GIGA-map is also mentioned to make an understandable setting for dialogue and opportunities to find new solutions. The students also mentioned that a GIGA-map would be great for use in a training program. GIGA-maps also create shared images for the designers.

Most of these aspecta could be equally beneficial for the operators that use a GIGA-map, but it would be especially beneficial in a training situation for gaining a good mental model of a process. A GIGA-map would give an overview of the whole process and help the operators understanding of what is going on. Since there are a lot of automation in systems, this understanding might help keeping the human-in-the-loop, and make it easier for the operator to figure out what went wrong if something does.

As an alternative, for use in the control room work, one could use the GIGA-map as an interactive map. The operator could use a zoom in-out function to show everything at once, and then look at one specific part. This could help the problem with *key-hole-effect* as mentioned in Section 3.7. Implementing this solution requires a lot of training of the operators. Both design, implementation and training will have a high cost, and one has to be sure it is beneficial for the company before going through with these initiatives.

A third way of using GIGA-maps could be to have it in addition to the already existing large screens. It could be located on one of the large screens on the wall to give an overview of the whole process and show where the alarms (in different colors for different levels) are located.

A GIGA-map will contain a major amount of information, so it would not be advisable to use this as the only information sharing system in the control room. In situations that need quick and wise reaction, a system with this much information might be confusing because of excessive amounts of information (information overkill). As the processes in oil and gas are very complex, the maps might be so complicated that they can be almost impossible to understand for persons that have not been in the design process themselves.

Either way, the use of GIGA-maps could help the operators to get a good overview of the situation, and prevent *the key hole effect.*

5.4 360 Degree Control Room

At Høyskolen in Buskerud and Vestfold a project named the SimSam project has been outlined. SimSam is a laboratory for simulation and interaction. SimSam comprise of a major round screen that is four meters high and eleven meters in diameter. Seven projectors makes it possible to display one picture in 360 degrees or seven different pictures. The screens has a total area of 144 m^2. The projectors are distributed on two work stations, providing two different work areas. So far, the 360 degrees screens have been used in planning of projects, and they have often used 4 of these 7 screens for a presentation and project criterion, while a separate machine has been used for work with 3D drawings, visualisation of solutions etc.

Figure 5.4: SimSam used for project work, from (ElectricMobility, 2013)

When they have used SimSam for projects, a conference table has been placed in the middle of the room and they have used standard interaction - mouse, keyboard and 3D mouse for designing.

The people working on SimSam has also explored the possibility for using a touch solution. They tried using a SUR40 multi touch table for controlling the visual parts, but is was concluded that the standard solution was more efficient. They also concluded that using other hardware might have worked better - maybe another set up using a computer with touch screen instead of a solution with all in one.

In a design process the screens can be used by setting possible solutions next to each other, and then they could make a decision by comparing the different solutions.

5.4.1 How Can 360 Degree Control Room Support Situation Awareness

This solution has neither been tested as a solution for control rooms nor been built for that kind of use. This solution might present some challenges in the information flow if used it in a control room. The people working with SimSam have considered the possibility of using it as a room for emergencies - a room where everyone can gather and gain the same information and handle together in an efficient manner.

360 degree control rooms will, as the two previous solutions, provide the operators with a shared overview. This shared overview contributes, as mentioned earlier, to developing a shared mental model.

An advantage of 360 degree control room is that operators are able to move around the room and change the placement of the different elements displayed. As an example, when a group is working on trying to locate a piece of equipment for analysis, they could "create" a workspace on the wall where they can place the piping and instrumentation diagram, next to the 3D model so they could get complete understanding of the situation.

Similarly, when working on a disturbance situation involving different systems they could place the relevant screens, diagrams and data sheets in the same place of the room to increase shared SA.

The screens used in this control room are larger than the screens usually used in control room with that solution. Bigger screens can provide more information on a screen with a smaller risk of being confusing, which can be god for the operators. There might be room for e.g. having parameter limits next to the real values, which would help the operators in that manner that they need to remember less - the memory load is reduced.

With the possibility of having 7 different screens up at the same time, the operators will have a lot of information available, but the question is - will it be to much information? With a control room design like this, the operator will be surrounded with information on all angles, probably in addition to desktop computers. This is a lot of information at once, and operators might only concentrate on parts of it a time. So, is it necessary with all this information for the operators when there might be hard for the operator to handle it all?

A lot of information will be distributed on these screens, and several solutions are possible if using this a control room. One could either "divide" the responsibility between the operators, and let them be responsible for some screens each, and have some screens in common as well. Or one could use it as the large screens are used - with work stations for the operators in the middle of the room, with shared information on the walls.

Maybe a solution with these screens a 180 degree control room would be more sufficient for this kind of control room?

SimSam, mentioned in the previous section, is designed for use in design processes to involve different part of the design team - both designers and clients. This kind of room could be interesting to use in the training of operators. Using it as a "cinema" for the operators and guide them around in the process of the plant/system.

5.5 Reflection

The solutions have to be placed in such a way that all operators can see the same picture - large screens are not worth having if only one operator can see it.

All three solutions can provide the operators with a common overview, but it might be the solution used today - the large screen displays, that are the best suited solution for this kind of work. Both GIGA-mapping and 360 degree control room may provide too much information for the operators in a control room situation, as these solutions are both meant for the design processes. On the other hand, both solutions might be good for training of the operators, as both concepts are good for explaining processes.

Whichever solution that is chosen for the control room, it is the training of the operators that is most important. A good interface design will not help if the operators do not know what happens in the system when performing tasks.

The solution should also have a consistent interface, with a consistent use of symbols and colors. The amount of information should not exceed the amount of necessary information - unnecessary information will only confuse the operator.

A control aspect for collaboration is to generate a shared mental model, which can be achieved through training. It is important for the companies to have a structured plan over training of the operators to have the best outcome of a process as possible.

Chapter 6

Observations and Interviews

Observations were needed in order to evaluate the different solutions of information processing in control rooms. The observation showed how the operators worked together and how the work situation in the control room was. To get some insight into this work environment, a simulator for a control room was visited, and some operators were interviewed(questions asked are attached in Appendix A).
This chapter will give the results from the observations.

6.1 IO-center

To learn more about control rooms, before visiting a real one, SINTEFs IO center was visited. The center had two "control rooms", which both contained one large screen. One of the rooms was furnished with a long desk looking like a control room, while the other room was furnished like a classroom. The large screen, which both room contained, could either be used as one, or used to display several screens. The large screen could also show pictures in 3D if the person looking at it used special glasses. Several cameras were installed as well, both in the back and in the front of the desks, making video conferences with persons outside the room possible. By using the camera in the back of the room, the operators could show pictures from the process on the large screen to the people in the video conference.

6.2 Operator Training at Statoil Stjørdal

The Åsgard oilfield is located at the Haltenbank in the Norwegian Sea, which is located 200 km offshore Norway. Åsgard A is a production ship for oil, which has been in use since February 8th 1999 (Statoil, 2015). The operators working on Åsgard A travel to Statoil Stjørdal to learn and get more practice on what to do in both normal situations and more extreme and critical situations that may occur during a day at work. The training of the operators is important in order to make the operators get a shared mental model and to get a better awareness of the situation when something happens on the vessel.

Figure 6.1: Åsgard A, from (Steensen, 2009)

When working in this kind of industry, the employees work on rotation - they are on the ship for two weeks and then home for four weeks. At Åsgard A, the control room workers work 12 hours shifts on the ship, and they work in teams of two. The operators do not have a permanent working partner, so when making a shared mental model, it is important that *everyone* working in the control room have the same. A common training programme where everyone hears and learns the same would be preferable.

To maintain a good awareness, the operators sometimes have training sessions where they get drilled in both extreme and everyday situations. To both educate and test the operators' SA, the operators are not always told what the next situation will be. To make the training session as real as possible they use a simulator, which is a room that is furnished almost like the control room on the ship. It comprises of two desks and five large screen displays on the wall in front of the desks. The operators are equipped, as shown i Figure 6.2, with three computer screens, telephone, walkie talkie and a TIPO-panel (a short key panel). They also have a DFU-binder with procedures for P-messages, which are important messages read on the speaker system to the rest of the workers. A computer with internet is also located in the room, for e-mail, Lync (chat program for companies) and general communication with people outside the room or the ship.

During the observation, the five large screen displays on the wall showed what was thought to be the most important information, e.g. the process view with the overview of alarms. These large screens are important for the cooperation between the operators, as they use them when they discuss situations and find solutions to problems. The communication between the operators are important since they are located on separated desks with some space between them. It is important to inform co-workers on what you intend to do and what actions you are performing, in order to keep everyone in the loop.

As mentioned in Chapter 3.7 good communication is also important, because it can contribute to a improved shared mental model. When sharing information, the information needs to be accurate in order to avoid misunderstandings - values, letters and abbreviations can easily be mixed up, and it is important that the operator double checks his or her observations and information before sharing it.

In case of a critical situation the operators have to send a message to the workers on the ship - the mentioned P-message. Whom of the operators that give the message over the speaker system should be decided in the beginning of the shift. This is very important in order to assure that the message is delivered clearly and fast in case of an emergency.

The communication is not just important inside the control room, it is important to communicate with the outside operators and the manager as well. The telephones and walkie talkie are used for that. The possibility of going out of the room (or ask him or her to come in) to talk face-to-face to the manager are also there, as the manager is located in a room next to the control room.

Figure 6.2: Control Room Simulator at Statoil Stjørdal

The interface used at Åsgard A is quite old, and some things in it should be designed differently in order to help the SA. In Figure 6.3 a screen from the interface is shown, and the use of colors could have been better in order to prevent visual fatigue. Better colors in this case means calmer colors, which you can look at for 12 hours.

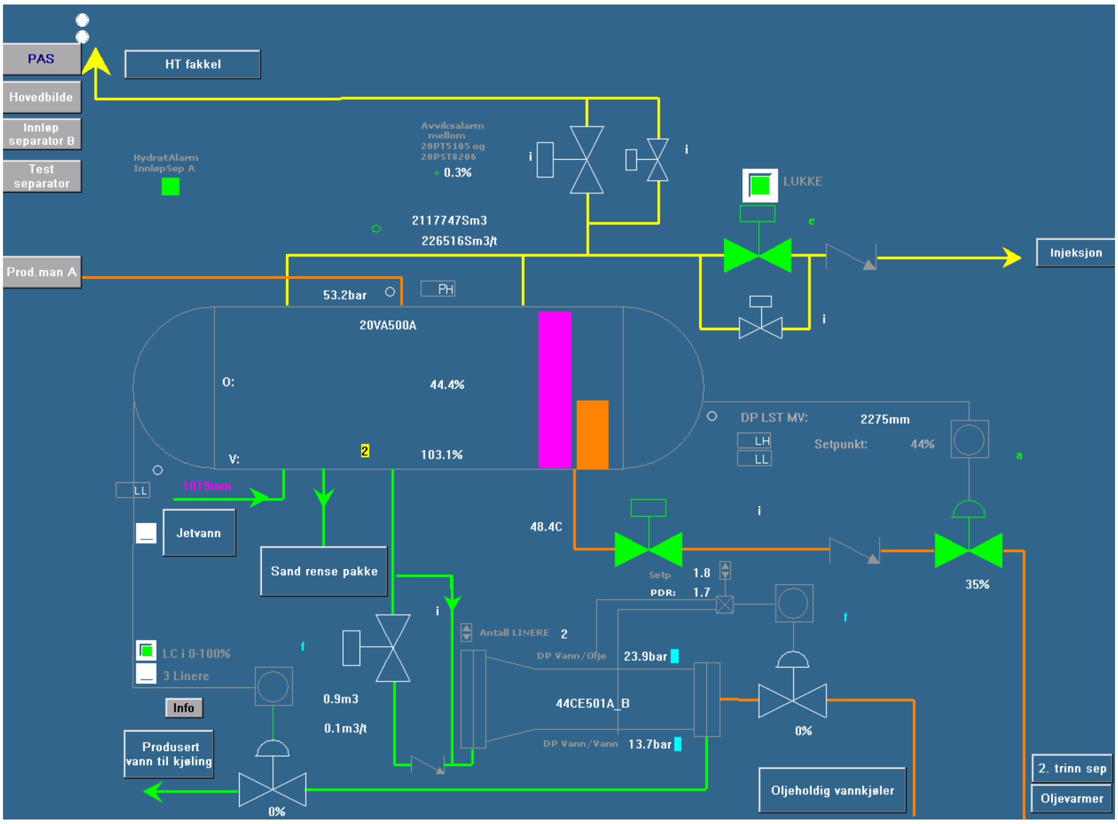

Figure 6.3: Process picture at Åsgard A

The alarms are shown on one of the large screens in front of the desks. There are four levels of alarms, and they have different colors and sounds according to their priority. These are the levels of alarms, and a process picture of the alarm screen is presented in Figure 6.4.

- 3 - the highest prioritized alarms, color: magenta
- 2 - high priority alarms, color: red
- 1 - low priority, color: yellow
- 0 - no priority, this is more information than an alarm, color: white

Figure 6.5 shows a TIPO-panel, which is panel of short-cut keys. This panel is good for navigating fast, but demands a lot of training as all the keys only show a number or an abbreviation. A lot of memory is needed to remember the information, but the grouping of the keys with different colors for different groups provides some help. This is good design thinking according to the theory in Chapter 3.8.2.

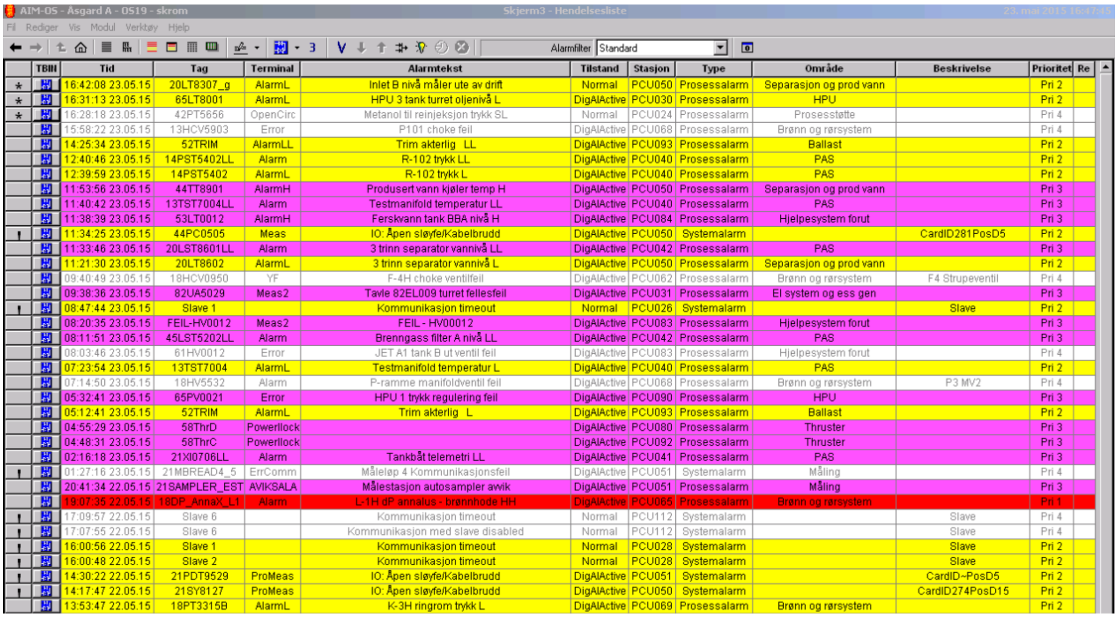

Figure 6.4: The alarm screen at Åsgard A

The operators can decide what they want to display on their screens themselves. A general picture is shown of the process, and the operators can decide to go deeper into the system if they want to see further details. Several clicks are required in order to go deeper into the system. This solution requires some extra time to get to the right place, but too much information on a screen might not be a better solution. (Experienced users might only need one or two extra clicks.)

By going deeper into the system, and only seeing smaller parts of it may cause *the key hole effect* as mentioned in Chapter 3.9. That the operator only focuses on one thing, and forgets about the other factors that might be affected or has affected this alarm.

All the desired levels of gas, oil and so on in the different parts of the system needs to be remembered by the operators. This requires a good memory and a lot of experience. As well as all the desired values have to be remembered, the HMI offers a rather poor help for the operators regarding where the values belong. Some places there are no connection between the values and where they belong to, so this also needs a lot of practice to understand. A better link here will provide a better SA, because reading the wrong number in a dangerous situation might be very crucial for the outcome of a situation.

Figure 6.5: The shortcut panel

The operators who were observed for this thesis have a lot of experience and are trained at using systems like this, major modifications are therefore not desired from their point of view. Major changes will require that all the operators need to be re-trained, and their mental models may need to be changed to have a good SA.

The two operators observed were both males, but they had different background and different experience in using such systems. The one with most experience had technical school background and experience from Åsgard and offshore at Oseberg. The youngest had certificate of completed apprenticeship in chemical processing after one year of school and two years at Mongstad. He worked at Mongstad for 7 years in total, both out on the platform and in the control room. He has just started working at Åsgard A, and has only been out on the ship twice for training.

The tasks they spend the most time on during a shift are the tasks performed in the control room and preventive work such as verification of the equipment, checking that everything is working according to the requirements and testing. The operators do also perform the mentioned tasks in Chapter 2.2.

As the operators are experienced in using these kind of systems, they will have *skill-based behaviour* (mentioned in Chapter 3.5) in most of the tasks. They seemed to have good understanding of what was going on and performed their tasks naturally without thinking to much before they decided on what to do. As their understanding of what was going on is good, it is assumed that their SA is somewhere between level 2 and 3 (fom Chapter 4), at least for normal situations. In new abnormal situations the level might be lower due to less experience and therefore less ability to simulate future status. In abnormal situations the behaviour mentioned in Chapter 3.5 also be at a lower level than skill-based behaviour.

The automation system used at Åsgard A is estimated to be something between level 6 and 7, using Table 3.1 in Chapter 3.3. According to this table, the degree of automation is high and the system will do some things automatically (the system will only notify the operator if it is necessary and not for every little thing), but the operators will have to do some things themselves as well. In the case of high alarm the operators will sometimes get some time to fix the problems, but if the emergency alarm is reached (e.g. if the operators are not able to fix the problem or did not fix it fast enough) the system will start a process to solve the problem or shut down the process to secure the process.

6.3 Interview with operator from Draugen

To get some more input on control room work, an operator working at the oil platform Draguen was interviewed. Draugen is an oil field located in the Norwegian Sea, about 150 km north of Kristiansund and at 250 m depth (Norge, 2015a). The production started in 1993 and the platform is still operative, even tough the life time estimate was 17-20 years.

The interviewed operator had a certificate of completed apprenticeship in chemical processing after being an apprentice in Shell. After this he had worked on Draugen

Figure 6.6: Draugen, from (Norge, 2015b)

for 10 years working as a process operator, and he is now being re-educated as a simulator instructor.

Like the operators on Statoil, the operators on Shell work a 2-4 rotation. The control room operators at Shell have one week in the control room and one week out on the platform during their working periods. This arrangement is also used in the operators training periods, and gives broader understanding of the whole process from the start.

The platform produces oil, gas and condensate. The oil is exported on the Åsgard line and the gas is sent to Kårstø through a pipeline. The process at Draugen is very complex, and the main objective is to produce as much oil as possible. The platform is at the end of its life line, and the oil reservoir is near an end. They have demands on the oil and gas – the oil has to fulfil certain specification and the gas has a specified content of water and H_2S values.

The control room at Draugen is furnished similar to the one at Åsgard A, but it has five operator station instead of two - but still only two operators a time. The operator interviewed said that it was practical in that manner that they could have a different picture up on the different stations and then move between them. The operator did also mentioned that it would have been nice to be three operators instead of two.

When a new operator starts, he or she starts working out on the platform first under his or her training period. After that, the operator is trained both inside the control room and outside to get a better understanding of the process.

The operators at Draugen starts the day with a morning meeting where the operators that finish their shift updates the new shift about what they have done during their shift and gives an update of the current situation. Each shift consists of two operators. The meeting room is located next to the control room.

Since the process is automated, it will stop if some of the values move close to the upper or lower level. And the operators have procedures to follow in these situations. These procedures are gathered in a ring binder.

Draugen got new and better HMI last year, that follows a Shell standard. The old interface had stronger colors, and the new interface had calmer colors. The new interface required more clicks to get to the right place – it has been fewer things to remember but it takes some more time to get to the right place. This solution reduces the key hole effect, but will again lead to the operator using longer time in critical situations.

They have procedures for temporary replacement of work task in order of illness etc. Because of the training process the outdoor and indoor control room operators know each others jobs. In addition, the operators do exercise drills for emergency situations, such as fire drills, every week. This is in order to prepare the operators, and gain mental models and schemata of how to handle a situation that need the right reactions in order to have a good outcome.

Temporary instructions in the process is given on paper, and has to be remembered by the operators during the work day. To reduce the memory load for the operators, there could have been placed a flag in the process picture where these temporary instructions were.

Since Draugen also uses the solution with large screen displays, and work stations for the operators, a lot of the factors mentioned in the chapter about Åsgard A (Chapter 6.2) will be the same for the operators at Draugen, such as the challenge with the key hole effect and a high requirement on their memory. The automation level at the platform is also estimated to be almost the same as at Åsgard A.

6.4 From An Engineers Perspective

To get another perspective on control room, a person not working in a control room, but with a lot of knowledge on the subject, was interviewed.

An engineer working with integrated operations was interviewed, he had some inputs on how the operators in a control room should work to make the process better. He explained that there is a lot of focus on the understanding of the alarms on the platform, but more focus is needed on the usability of the system. The understanding of the process and control of the system need more focus during the training process. Because of the lack of usability knowledge, the operators do sometimes find their own solutions to problems. These solutions aren't really good solutions, but they may work well enough to fix the current problem. However, this solution may be dangerous if the operators do not know what they are really doing. This solution will be used over and over again by the operators, because it is stored as a mental model in the memory and remembered as a good solution. It should therefore be more focus on understanding the basis on what is going on in the training process. To make the operators aware of what happens if they set one control to auto. To make the operators understand better, the HMI should display more information to the operators.

Two examples on typical process pictures are given in Figure 6.7 and Figure 6.8. The first one shows the concepts of sequences in a process, where the picture to the left shows an informative sequence, while the figure on the right shows a less informative sequence. The green lights means that the conditions are fulfilled. For a person understanding the process, the left picture, will give good information of what conditions are fulfilled and which are not. The information provided by this sequence picture allows the operator to find out where in the process, what conditions are not fulfilled and then fix the problem.

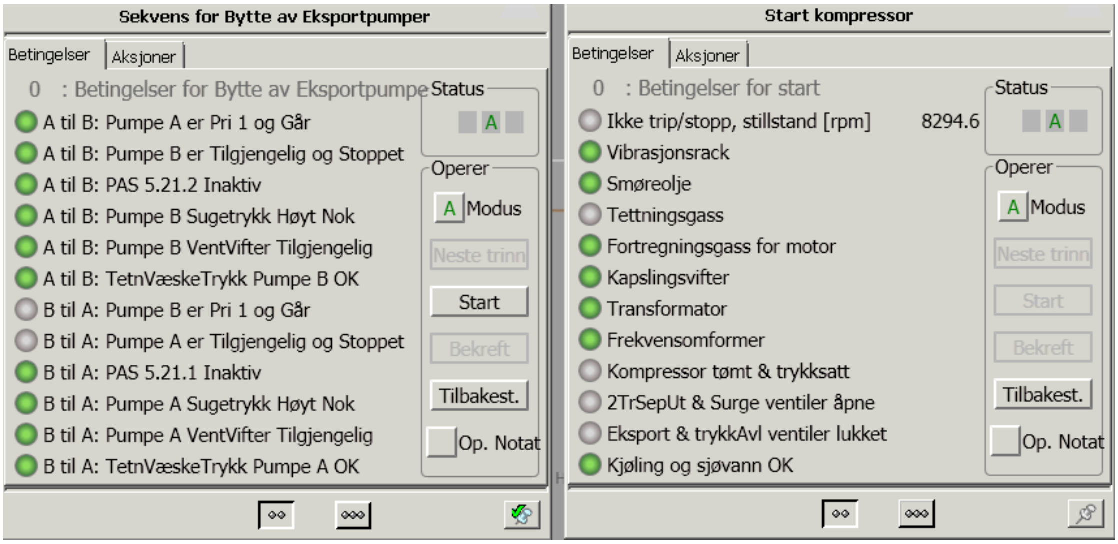

Figure 6.7: Sequences

The sequence picture on the right, does on the other hand, not provide the operator with good information. If one of the twelve conditions in this sequence should not be fulfilled, it is hard to find out what went wrong from this picture. As a new operator it is close to impossible to get some meaning of of this picture.

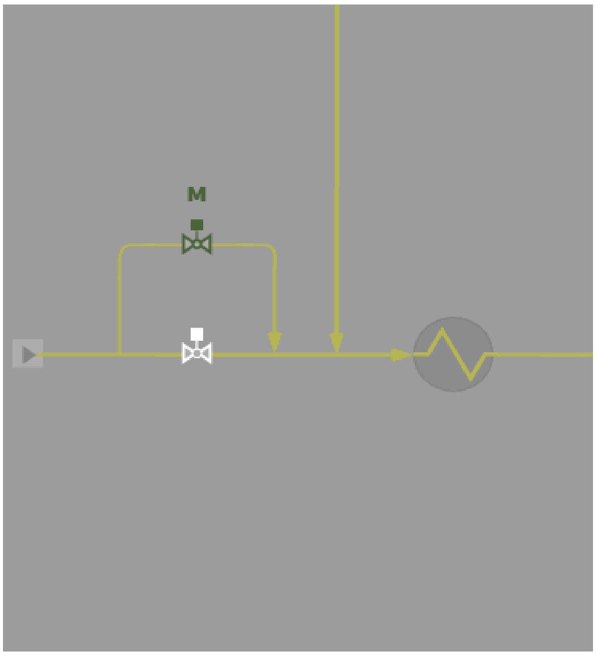

Figure 6.8: Valve

Figure 6.8 shows a typical process picture of a valve. In some HMI a white valve means that it is closed (by PAS/PSD process Shutdown), and the operators or logic are not allowed to open it. In other HMI it means that it is an interlock that hinders the operator or logic from opening it. Either way, the operators do not know the reason for this - there is no information informing the operator on why it is closed.

Chapter 7

Evaluation

As concluded in Chapter 5, large screen displays, GIGA-maps and 360 degree control rooms are considered as appropriate solutions which can support high SA. However, some drawbacks and limitations were found as well. The two latter may e.g. have the ability to decrease the key hole effect, while they at the same time may provide the operators with an information overload.

The operators interviewed in this thesis use large screens displays, and they stated that this was a good solution. The large screens in control rooms have both pros and cons. The large screens provide the operators with a common picture, which makes it easier for the operators to discuss a situation. It is important that the screens contain the right amount amount of information to the operators. Too much information causes information overkill, while information distributed over to many screen levels may cause the key hole effect. For experienced users, who know the system in and out, a lack of information might not be a problem. To find the right balance of how much information is needed, is an important factor when designing a user interface.

GIGA-mapping may contain too much information and can be confusing if that is the only solution used in the control room, especially if the map is not structured following the mental models inside control room operators head. Using GIGA-maps in a training process would be a good idea as it can help operators understand what is going on everywhere in the process. If the GIGA-maps were designed as an interactive map the operators could have used it to zoom in and out to see the whole process or just parts of it. As the GIGA-maps contain a lot of details, these overview could have included symbols for where the alarms was located in the system, and e.g. a flag for where the temporary instructions belonged to, that could have improved the operators understanding and memory load. The biggest concern for using GIGA-maps in control room is that they might provide the operators with too much information, which could confuse the operators and give information overkill.

360 degree control rooms, as the one developed at Høyskolen in Buskerud and Vestfold, is evaluated to be better suited for use in a training programme than in a control room situation, at least for the time being. With some more development and testing it might be a better solution in the future. For use in control rooms, it is proposed to deploy some of the same solution as for large screen displays, but as these screens are even larger it has the potential of containing more information. More information may decrease the key hole effect, but on the other hand it could give information overload as well. The line between these two factors have to be found in collaboration between the users and the designers.

In order for the operators to have good SA, the information presented to them must be accurate and given in an appropriate amount. Regardless of what kind of information presentation solution is used, it is important that information is presented in a consistent way, so that the operators can concentrate on his or her task instead of trying to understand the interface. Even if the operator adjust to it after a time, it may make poor mental models for later use. The balance between too much and too little information might be hard to find, and how much information needed depends on how experienced the operator is. As people only process a restricted amount of information it is important not to put too much information on the screens.

When designing an alarm system it is important to make the design such that the operators attention gets directed to the right place. Misplaced salience will hinder the SA , while right use of attention will promote the SA. The use of flashing lights, red symbols and high noises should therefore be limited to where it is really needed.

Some of the interfaces could ideally have been modified with respect to colors and placement of information. The interface used at Statoil had numbers placed too far from where they belonged to, making it sometimes hard to understand, which could potentially lead to the operator misunderstanding the situation.

The reason the usability of the HMI is poor might be that the people working with the commissioning of the plant lack insight in what the control system consists of. In addition to this, the projects is under a though time schedule, where a lot of activities happens in parallel - it is a lot of modifications and the pressure on getting the project finished at time is extremely high. In the engineering process the focus lies on the application, and that it should be easy for the operator to understand the alarms, where they come from and what the consequences for the security of the plant could be. The control system is the last part started under the commissioning, which leads to the persons closest to this process do not get enough time to change factors. Generally, the usability of the process control on the plant should get more attention in a project to secure a better SA among the operators.

There is also a good idea to have meetings on a regular basis on the platforms and ships, this is in order to ensure that the operators are up to date on the work situation. There should e.g. be morning meetings to let the operators going on a shift know what has been done during the previous shift.

From observation and interviews, the focus on SA is also directed to the training of the operators in addition to what kind of system they use. The focus in the training process should not just be on *what* you should do in different situations, but *why* you should do this. This kind of training of operators will lead to an improved mental model, a higher level of SA (Chapter 4) and change the way operators behave in situations (Chapter 3.5).

Training sessions in between work periods are also important in order to make the process in the control room more efficient. It is important to practice what to do in abnormal situations in order to handle correct and develop a mental model to use in these situations. There could be a good solution to pair up an operator without much experience and a more experienced one in training situation, because transfer knowledge from experienced to new operators is important in working environments such as control rooms. Training session will also increase the operators SA level (Chapter 4) and behaviour (Chapter 3.5).

Rotation between the working teams is also important because it forces the operators to have knowledge about the whole process. As mentioned in Chapter 3.2, it is important that the operators have knowledge about everything - it is not sufficient that one only knows a lot about one part of the process and a little about the rest.

The impression from the visit at Statoil Stjørdal was that the operators had a very good SA and that they knew what to do in both situations where they were informed of what could happen and situations where they were not informed. With three screens each and a space of 1 meter between them, good communication is required to have a good team work and team SA, and the communication between the observed operators was good.

As there where not observations, only a interview outside the control room with one operator from Shell, it is hard to evaluate the behaviour at this platform.

Chapter 8

Discussion

Before deciding on which solution to use in the control rooms it is important to remember that new solutions require a lot of training of new and old operators, in addition to a high cost from e.g. developing the new solution, testing it, training sessions and new equipment. New solutions may also require new mental models, and there may occur new problems that has never been thought of before. It is important to have a throughout testing of the system, because the safety on the plant is one of the most important matters. After the testing process, and if decided to go with the new solution, all the operators have to go through a training programme to get the best outcome as possible.

Users that have used one solution for a long time, may have a hard time adjusting to the new system. People have natural reluctance to new systems, even when they will perform better. In the interview process the other solutions, GIGA-mapping and 360 degree control room was mentioned for the operators, without getting a lot of positive response. The operators interviewed have worked with the large screen solution all their working career, and for them it is hard to imagine a solution that could be better. New systems based on different technology are therefore challenging to implement, gain acceptance from experienced users and eventually being used as expected.

New solutions should only be introduced if it brings a positive value to the operators and helps them do a better job. In a design process, the users of the system, here the operators, should be included. The operators interviewed mentioned that some of the new solutions suggested by design engineers did not work very well, probably because these engineers did not see it from a operators point of view. When designing, it is therefore important to include the users. They are going to use this system on an everyday basis, and it should be usable from their point of view.

New control room solutions may require a lot of reconstruction on the platform, as the control room built on the platform is made to meet the requirements sat for the room at an earlier point of time. For that reason new solutions may not be built in the platform before the companies decide to build a new platform.

The solution best suited for control room as for now, will be the existing large screens, as the other two solutions are more designed to give an insight in a design process and thereby may give an information overload to the operators. Large screen displays provide the operators with a more appropriate amount of information.

Last, but not least, it is important to remember that one solution that works perfectly for one team may not work at all for another. All teams are different, and finding a solution that fits all perfectly is not possible.

Chapter 9

Conclusion and Further Work

To have high situation awareness and understanding of what is going on in a situation is important when working in a control room. As the operators work in teams, it is important that the operators have some of the same understanding and a common mental model of situations. For providing the operators with common information, factors like training and how the information in the control rooms is presented are important. This thesis evaluated three different information presentation solutions, large screen displays, GIGA-maps and 360 degree control room, in light of how they could support situation awareness.

As for now, it is the present used large screen displays, that is the best suited solution for control rooms in the oil and gas industry. The main reason for that is that the large screen displays provides the operators with an appropriate amount of information on a common screen which gives the operators a better opportunity for making a shared mental model and better conditions for cooperation. Some study should on the other hand be done on how and what information is presented on the screens, in order to increase the situation awareness.

Even though the information presentation solution has an impact on the situation awareness, the training of the operators will have a larger impact. Using large screen displays in the control room, naturally implies that the large screen displays are used in the training process to teach the operator to use the system. The two other solutions reviewed, GIGA-maps and 360 degree control room, are more suited for use in training of operators than for the control room work. Both of these solutions are developed in order to share information and get more insight in a design process, and would therefore be good tools to give the operators more insight in the process on the plant. This is very important in order to teach the operators what happens and why, not just how to fix a problem.

Regardless of the information presentation solution, there are some common factors for all solutions to ensure a better situation awareness. The information should be presented in a consistent manner, there should be an appropriate amount of information on the screen (to avoid information overkill and the key hole effect) and the interface should be designed to avoid misplaced salience.

Even though the conclusion of this thesis is that the large screen display are the best suited solution, the applicability of these above mentioned technologies is still open for question and current topic of investigation by the human factors community in Norway. More field work is needed in order to define all requirements from the industry (and control room workers) before these solution start being developed.

As further work one could make a GIGA-map for use in training of the operators. The solution should be developed in corporation with people with insight in process control and tested on the operators to see if this a solution suited for training. For the large screen displays, investigating the information displayed on the screens could be done, in order to assure that the displays give the right amount and well describing information. 360 degree control rooms should also be investigated further. As a start the group working on the SimSam project at Høyskolen in Buskerud and Vestfold could be visited in order to discuss more about the use of this room in oil and gas industry.

In addition to these three solutions, there might be other information processing solutions suited for this industry that could be explored further as well.

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Appendix A

Spørsmål brukt i observasjon og intervju

Introduksjon:

- Hvem er jeg, og hva er bakgrunnen for og målet med besøket

Intervjuobjekt:

- Utdannesle
- Hvor mange års erfaring fra dette anlegget?
- Hvor mange års erfaring fra lignende anlegg?

Bakgrunn for å forstå anlegget:

- Hva er hensikten/formålet med anlegget?
- Beskriv prosessen
- Hvor komplekst er systemet?
- Hva er main objectives/hovedmålet som anlegget styres etter (en viss mengde, kvalitet, forespørsel, ...)?

Teamsituasjonen:

- Hva er oppgavene til operatørene? / Hvilke oppgaver har operatørene?
- Hvor mye tid bruker operatørene på XX, YY og ZZ? (f.eks. de tre oppgavene som tar mest tid)
- Hvilke andre grupper/team samarbeider du med?
- Hvordan ser teamet ut – hvilke disipliner er involvert?
- Hvor befinner de andre teamene seg? Hvordan foregår kommunikasjonen? I faste/sporadiske møter, når det trengs, videokonferanse, ...?

- Hva fungerer best? Hvilke oppgaver fungerer best/er enklest å gjennomføre?
- Hvilke oppgaver/kommunikasjon er tungvinte og vanskelige å få til?
- Er det noen oppgaver som burde tatt kortere tid enn det tar i dag?
- Er alle opplært i alle deler, kunne de tatt over hverandres oppgaver?
- Har alle et helhetlig overblikk over hva som skjer overalt i prosessen?
- Hvordan skjer kommunikasjon med både hverandre og ledelse?
- Øker løsningen interaksjon mellom operatørene?
- Hva slags tools blir brukt for å jobbe sammen?

Til løsningen (for eksempel large screen displays):

- På hvilken måte er løsningen nyttig i arbeidssituasjonen? (Gir den riktig oversikt, korrekt mental modell, hjelper den på teamwork, oversikt over problemer i prosessen)
- Gjør den samarbeidet i teamet bedre?
- Fornøyd/ikke fornøyd – noen elementer som er vanskelige å lese av?
- Noen tanker om designet, eventuelt ønsker for endringer?
- Pålitelig informasjon på skjermen?
- Jacob Nielsens liste
- Gestaltprinsippene
- Hvordan ser feilmeldingene ut?
- Må man ha mye bakgrunnskunnskaper for å kunne forstå bildene?
- Hva vises på storskjermen? Informasjon som er felles for alle? Informasjon som gir overblikk over hva som skjer?
- Er det det samme bildet på storskjermen hele tiden, eller kan man bytte det ut? Hvem har i så fall «makt» til å gjøre det?