19th Annual Conference on Systems Engineering Research
Transdisciplinary nature of SE:
Impact on traditional and novel applications
March 24-26, 2022 - Norwegian University of Science and Technology

2022 Conference on Systems Engineering Research

Situational awareness and human factors when designing complex systems

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Abstract

The background for this paper is to prepare for the execution of a research project in systems engineering about situational awareness and human factors. The authors use a major defense company as the case for this research. The company is developing a new weapon system that allows one operator to operate multiple remote weapon systems. The systems will produce a large amount of data that the operators must use in their decision-making process. To make the right decisions, the operators need good situational awareness.

The authors have examined publications about situational awareness and human factors and elaborated on the research design for the upcoming research project. Findings in the literature suggest that situational awareness consists of three levels. In all three levels, several factors affect an operator's ability to build and maintain situational awareness. The hypothesis for the upcoming research project is that the company lacks in-depth knowledge about situational awareness.

Keywords: situational awareness; human factors; remote weapon systems; SAGAT

1. Introduction

A major defense company is developing a new generation of a land-based remote weapon system. The new system will allow one operator to operate multiple remote weapon systems. Such a system is a complex and dynamic combat system with multiple subsystems that need to be controlled. The operators that are operating the weapon systems are often young people with varying degrees of experience. The operators must operate the system in highly demanding environments and situations.

Symptoms. The weapon system will process a large amount of real-time data from different sensors, cameras, radars, etc. The data will be analyzed and presented to the operator. The operators that are presented with the data

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must understand the data and make the right decision. To be able to take the appropriate action, the operator must build and maintain situational awareness. Situational awareness is a critical part of the decision-making process. In a safety-critical system, such as a remote weapon system, the lack of situational awareness can have catastrophic consequences. The lack of situational awareness has been identified as the main factor behind several large accidents and failures. [1, 2, 3]

Problem. The operator will be presented with an extensive amount of data. The data will help the operator to build and maintain situational awareness. How the operator perceives and processes the data is not only affected by the quality of the data, but also by different human factors. In a combat situation, the operator will experience that different human factors affect their ability to build and maintain situational awareness. The problem for the company is to develop systems that allow the operator to build and maintain situational awareness under the influence of different human factors. The company has long and great experience in developing new technology solutions. However, they lack in-depth knowledge about situational awareness and how different human factors affect the operator's ability to build and maintain situational awareness.

Rational. Technological advancements have allowed the company to develop more and more complex weapon systems. When the weapon systems become increasingly complex, designing for situational awareness and human factors becomes more important. Complex systems can produce a large amount of data. The data can be useful information for the operator to build and maintain situational awareness. However, the data that is being produced can also hinder an operator from building and maintaining situational awareness. The amount of data can be too large to process or not relevant for the current situation. More data does not necessarily mean more information.

Goal. When developing complex systems, one of the goals should be to design the system so that the operator can build and maintain situational awareness. The developers and designers need to be familiar with situational awareness to reach that goal. The developers and designers also need to know what kind of human factors can affect an operator's ability to build and maintain situational awareness.

Solution. By increasing knowledge about situational awareness and which factors affect situational awareness, the company can develop a system with a better human-machine interface (HMI). A better HMI design will increase the operator's ability to build and maintain situational awareness. The upcoming research aims to increase the knowledge about situational awareness in the company. To increase the knowledge about situational awareness, the authors have formulated three research questions:

RQ1. What is situational awareness?

RQ2. What human factors affect an operator's ability to build and maintain situational awareness?

RQ3. How can the company measure an operator's situational awareness?

2. Literature

2.1 Toward a theory of situation awareness

The first article in this literature survey is the article from Mica R. Endsley, Toward a theory of situation awareness. (1995) The background for this article is that technology development has made it more difficult for the operator to act effectively and make timely decisions when operating complex dynamic systems. The operator must build and maintain situational awareness to make timely and effective decisions. To acquirer and maintain situational awareness, it becomes more difficult when the complexity and dynamics increase. [4]

Before Ensley's publication, the research on situational awareness was limited. Endsley wants to show two things:

a) The importance of situational awareness in decision making and the benefits of a model that takes situational awareness into account.

b) A developed theory for situational awareness that shows that it involves more than being aware of different types of information.

Endsley argues that situational awareness is needed in a wide range of different operating environments, and it goes beyond traditional information processing. Operators in aircraft, air traffic, large system operations, tactical, and strategic systems must build and maintain situational awareness.

Endsley defines situational awareness as "the perception of the elements in the environment within a volume of time and space, the comprehension of their meaning, and the projection of their status in the near future." [4]

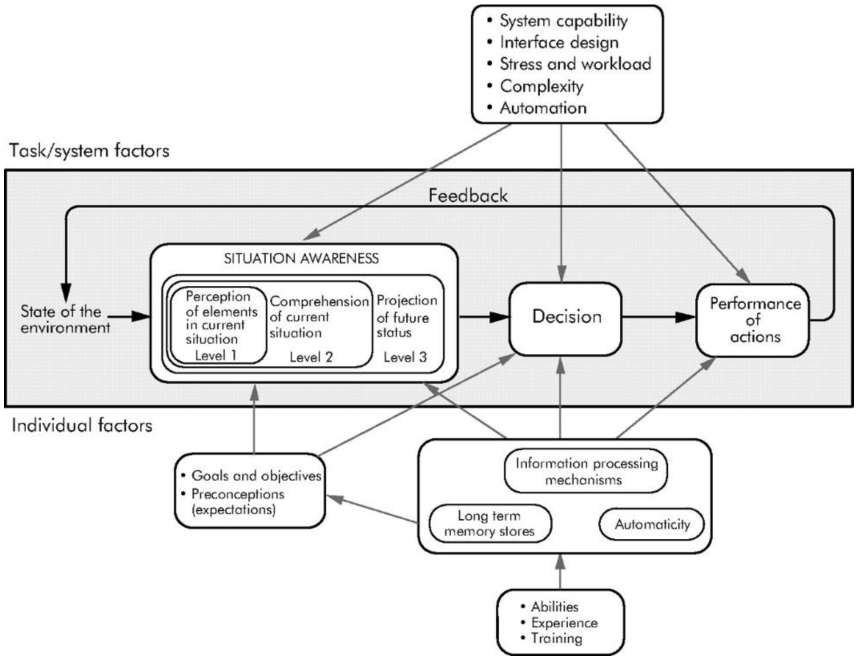

Fig. 1. Model of situational awareness [4, 5]

The model for situational awareness, as shown in Fig. 1, consists of three levels:

Level 1. Perception of elements in the current situation. The perception of the elements in the current situation is the first step of achieving situational awareness. At this level, the operators "perceive the status, attributes and dynamics of different elements in the environment". [4] The operator needs to perceive and understand the elements in the environment. [4] For a weapon system operator, the operator needs different types of information and data about the operating environment.

The operator needs information and data about all enemy and friendly forces in the operating environment. The operator needs information and data about their enemies and friendlies positions, capabilities, number of forces, etc., in their operating environment.

Level 2. Comprehension of the current situation. Level 2 is based on the knowledge from the information and data acquired in level 1. In level 2, the operator is aware of the surrounding elements. Since the operator is aware of the elements and the significance those elements have on the operational goals, the operator can form a holistic view of the environment. The operator can understand the significance of different objects and events in the operator's environment. An example Endsley gives is that a fighter pilot must understand what the appearance of an enemy fighter plane in the environment will do to their objectives. [4]

Level 3. Projection of future state. Level 3 is the highest level of situational awareness. Level 3 combines the knowledge acquired in level 1 and level 2. The combination of the knowledge makes it possible for the operator to predict the future states and actions of the elements in the environment. To predict the future actions of the elements in the environment, the operators rely both on the knowledge about the status and dynamics of the elements and an understanding of the situation. [4]

One example the author gives is knowing that an enemy aircraft is hostile, and that the location of the enemy aircraft will allow the pilot to predict if the enemy aircraft is likely to attack. This information gives the pilot knowledge and time to act in the most favorable way to meet the pilots' objectives. [4]

Endsley concludes that the model shows that situational awareness is more than just perceiving data and information. Situational awareness also includes that the operator must understand the information and compare it with the operators' goals and predict the future states of the environment. All of this gives the operator valuable knowledge and information for decision-making. [4]

The article further discusses different factors that can influence an individual's situational awareness. The author discusses the factors stress, workload, complexity, attention, and working memory.

Stress. The author categorizes stress into two groups of stress:

1) Physical stress that comes from noise, heat, vibration, boredom, and fatigue. [4]

2) Social physical stress comes from fear, uncertainty, mental load, and time pressure. [4]

Both stress groups will influence the operator's situational awareness. A high amount of stress may have catastrophic consequences. However, a minor increase in stress may improve the performance of an operator. [4]

The stress factors will influence the operator's situational awareness in different ways. First, a high stress level will negatively affect situational awareness by narrowing down the operator's field of attention. Second, stress results in a phenomenon called cognitive tunnel vision. Cognitive tunnel vision happens when people only focus on a limited source of information. By only focusing on a limited source of information, the operator will reduce their situational awareness. [4]

Endsley argues that the negative effects of stress will significantly affect the operator in the early decision-making and assessment phase. The early decision-making and assessment phase is the same as level one in the model for situational awareness: Perception of the elements. [4]

Workload. Another factor that affects an operator's situational awareness is workload. If there is a high workload level on the operator, it may affect situational awareness. How high levels of workload affect the operator's situational awareness depends on the system design, the operator's tasks, and the individual capacity of the operator. [4]

Complexity. The complexity of the system will affect the operator's possibility of achieving situational awareness. A complex system will negatively affect the operator's workload and situational awareness. The negative effect comes from an increase in components and the interaction between the components. The workload for the operator increases when the level of complexity of the system increases. These factors will increase the mental workload of the operator. If the mental workload increases beyond the operator's capability, the level of situational awareness decreases. [4]

Attention. When an operator is using attention in the perception phase, it may constrain the operator's "ability to perceive multiple items in parallel". [4] This will have a significantly negative effect on the operator's ability to achieve and maintain situational awareness. Attention is needed in both perceiving information and data, and the decision-making phase. [4]

Working memory. The information an operator has perceived is stored in working memory. New information in combination with the operator's existing knowledge forms a holistic view of the situation. This is level 2 in the situational awareness model: comprehension of the current situation. The proper action to the situation is also stored in the working memory of the operator. This is level 3. All these processes put a high demand on the operator's working memory. The author argues that the high demand for the operator's working memory is one of the main obstacles for an operator to achieve and maintain situational awareness. [4]

Conclusion. The article addresses many relevant topics for the upcoming research project such as situational awareness and the effects human factors have on situational awareness. Endsley's article is a foundation for understanding situational awareness. It has almost 10 000 citations.

Other researchers have criticized the model of situational awareness for lacking empirical evidence. Salmon et al. [6] criticize Endsley for separating the product of situational awareness and the process to achieve it. The authors argue that the three levels are all one process in developing situational awareness.

2.2 Stress, fatigue, situation awareness, and safety in offshore drilling crews

The second article addresses stress, fatigue, situational awareness, and safety in offshore drilling crews. [3] The background for the article was the BP Deepwater Horizon disaster in 2010. After this disaster, situational awareness for oil and gas workers became increasingly important. To prevent future dangerous accidents like BP Deepwater Horizon, the workers must have good situational awareness. Several factors contribute negatively to how the workers gain and maintain situational awareness. The article investigates how stress and fatigue influence the oil and gas workers' situational awareness. To measure situational awareness, the authors developed a self-report measure to indicate the individual level of situational awareness. The self-report is a scale that measures the operator's general awareness of the drilling environment. The report was based on a Cognitive Failure Questionnaire (CFQ) [3].

Sneddon, Mearns, and Flin describe the theoretical background for addressing stress, fatigue, sleep disruption, and how these factors affect situational awareness. The authors argue that stress can affect the operators' situational awareness in several ways:

1) Elevated stress levels may affect the workers working memory capacity. [3]

2) Stress can result in a reduced concentration for the oil and gas workers due to an overload of the cognitive resources of the individual worker. Reduced concentration may lead the worker to misinterpret the situation. [3]

3) Elevated stress levels can lead to cognitive tunnel vision that results in a worker only focusing on a limited number of tasks. [3]

Fatigue, sleep disruption, and situational awareness. Fatigue and sleep disruption can negatively influence workers' situational awareness. Fatigue and sleep disruption will lead to a lower level of alertness that leads to a lower level of situational awareness. Sleep disruption and fatigue harm cognitive processing. The effect can be compared to driving under influence. All these effects have been shown in other research within the maritime industry, transportation industry, power generation industry, and the oil and gas industry. [3]

The hypothesis Sneddon et al. stated was that "stress and fatigue will have a destructive impact on situational awareness, and that the individuals with a lower situational awareness will cause more accidents, near-misses and report more unsafe behavior due to a lower attention and alertness". [3] To test their hypothesis, Sneddon et al. formulated several sub hypotheses:

1a) "Stress will be negatively associated with WSA (Work Situational Awareness)"

1b) "Sleep disruption will be negatively associated with WSA"

1c) "Fatigue will be negatively associated with WSA"

2a) "WSA will be negatively associated with unsafe behavior"

2b) "WSA will be negatively associated with accident involvement"

2c) "WSA will be negatively associated with near-miss occurrences"

They also formulated a hypothesis that "WSA mediates the relationship between the performing shaping factors (fatigue, sleep disruption, stress) on unsafe behavior".

Method. They sent the questionnaire to 378 drilling personnel, where 185 of the questionnaires were analyzed. The respondents worked at all levels of the hierarchy. 74% of the respondents had worked at the rig for less than five years. To analyze the data, the authors used principal components analysis to examine the structure of the WSA. The relationship between stress, fatigue, and WSA levels was analyzed using correlation and regression analysis. To test for mediation effects of WSA between stress and safety non-compliance, they used the Sobel test. [3]

Results. The result of the analysis showed that higher levels of stress had a negative effect on situational awareness. They also found the same effects when they analyzed the effects of sleep disruption and fatigue. The research also showed that unsafe behavior was significantly related to lower levels of situational awareness. From the regression model, the authors got a result showing that high levels of stress have a negative effect on the workers' situational awareness. [3]

Conclusion. The research showed similar results that other researchers have reported on the impact of stress, fatigue, and sleep depression on situational awareness. The work environments for oil and gas workers and operators of remote weapon systems are very different. How the oil and gas workers and the soldiers are affected by stress and sleep disruption may also be different. Soldiers are often tested on how well they manage stress when entering the military. Because the soldiers are tested on how well they manage stressful situations they may be more robust when handling stress than oil and gas workers. Training is also a factor that can make a difference between oil and gas workers and soldiers. Soldiers get extensive training in stressful situations and are often under sleep disruption. Based on this we may assume that soldiers handle stress and sleep disruption better than oil and gas workers, but there will be individual differences.

Even though there may be differences between oil and gas workers and soldiers, this research shows that stress, fatigue, and sleep disruption will have a negative effect on situational awareness.

*2.*3 S*leep deprivation, fatigue, dehydration, and starvation effect on soldiers*

In 2001, Hassfjell conducted a study showing that sleep deprivation, fatigue, dehydration, and starvation would severely affect a soldier's situational awareness. The background for this study was to enhance the knowledge and the awareness of the effects of sleep deprivation, starvation, dehydration, fatigue, and mental reactions has on soldiers in a combat situation. [7]

To show the effects that sleep deprivation, fatigue, dehydration, and starvation have on soldiers, the author refers to a study conducted by Opstad. [8] The study from Opstad showed that soldiers experienced severe physical and cognitive symptoms. After 24 hours the soldiers experienced impaired social skills, became less caring, depressed, and had reduced motivation. [7, 8] The symptoms became even more severe after 48 hours. After 48 hours without sleep, fatigue, starvation, and dehydration the soldiers began to experience lower alertness levels, decrease in creativity, reduced capacity for solving complex tasks, reduced situational awareness, slower response time, and reduced concentration. [7, 8] After 72 hours the soldiers experienced balance disorder, hallucinations, blurred vision, physical exhaustion, and microsleep. Microsleep is when a person is falling into sleep in short periods under activity, including while standing. [7, 8]

Conclusion. The effects on sleep deprivation, fatigue, starvation, and dehydration were studied on light infantry soldiers. These soldiers will have a different operating environment than an operator of a weapon system. The light infantry soldiers and weapon system operators are put under different physical and mental stress. How these factors affect the operator of a weapon system is not shown in this study. However, it is reasonable to conclude that the factors will affect the operator to a varying degree.

2.4 Cognitive Load and Situation Awareness for Soldiers: Effects of Message Presentation Rate and Sensory Modality

In 2019, Hollands, Spivak, and Kramakowski researched soldiers' cognitive load and situation awareness. The background for the research was that in a combat situation, soldiers have extensive communication by radio. The Canadian army introduced a new battlefield manager system (BMS) for its soldiers. The BMS allows the soldiers to communicate tactical information with text. The goal of the research was to determine what influence message presentation rate (MPR) has on the soldier's cognitive load. [9]

The research concluded that MPR affects the cognitive load, situational awareness, and workload of the soldiers. The research also showed that the presentation of tactical information by radio messages improved situational awareness and cognitive load. When the researchers compared visual presentation of information and radio messages, they did not find any improvement in situational awareness by using visual presentation. [9]

Conclusion. This research shows that visual presentation of information could increase the soldiers' cognitive load and workload. The increase in cognitive load and workload might reduce the situational awareness for the soldiers. The fact that there was no improvement in situational awareness when using visual presentation is something to consider when designing for situational awareness. It might not be preferable to design systems that rely too much on the visual presentation of information.

2.5 Situation awareness: State of the art

Different factors affect an operator's ability to build and maintain situational awareness. Some of those factors have been discussed in detail in this literature survey, but there are more factors. In the article "Situation awareness: State of the art" [1], Endsley summarized eight factors that can affect an individual ability to build and maintain situational awareness. Those factors are:

1) Attentional narrowing. Individuals often fall into the trap of attentional narrowing. Attentional narrowing is when an individual only focuses on a limited set of information. Because of attentional narrowing, the system needs to be designed to support multitasking and decision-making across different goals. [1]

2) Requisite memory-trap. People tend to have limited short-term memory, and it is easily disrupted. The system should be designed to not require people to hold information in their working memory. [1]

3) Workload, fatigue, and other stressors. These factors will hinder a person's ability to build and maintain situational awareness. These factors disrupt working memory and information gathering. [1]

4) Data overload. Too much data can outpace a person's ability to keep up with the presented data. [1]

5) Misplace salience. If the design relies too much on visual features like lights and colors, it may overwhelm an operator's attention. [1]

6) Complexity creep. A system can become too complex for an operator to build and maintain situational awareness. [1]

7) Errant mental models. The operator must build a good mental model of how the system works. If the operator does not have a good mental model, he or she may misinterpret the data. [1]

8) Out-off-the-loop syndrome. If the system is highly automated, it could lead to the operators having a low awareness of the states of the system. [1]

Conclusion. This part of the article summarizes the factors that influence an operator's ability to build and maintain situational awareness. Some of the factors have been described in more detail by the other articles. The summarization is based on years of research the authors have conducted.

2.6 Situation Awareness Global Assessment Technique (SAGAT)

When designing complex and dynamic systems that require the operator to build and maintain situational awareness the designer must be able to measure situational awareness. The article "Situation Awareness Global Assessment Technique (SAGAT)" [10] provides a technique designers can use to measure an operator's situational awareness.

The background for this article is that the goal for any interface design is to build and maintain an operator's situational awareness. To design an interface that can build and maintain the operator's situational awareness, the designers must be able to measure situational awareness. SAGAT is a technique to objectively measure an operator's situational awareness at any given interface design. [10] SAGAT was originally developed to assess aircraft pilots' situational awareness.

To measure and compare different designs against each other, Endsley recommends that the designers must evaluate different technologies and concepts. They must evaluate:

1) "Displays symbology and design"

2) "Control/displays concepts such as 3D displays, voice controls, flat panel design, head-up displays, helmet-mounted displays, helmet sights, tactile display devices"

3) "Avionics and system concepts"

4) "Advanced software concepts"

5) "Expert systems and automation"

6) "Training techniques"

The following procedure is done to measure a pilot's situational awareness with the SAGAT:

1) The pilot flies a simulated mission with a given aircraft system.

2) The simulation freezes at a random time and all the displays in the simulator are turned off.

3) The pilot is asked a series of questions. The questions are asked to determine the pilot's knowledge about the situation when the simulation was stopped. The questions that the pilots are asked are developed from the requirements of the pilot's situational awareness.

4) It is impossible to ask questions about all the requirements for the pilot's situational awareness. Only a small portion of questions are randomly selected to secure the validity of the sampling.

5) After the pilot is asked the questions, the answers are evaluated. The evaluation is done by comparing the answers with what was happening in the simulation. The comparison will give an objective measure of the pilot's situational awareness.

6) The different designs are given a SAGAT score. The SAGAT score is given in three zones, immediate, intermediate, and long-range.

7) To provide statistical significance for the comparison of different system designs, the procedure is conducted with several pilots using the same system. The SAGAT scores from the different system designs are compared to determine the best design when it comes to situational awareness.

Conclusion. SAGAT was originally developed for aircraft system design and pilots' situational awareness. Even though there is a difference between aircraft and remote weapon systems and between pilots and operators, the technique is general. The technique could be conducted to determine how different interface designs affect the operator's situational awareness. By simulating different missions, this technique can be used for remote weapon systems.

2.7 Measurement of situation awareness validity and use of SAGAT

In the article Direct measurement of situation awareness: Validity and use of SAGAT, [11] Endsley discusses several implementation recommendations when applying SAGAT. The recommendations have been developed based on previous experience of the SAGAT procedure.

Training. Endsley recommends that the test subjects should be briefed and explained the SAGAT procedure before the test. It is also advised that the test subjects can go through several training runs. This will allow the test subjects to clear up any uncertainties about the procedure and how to answer the questions. Based on previous experience Endsley recommends three to five training runs. [11]

Test design. SAGAT does not need any special test considerations other than a simulator. The SAGAT procedure follows the same principles as experimental design. [11]

Procedures. The test subjects should perform their tasks as they usually would have. The SAGAT procedure should be considered secondary. When the simulation stops, no visual aids and displays should be accessible. The test subjects should be encouraged to make their best guess on questions they do not know the answers to. The author recommends that the test subjects should not be able to talk and share information during the test. [11]

Random selection. The test subjects' questions should be a random selection of a set of questions. Some subjects may feel that their questions are not relevant to consider when the simulation freezes. The feelings may come from attentional narrowing or lack of information. [11]

Experimental control. Due to the limitations of the simulator, some queries may have to be omitted. Which queries that must be omitted are based on the simulator's capacity and the test design. [11]

When to collect SAGAT data. Endsley recommends that the freezes of the simulations must be randomized. A randomized freeze of the simulation will ensure that the test subject cannot prepare themself. A recommendation is that the freeze of the simulation does not occur before three to five minutes and that two freezes do not occur within one minute of each other. [11]

How much SAGAT data to collect? How much data to collect is dependent on the variability of the dependent variable. The article recommends between 30-60 samplings per situational awareness query. There is a possibility of freezing the simulation more than once in one trial run. The author also recommends that the freeze lasts for a specific amount of time before resuming the simulation. The simulation should be resumed even if not all questions are answered. [11]

Data collection. The questions should be evaluated as correct or incorrect. The questions not answered are recommended to consider as incorrect. To analyze the data, the recommendation is to use a correction factor to analyze the correlations. A chi-square, Cochran's Q, or a binomial t-test can be used to test the statistical significance. [11]

Conclusion. The article shows the procedure to measure an operator's situational awareness with different interface designs. The procedure is a general description of the SAGAT technique. To measure situational awareness for operators of remote weapon systems, the procedure might have to be adjusted. SAGAT is described as a technique that does not require any expertise and uses low resources.

2.8 Situation Awareness Rating Technique (SART)

Another technique to assess an operator's situational awareness is the Situation Awareness Rating Technique (SART). SART is a subjective rating technique in contrast to SAGAT, which is objective. Since SART is a subjective technique, it provides a subjective rating of the situational awareness of the operator. [12]

The SART technique requires the operators to rate a system design based on their own perceived situational awareness. The rating is performed with the operators' rating on how much demand the system puts on their attentional resources, how much, and how good the systems supply attentional resources, and the operators understanding of the situation. SART then measures the operator's perceived understanding of the situation. [13]

The article "A comparative analysis of SAGAT and SART for evaluation of situational awareness" [12] compares the two techniques on how well they measure situational awareness. The conclusion from the authors was that the objective measure (SAGAT) was better than the subjective measure (SART). The reason for this conclusion was that the measures in SART were highly correlated with the confidence level of the operators. [12]

Conclusion. This article concludes that the best technique to measure situational awareness is SAGAT. Since

SAGAT is an objective technique, the results are not correlated to any personal traits of the operator.

2.9 Designing Systems for Situational Awareness

Many of the topics discussed in this literature survey are topics that the book "Designing for situation awareness: an approach to user-centered design" [14] covers.

The background for this book is that there is a wide variety of complex and dynamic systems in different sectors and industries. All these systems need a user interface that allows the users to build and maintain situational awareness. [14]

The book aims to provide engineers and designers with a method to design systems for situational awareness. Amongst other things, the book describes 50 design principles for designing for situational awareness. The design principles are based on relevant research and design issues. [14]

Conclusion. The book describes and discusses most of the topics that are discussed in the other relevant articles. In addition to providing a theoretical background of situational awareness, it also provides practical solutions to design for situational awareness. The topics the book describes will be relevant for the upcoming research project.

2.10 Dual-task method

The dual-task method is an objective measurement of cognitive load. [15] It involves the test subjects performing two tasks simultaneously, one primary and one secondary task. By using this method, it is possible to measure the cognitive load the primary task puts on the test subjects. By simultaneously performing the primary and secondary tasks both tasks share the same cognitive resources the test subjects have at their disposal. [15, 16, 17]

This reasoning comes from cognitive load theory. The cognitive load theory states that if two tasks are performed simultaneously and require the same cognitive resources the cognitive resources would be distributed between the two tasks. [17, 18]. By having a simple secondary task that does not suppress the primary task it is presumed that an increase in cognitive load in the primary task will decrease the performance of the secondary task. [16, 19]

Research has shown that the dual-task method is a reliable and valid method to use for measuring cognitive load. [15, 19, 20]

A simple secondary task that could be used is the tapping of a finger or foot. The tapping should be performed in a steady rhythm with, for example, one tap per second. Using tapping as a secondary task would not impose the test subjects to use any additional cognitive resources. [21]

When analyzing the results of the performance of the tapping of the foot or finger, unrhythmical tapping indicates an increased cognitive load. A complete stop in the tapping would indicate cognitive overload. [21]

In 2011, Albert concluded in the article "Tapping as a measure of cognitive load and website usability" that the tapping test was an acceptable method for measuring cognitive load. [22]

3. Research design

The research design of the upcoming research project will consist of both interviews and two surveys. The plan is to perform an initial survey to determine the current state of the company. The questions will be formulated to determine how much they know about human factors and situational awareness. The survey will also determine how important they consider human factors and situational awareness when developing the weapon system. The results from the surveys will be analyzed and discussed.

A second survey will be conducted in the same way. The difference is that before the second survey, the employees will receive a summary of the research findings on human factors and situational awareness. The questions in this second survey will determine if they have gained a better understanding of human factors and situational awareness. The respondents will also be asked about their opinions on the importance of human factors and situational awareness have changed. The results of both surveys will be analyzed and compared to investigate the attitude towards the importance of human factors and situational awareness, potential changes in opinions, and the employees' understanding of the topic.

Research method(s). The research will use the standardized format with a structured data collection. The researchers will prepare a questionnaire. The questionnaire will consist of closed multiple-choice questions where the respondents can respond on an ordinal scale. The surveys will be produced in the survey tool Nettskjema. [23]

Data collection. The questionnaire will be distributed by e-mail to potential respondents within the company. The respondents will be selected based on what department they work in. Not all departments in the company are relevant for the surveys. The company has a separate team that works with HMI design. That team is relevant for the survey, but only two to three people are working in that team. To conduct the research, there is a need for more participants. To determine which departments to conduct the survey in, the researchers must get help from relevant company contact persons.

The interview will get more in-depth answers than the surveys. The questions for the interview will be formulated in a way that will help determine the company's views on human factors and situational awareness. The researchers will ask about how they have currently designed HMI and how they want to do it in the future. The researchers will try to determine if they consider human factors and situational awareness to be more important in the future by interviewing senior managers at the company.

For the interviews, the researchers will send the questions to the interviewee before conducting the interview. Follow-up questions are allowed. If granted permission, the interview will be voice recorded. This makes it easier to analyze and report the findings. Follow-up questions might be asked after reviewing the interview notes and recordings. This will be done by e-mail or a new face-to-face meeting.

Data analysis. The data received from the respondents through the survey tool will be analyzed with Excel. How the data will be analyzed depends on the questions in the survey. The researchers would like to use a Likert scale. The Net promoter score works well for the assessment of Likert scale questions. [24] The analysis of the two surveys will be a comparative analysis.

For the interview, the researchers will use the recordings or notes to discuss the findings.

4. Discussion

The research goal is to determine the company's knowledge about situational awareness and the human factors that affect situational awareness. The researchers also want to determine the employees' views on the importance of situational awareness when designing the new type of weapon system.

The results from the research are expected to show different results. In the first survey, the expected result is that the company lacks sufficient knowledge and expertise in situational awareness and human factors. Second, the researchers expect the results to show that the company considers situational awareness important when designing the new weapon system.

The second survey will be conducted after the participants have read the authors' findings on situational awareness and human factors. The expected result from the second survey is that the employees have gained more knowledge about situational awareness. Another expected result is that they view situational awareness and human factors more important than they did in the first survey.

From the literature we have learned that to build and maintain situational awareness the operators must undergo a process that consists of three levels. 1) Perception of elements in the current situation. 2) Comprehension of the current situation. 3) Projection of the future states. Within this process there are different human factors that will affect the operator's ability to build and maintain situational awareness. Below is Table 1, that summarize the human factors and the effects they have on the operator's ability of building and maintain situational awareness.

To measure situational awareness the company could use the SAGAT technique. From the literature survey the authors learned that the SAGAT technique gives an objective measurement of an operator's situational awareness. The technique, in itself, would require relatively low investments in time and resources to implement. The drawback with this technique is that it would require the company to have simulation capabilities that could support this technique. If the company does not have such simulation capabilities, it will require large investments in time, money, and other resources.

Table 1. Summary of human factors and their effects

Human factor	Effects
Stress	Narrowing down the operator's attention.
	Cognitive tunnel vision.
Workload	Disrupts working memory and information gathering.
Complexity	Increase the operator's workload.
Attention	Lack of attention will have a negative effect in perceiving data and information.
Working memory	High demand on the working memory will disrupt the processes in all the three levels.
Sleep disruption	Lowers the level of alertness.
	Harm cognitive processes.
Attentional narrowing	Focus only on a limited set of data and information.

From the literature, there is evidence that different human factors are affecting an operator's ability to build and maintain situational awareness. The company should also measure those human factors and how they are affecting the operator's situational awareness. The measurements can tell the company where they must change their HMI design to support the operator's ability to build and maintain situational awareness.

One method the company can use to measure cognitive load is the dual-task method. By using the dual-task method, the company would get insight if and where their HMI design is increasing the cognitive load on the operator. The advantage of the dual-task method is that it would require little resources and is easy to implement.

Potential risks in the research need to be considered and potentially mitigated. The first risk is in the questionnaire design. Several considerations must be made when designing the questionnaires. If the design of the questionnaires and questions are wrong, the results might not answer the questions that the research aims to answer.

There is a risk of the research not showing any statistical significance and will not be valid. If the results are not valid, they cannot be analyzed and reported. The results might not be valid because there is a risk of a too low number of participants. There is a risk in performing two runs of surveys. If there are few participants in any of the surveys, it will not be possible to reveal potential differences between the two surveys. The result will be that the research cannot determine if the participants have gained any knowledge about situational awareness.

The risk must be taken into consideration when performing the research. If the risk is not considered and possibly mitigated, the research might not be valid.

5. Conclusion

This paper aims to prepare for the execution of a research project in the spring of 2022. In this paper, the authors have introduced the line of reasoning for the project, reviewed relevant articles, and elaborated on the research design.

The literature survey shows that situational awareness consists of three levels. 1) Perception of elements in the current situation. 2) Comprehension of the current situation. 3) Projection of the future states. In all these levels different factors affect an operator's ability to build and maintain situational awareness. To be able to design and develop weapon systems, the company should measure situational awareness. Two different measurement techniques were discussed. The two techniques discussed were SAGAT and SART. SAGAT is an objective measurement technique, while SART is subjective. One of the papers concludes that SAGAT is the most suited technique to measure situational awareness.

The research will consist of two surveys and one interview. The research aims to find the level of knowledge and expertise the company has in situational awareness. The research has some risks that must be considered. The risk that the authors have identified is in the questionnaire design and the possibility of a low number of respondents.

The expected results from the research will show that the company lacks in-depth knowledge and expertise in designing for situational awareness.

Acknowledgements

This research is part of a larger research project, the second iteration of the Human Systems Engineering Innovation Framework (HSEIF-2), funded by The Research Council of Norway (Project number 317862).

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