Barrier considerations in crisis information systems

A qualitative study on uncovering barriers that can impede the use of information systems to attain situational awareness during crisis situations for crisis responders.

KIRSTI NÆSAGER NESSE
SINDRE BROBY FOSS

SUPERVISORS

Jaziar Radianti

Terje Gjøsæter

University of Agder, 2023
Faculty of Social Science
Department of Information Systems

Acknowledgements

We would like to express our gratitude to our supervisors Professor Jaziar Radianti and Associate Professor Terje Gjøsæter from the Department of Information Systems at the University of Agder and researchers at the research center CIEM (Center for integrated emergency management). Throughout this research they have provided guidance, support, and expertise. Their insight and constructive feedback have been invaluable in shaping this thesis.

We would also like to thank friends and family for their encouragement and support throughout our academic journey. Their support has been a source of motivation and inspiration. We would also like to give a special thank you to our classmates who, throughout the past year, have brought us a lot of joy and laughter.

Finally, we would like to acknowledge the essential contributions of all the participants who took part in the interviews. Without their willingness to share their experiences and insights, this research would not have been possible. Their contributions are important to achieve more effective crisis management, which can hopefully save more lives.

Kristiansand,
June 2nd, 2023

Sindre Broby Foss

Kirsti Næsager Nesse

Abstract

Good decision-making during crisis situations is crucial to ensure fortunate outcomes by minimizing loss and damage. There are many factors that compose good decision-making, but the level of situational awareness attained is undoubtedly a strong indicator for the quality of decisions. A high level of situational awareness provides the decision maker with a viable basis for making favorable decisions. Thus, to decrease detrimental outcomes of crisis situations, researching how to increase the level of situational awareness is key.

Information systems provide situational awareness by enabling users to obtain and share information. They are used extensively in crisis situations, particularly among crisis responders from police, health, and fire departments. Previous research indicates that there are barriers for using information systems to attain situational awareness in crisis situations. However, there is a lack of previous research that systematically uncovers these barriers and offers a holistic view on barriers and how to mitigate them. The goal of this thesis is to fill the research gap by uncovering barriers that can impede the use of information systems to attain situational awareness during crisis situations.

In this thesis, a qualitative study was conducted where 14 crisis responders from police, health, and fire services at the tactical and operational level were interviewed. The coding and analysis of the collected data resulted in a total of 43 barriers and themes. All barriers were categorized into one of the following overarching themes: *Cognitive*, *Physical* and *Technological*. Additionally, the data analysis revealed instances of cause-and-effect relations between some of the barriers, meaning that the occurrence of one barrier could cause or amplify other barriers. The findings provide useful insight for further research and practice by highlighting aspects of information systems in crisis response that should be considered to improve situational awareness.

Keywords: Crisis management technology, situational awareness (SA), situational disabilities, SA demons.

Table of contents

List of figures

List of tables

1 INTRODUCTION

1.1 Initial research motivation

Storms, natural disasters, sabotage, technical problems, terrorism or acts of war are examples of crisis scenarios that can harm a country and its population. DSB – The Norwegian Directorate for Civil Protection published a report in 2019 listing nuclear accidents and landslides as two of four crisis scenarios that carry the greatest risk in Norway, as well as other risks with lower probability like earthquakes, quicksand slides, ship collisions and more (Norwegian Directorate for Civil Protection (DSB), 2019). In addition to the threat of these major crisis situations, smaller crisis situations occur daily in Norway. In 2021, the health emergency service, police, and fire service received about 789 000, 750 000 and 91 000 inquiries respectively (Norwegian Directorate for Civil Protection (DSB), 2023; Norwegian Police, 2022; Vold, 2022). Due to the potential for destructive outcomes, it is crucial to ensure that crisis situations are dealt with effectively to minimize their adverse impact and mitigate unfavorable consequences.

In a crisis, time is of the essence. Making favorable decisions within a limited timeframe is pivotal for assuring the safety of those affected by the crisis. To achieve a well-founded basis for decision-making, attaining situational awareness (SA) is critical. Attaining SA goes beyond the acquirement of information. Understanding the significance this information has on achieving the desired goals, and projecting (predicting) how relevant information might change over time are essential aspects of SA. (Endsley, 2021, p. 2). The formal definition of SA is "*the perception of the elements in the environment within a volume of time and space, the comprehension of their meaning, and the projecting of their status in the near future*" (Endsley, 1988a).

The importance of SA is not restricted to crisis responders; SA also benefits victims by facilitating evacuation and safe decision-making. Poor SA will increase chances for poor decision-making during a crisis, both on an individual level and on a team level, which can be detrimental to the outcome of the crisis (Endsley & Garland, 2000).

A foundation for attaining SA is created by perceiving the relevant information in the situation. The situation generates cues that let you recognize patterns which activates a course of action (Luokkala & Virrantaus, 2014). The cues that occur in a situation can be received by using bodily senses. For example, during a fire, cues can be received through hearing (e.g., an alarm or authority warning), smelling (e.g., smoke), seeing (e.g., seeing others running), tasting (e.g., sulfur dioxide or hydrogen chloride), and/or touching (e.g., heat) (Kuligowski et al., 2017). SA can also be attained from communicating and sharing information. This can be done by using information and communication systems that provide supporting tools for establishing SA. Information systems can also offer tools beyond communication for attaining SA, such as sensors, GPS, alerting systems, cameras, and thermal imaging (Schroeder et al., 2018). For a variety of emergency management stakeholders, digital tools have become essential to identify and interpret observations, predict further developments, and communicate observations to other stakeholders (Lund, n.d.). A phone is essential for an emergency call center to receive emergency calls, and their computer systems plays a vital role in determining the location of the crisis and coordination with health, police, and fire services to send the required help to the location. The radio provides opportunities to share information and supply SA both across and within emergency agencies. Additional technology such as map systems (Solberg et al., 2018) and video sharing software (Nasjonalt Kommunesamarbeid For 110-Sentralene, 2022) provide better SA by providing graphical visualizations. More advanced technology such as infrared cameras helps firefighters see through smoke and provides increased SA about the insides of a smoke-filled house (Brann & Redning, 2006). Technology provides opportunities for increased SA in crisis situations. However, there are barriers that may impede the use of this technology.

Crisis situations can vary greatly from one another in terms of incident type, scale, people involved, location, time of occurrence, and more. This means there are several factors that can influence how technology is used by crisis responders, both due to the mental state of each responder, and due to the physical conditions of the crisis itself. Research suggests that there are barriers that needs to be taken into consideration when technology and information systems are developed for crisis situations (Gjøsæter et al., 2019). These barriers are typically related to the cognitive and physical limitations of human beings when interacting with technology under the conditions that emerges in a crisis (Endsley, 2000). Examples of barriers from previous research are situational disabilities (Gjøsæter et al., 2019) and Endsley's SA demons (Endsley, 2000). SA demons arise during the interaction between complex information systems and human beings who all suffer from cognitive limitations. An example of an SA demon is *Data overload*, which refers to the inability for a human to process the amount of information taken in, leading to lapses in SA (Endsley et al., 2003). A crisis responder could experience *Data overload* if they receive duplicate information from multiple sources, resulting in the need to process too much information at once (Prasanna et al., 2013). Situational disabilities encapsulates everything that restricts a person from using technology based on their context or situation, and may render them unable to operate technologies that they use on a regular basis (Gjøsæter et al., 2019). Examples of situational disabilities that may be experienced during a flood is cold and wet hands, because the resulting loss of touch and dexterity impedes the use of mobile phones (Ogbonna et al., 2022).

Barriers for using information systems to attain SA are important to uncover, because SA is a key component of decision-making and performance. SA significantly increases the likelihood of good outcomes. In a meta-analysis of some 46 studies across a wide range of domains, Endsley found that SA was predictive of performance in 89% of the studies (Endsley, 2021, p. 5). Problems with SA constitute much of human error in a variety of domains. For example, of accidents in commercial aircraft that were attributed to human error, 88% were found to be due to lapses in SA (Endsley, 2021, p. 5). SA has been cited as critically important and challenging to achieve for personnel involved in emergency and disaster response by several authors (Endsley, 2021, pp. 5-6). As of now, there is a lack of research that aims to map out barriers that are experienced during crisis situations by crisis responders. Thus, uncovering barriers for using information systems to attain SA is an important step in finding ways to alleviate these barriers.

1.2 Scope, research aim and research approach

The research goal of this thesis is to systematically uncover and map out barriers. The scope of barriers is anything that may impede the use of information systems to attain SA during crisis situations, which encapsulates and expands beyond the SA demons and situational disabilities. When it comes to the scope of crisis situations, this thesis appertains to physical crisis situations that are both natural and man-made. However, the focus is on short-term crisis situations like landslides, fires, or terror where decisions must be made within a small timeframe, instead of potential long-term crises such as the Covid-19 pandemic. In other words, crisis situations in this study refer to events that require quick action and swift decision-making. The scope of stakeholders is limited to crisis responders on the operational and tactical level from health, police, and fire services. This includes emergency control room workers, crisis coordinators, and first responders who physically resolve or alleviate crisis situations. These crisis responders use information systems in crisis situations on a frequent basis, and crisis information systems could be improved for them specifically, which is why they will be used for data collection in this thesis. Mapping out barriers will be done by answering the research question below:

> *What are the barriers that can impede the use of information systems to attain situational awareness during crisis situations?*

To answer this research question, data is collected in two ways. Firstly, from a systematic literature review where barriers from previous research are identified, and secondly from empirical data collection through interviews with crisis responders. The empirical data collection is conducted based on the knowledge acquired from the systematic literature review. Data from the interviews is analyzed and presented in findings. The findings from this research provide important insight for practice and a foundation for further research that could reveal remedies for mitigating barriers. In practice, this could lead to development of crisis technology that mitigate the identified barriers, ultimately leading to increased SA and better performance in crisis situations, potentially benefiting society and individuals alike with lower casualty rates and decreased material losses.

1.3 Thesis overview

Chapter 1 – Introduction provides a clear motivation for the research and presents the chosen research question and method used to conduct the research.

Chapter 2 – Background and related work explains important concepts relevant for this thesis and binds these concepts together to form a theoretical perspective that serves as a foundation for our research. A comprehensive literature review reveals the research gap and additional motivation for the research.

Chapter 3 – Research method presents arguments for why the chosen research method is suitable for this thesis. The data collection method and analysis are described. Measures to ensure validity and reliability are presented as well as ethical considerations.

Chapter 4 – Findings presents the barriers that were discovered during data collection, coding, and analysis.

Chapter 5 – Discussion compares our findings to previous literature, and intricate findings that require explanations and elaborations are included. Contributions to practice and theory are presented as well as implications for further research and limitations of this study.

Chapter 6 – Conclusion summarizes the thesis and concludes the research.

2 BACKGROUND AND RELATED WORK

The purpose of this chapter is to provide insight into previous literature and the ideas that shape this thesis. This includes an explanation of concepts that are relevant for this thesis. After the individual explanations, the concepts are incorporated to form a theoretical perspective. The theoretical perspective is used in the systematic literature review to examine how other researchers have studied this topic in the past. Finally, the research gap and additional motivation for the thesis is presented.

2.1 Concept description

Due to different definitions and understandings of certain concepts, it is necessary to address them to create a common understanding and explain how they are used in this thesis. The following concepts will be explained: *Crisis*, *Crisis management*, *Situational awareness* and *Barriers for attaining SA*.

2.1.1 Crisis

The word *crisis* has several definitions, which means it can be used and understood differently. The Official Norwegian Reports defines crisis as "*an event that has the potential to threaten important values and weaken an organization's ability to perform important function*s" (Official Norwegian Report, 2000). From a crisis management perspective, a broader definition is needed that encapsulates the human aspect in a crisis. Booth (1993), cited in Kyne and Pathranarakul (2006) explains that "*A crisis is a situation faced by an individual, group or organization which they are unable to cope with by the use of normal routine procedures and in which stress is created by sudden change*.". The unexpectedness and uncontrollability of a crisis situation is also empathized by Alexander (2005), arguing that "*the significance of crisis is its unexpectedness and uncontrollability which disrupts and/or impedes normal operations*".

The word *crisis* is closely related to *disaster* and *emergency*. There are some characteristics about these words that differentiate them, but many of these characteristics overlap, and the words often are used interchangeably. Al-Dahash et al. (2016) carried out a qualitative conceptual content analysis to establish the differences and similarities between disaster, crisis, and emergency. The findings are presented in Figure 1.

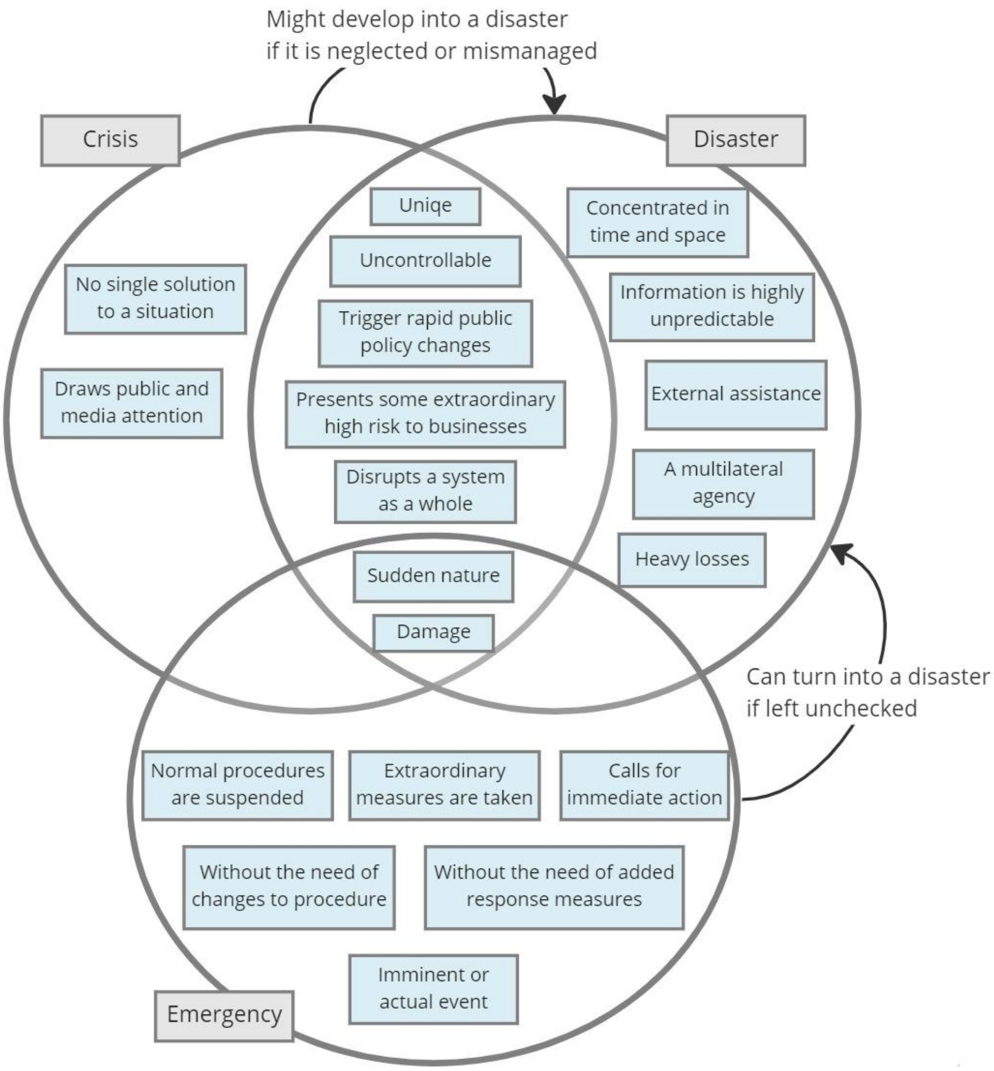

Figure 1 Comparison between crisis, disaster, and emergency (Al-Dahash et al., 2016).

Al-Dahash et al. (2016) explain that the main features related to a crisis are uniqueness, danger, trouble or damage caused, unexpectedness, uncontrollability, emotional involvement, and often drawing public and media attention. Disasters are characterized by their sudden and uncontrollable nature, resulting in heavy losses and significant damage. They typically require external assistance and involve multiple stakeholders. The features of an emergency often vary depending on the situation. Key features can be the need for urgency, being unanticipated and imminent, creating damage, and calling for immediate actions. It is also possible that an emergency does not include the need for changes to procedures nor the need of added response measures. In the intersection between crisis, disaster and emergency, the features of sudden nature and damage appear. The sudden nature entails swift decision-making if the circumstances are time critical. In combination with the risk of damage to health and property, the importance of attaining SA is elevated, and the impact of barriers for attaining SA through information systems becomes adverse.

Crisis is placed between disaster and emergency in terms of scale and severity. Disasters are often associated with severe and vastly impactful events, while emergencies are associated with less severe and manageable events. In this thesis, crisis is used as an umbrella term that encapsulates crisis, emergency, and disaster because this thesis appertains to all three concepts, and crisis is the middle way that most accurately describes all three.

2.1.2 Crisis management

Previous literature divides a crisis into phases to facilitate systematic work and research (Aune, 2019). To understand why crisis situations occur and how they are handled, it is necessary to look at actions taken in each crisis phase. Researchers have suggested several different ways to divide the phases of a crisis. However, most of them have three main phases in common: Pre-crisis, acute crisis and post-crisis (Engen et al., 2016). Traditionally, the crisis phases have been presented as a linear process from pre-crisis to acute crisis to post-crisis. Engen et al. (2016) challenges this perspective, arguing that the acute crisis must be seen in the context of the pre-crisis and post-crisis. In such a context, the phase division can be presented as a circular process as shown in Figure 2 below. They illustrate the clear connection between measures for prevention and preparation in a pre-crisis phase, and the possibilities for effective crisis management. This also has implications for after-work, reconstruction and learning in the post-crisis phase. The idea is that learnings from previous crisis situations can ensure more robustness in the next crisis.

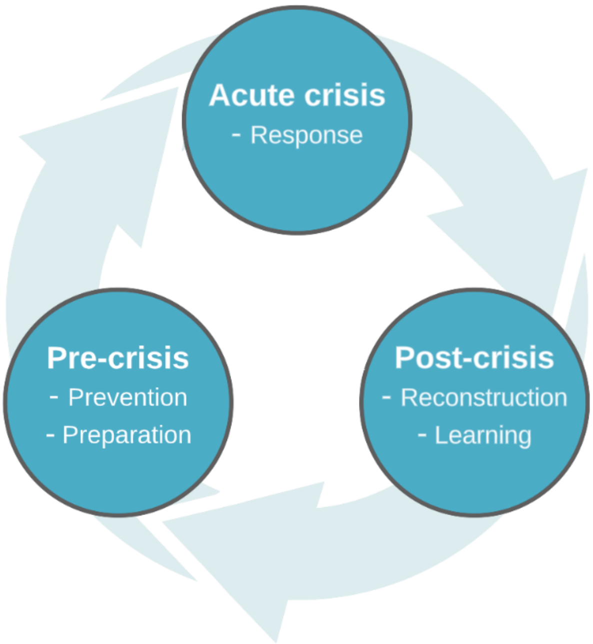

Figure 2 Stages of a crisis (Jacobsen et al., 2021).

Several definitions of crisis management exist. Engen et al. (2016) define it as "*the immediate and subsequent response, prepared or ad-hoc, when a crisis has manifested itself."*. Posey and Wigmore (2020) define it as something more prepared: "*the application of strategies designed to help an organization deal with a sudden and significant event*". Dealing with a crisis is largely about making decisions under a high degree of uncertainty, chaos and on an insufficient basis of information. Jacobsen et al. (2021) explains how crisis management is a test of whether established planning, competence, equipment etc. is sufficient and relevant when handling the crisis that may arise. Since a crisis often is related to unexpectedness and uncontrollability, there will always be a need for flexibility and improvisation. Because of this, the acute crisis phases are often divided into two processes: Implementation of planned and trained structures, and adaptation to the crisis (Jacobsen et al., 2021). In a crisis, the use of technology is necessary both in scenarios that have been trained and planned for, and in scenarios that have not. One could assume that more barriers arise in crisis situations where preparations are lacking. However, an awareness of barriers that could arise in crisis situations may be beneficial to achieve a favorable outcome of the crisis. Crisis management is a comprehensive process where practices are engaged before, during and after a crisis (Posey & Wigmore, 2020). Better crisis management in the acute crisis phase will provide a better learning basis for the post-crisis phase, which in turn can be used in the next pre-crisis phase to improve planning and preparedness. The research questions specify the identification of barriers experienced *during* a crisis, which is why the focus of this thesis mainly concerns the practices done in the acute phase. However, we recognize the interconnectivity between the established phases.

2.1.3 Situational awareness

According to Gilson (1995) cited in Stanton et al. (2001), the concept of Situational awareness (SA) was first identified and used during the First World War and addressed "*the importance of gaining an awareness of the enemy before the enemy gained a similar awareness, and devised methods for accomplishing this*". The concept has since moved away from being an individual endeavor, to being an emergent property of a complex socio-technical system, often referenced as *Distributed SA* (Salmon et al., 2017). The modern perception of the concept address the separation between the human operators' understanding of system status and actual system status (Stanton et al., 2001). The idea first received technical and academic attention in the aviation industry where they pushed for further research and development. System design was no longer optimized for human operation, and under some conditions, had overstepped the human's capability to keep track, much due to the increase of automation in flight control (Stanton et al., 2001). Endsley developed a definition of SA with the initial purpose of understanding aviation tasks. However, it could be extended into other domains such as power generation, petrochemical, nuclear, command and control, etc. As presented in the introduction, she defines SA as "*the perception of the elements in the environment within a volume of time and space, the comprehension of their meaning and a projection of their status in the near future*" (Endsley, 1988a).

Kaber and Endsley (1997) explains that despite being a concept with roots in aviation, SA is equally applicable to human supervisory control for land-based industries. This has led to the theory being researched in different fields of science. As technology has evolved over the years, many complex, dynamic systems have been created that challenge an operator's ability to act as effective, timely decision makers when operating the systems. A review of peer reviewed academic journal articles indicated that SA-related research had been reported in over 20 different scientific journals in 2017, covering a broad range of subject areas such as computer graphics, disaster response, artificial intelligence and more (Salmon et al., 2017). In the cyber security field, SA has become a popular subject and is often referenced as Cyber Security Situational Awareness (CSSA) (Tianfield, 2016). Due to the growing sophistication of cyber-attacks, it has become apparent that a holistic approach is a fundamental requirement to handle security data effectively. Tianfield (2016) are one example of researchers using Endsley's theory of SA to create a multi-level analysis framework for CSSA. Berner et al. (2016), contributing to the IS field, developed a Process Monitoring Benefits Framework drawing on the SA theory and theory of constraints, conceptualizing process visibility and suggesting that it is positively related to process performance. They elaborate on the importance of SA in process visibility to be able to handle complex IT infrastructure which in today's world portray the backbone for many businesses (Berner et al., 2016). Another example from the IS field is Luokkala and Virrantaus (2014) presenting ideas for developing information systems that are used in emergency situations as a means for supporting SA, interaction and decision-making. Due to the applicability of Endsley's definitions for domains beyond aviation, and particularly for crisis situations, they will be used throughout this thesis.

Three levels of situational awareness

SA refers to an individual's level of awareness in a situation. It involves a dynamic understanding of "What is going on?" (Salmon et al., 2017). Endsley's three level model describes SA as an internally held cognitive product comprising three hierarchical levels that are separate to the process used to achieve it. Each level is a necessary precursor to the next higher level. The levels show information processing from perception, through interpretation to prediction. Table 1 on the following page describes the levels presented by Endsley (1988b) cited in Nini (2020).

Table 1 Endsley's three levels of situational awareness

Levels	Description
Level 1: Perception of the elements in the environment	"Perceiving relevant information depends on access to information and recognizing this information. Communication and visualization of information are crucial to ensuring this step is possible."
Level 2: Comprehension of the current situation	"Comprehending relevant information is key to dealing with the information properly. Mental models help understand information, but their validity depends on information completeness."
Level 3: Prediction of future status	"The information received and understood helps predict future outcomes. Complex systems make prediction difficult, flawed mental models influence wrong assumptions. Constant reevaluation and adaptation of mental models is crucial."

Team situational awareness

The concept of SA is a crucial factor in effective crisis management, both on an individual and team level, as they are often closely related. Endsley (1995) defines Team SA as *"The degree to which every team member possesses the SA needed for his or her job*". It is not sufficient if one person on the team has a piece of information but does not successfully transmit it to another team member who needs it (Endsley, 2021). Members of a team share many similar characteristics with individuals functioning in a dynamic, complex environment. Thus, the collective cognition of a team working in e.g., a control room may be similar to the cognition of a lone control room worker. A person working with crisis management needs to know what others are doing, not only the status of their own systems/tasks. The goal is to achieve a Shared SA, which is the "*the degree to which team members have the same SA on shared SA requirements*" (Endsley, 1995). Team members have different roles and responsibilities, and thus different SA requirements, but it is important that they are all on the same page to ensure that actions are coordinated and appropriate (Endsley, 2021). Since team SA is a crucial part of crisis management, this thesis has an equal focus on the barriers experienced for attaining team SA and individual SA. Furthermore, team SA and individual SA will be considered as interrelated concepts, which will be referred to as just SA. This is because the distinction between these concepts is unnecessary for the purpose of this thesis, which is to look at barriers related to SA in general. However, it is useful to be aware of these distinctions to grasp the full meaning of SA. An exception is that the distinction will be used in the literature review to get an idea of how previous research has handled these concepts.

2.1.4 Barriers for attaining SA

As stated in the introduction, previous research has documented and suggested barriers that can be experienced in crisis situations when using technology to attain SA. This research has helped spark interest and motivation for this thesis and provides a starting point for uncovering other barriers from the literature review and qualitative data collection. These previously identified barriers are the SA demons explained by Endsley et al. (2003), and situational disabilities explained by Gjøsæter et al. (2019).

SA Demons

SA demons present a challenge for attaining SA. Endsley explains that: *"The reason why good SA is so challenging can be laid to rest both on features of the human information processing system and features of complex domains that interact to form what we will call SA demons. SA demons are factors that work to undermine SA in many systems and environments."* (Endsley et al., 2003). SA demons arise from the interaction between complex information systems and human beings who all suffer from cognitive limitations. Thus, the SA demons describes both cognitive and technological barriers for attaining SA. Endsley et al. (2003) describes eight SA demons in total, listed in Table 2 below.

Table 2 SA Demons

Demon	Description
Work-related stressors	"A state of mental or emotional strain or tension resulting from adverse or demanding circumstances. Some stress factors include time pressure, mental workload, and uncertainty."
Data overload	"Inability for a human to process the amount of information taken in, leading to lapses in SA."
Attention tunnelling	"Locking in on certain aspects or features of the environment but neglecting other aspects that could be important to attain SA."
Requisite memory trap	"Inability to keep information in the short-term memory."
Errant mental models	"Bad interpretations and projections of the situation. Can lead to cues being misinterpreted."
Misplaced salience	"The brain attempts to block out all the competing signals to attend to desired information using significant cognitive resources in the process."
Complexity creep	"Systems with too many features make it difficult for a person to develop an accurate mental model of how the system works."
Out of the loop syndrome	"When automation does not behave as expected, understanding the system or taking back manual control may be difficult."

Situational disabilities

Situational disabilities may render someone unable to operate technologies that they use on a regular basis (Gjøsæter et al., 2019). This is why it becomes a barrier for attaining SA in crisis situations. "*Situational Disabilities occur in situations that limit a person's ability to hear, see, use their hands, concentrate, understand instructions, etc. [...] These issues can be increasingly prevalent in an emergency situation, for example, caused by stress and cognitive overload, fear, deafening or distracting noise, shaking ground, cold or wet hands, and smoke or dust in the eyes*" (Gjøsæter et al., 2020). Thus, situational disabilities are barriers that encapsulate everything that may restrict someone from using technology based on their context or situation. As a result, the list of potential situational disabilities is virtually endless. However, situational disabilities can be categorized into broader groups. Table 3 below shows how situational disabilities can be grouped, based on Gjøsæter et al. (2019):

Table 3 Situational disabilities

Group 1	Group 2	Group 3 (Example)
Perception	Touch	Hot / cold / wet / protective gear leading to loss of feeling
	Vision	Dust / smoke
	Hearing	Noise / alarms
	Cognitive (understand, interpret)	Language barriers, information overload
Action	Speaking	Dust and/or smoke in the throat, language barriers
	Moving	Protective gear, crowds, panic
	Fine motoric / dexterity	Panic/stress, protective gear
	Cognitive (plan, act)	Information overload, confusion (wrong communication channel, forgetting protocol)

Gjøsæter et al. (2019) argues that crisis situations can cause situational disabilities, which in turn can trigger the SA demons. Different types of barriers experienced in crisis situations can therefore be connected and introduce new types of barriers. For example, a situational disability experienced during a crisis with cold climate, could be cold hands. Cold hands lead to shaking and a loss of touch sensitivity which makes it onerous to operate technology, particularly if the technology requires the user to press small buttons. The user's inability to properly operate the technology under time-critical circumstances can lead to increased stress levels, which makes it even more onerous to operate the technology, and the user's ability to achieve SA could be undermined further. Thus, mitigating barriers is crucial to minimize the factors that impede the attainment of SA.

2.2 Theoretical perspective

The purpose of this section is to define the theoretical perspective that serves as a foundation for our research. I.e., an explanation of how the preceding concepts are incorporated in this thesis to form a meaningful basis for this research. The theoretical perspective is primarily based on three ideas derived from Endsley’s work. The first idea is that SA is the main precursor to decision-making (Endsley, 2000). A high level of SA is associated with favorable decision-making, and a low level of SA is associated with poor decision-making (Johnsen, n.d.). However, a high level of SA does not always result in better decision-making and execution. Endsley argues that there are many external factors that influence successful execution. Examples are limited decision choices due to organizational or technical constraints, which consequently leads to reduced performance. The operators may lack experience or training, or the individual may lack characteristics that benefit their capabilities in crisis situations, resulting in impaired SA. It is important to understand the connection between SA, decision-making, and performance as distinct stages that can affect each other in a perpetual cycle, in addition to the external factors outside the cycle that undermine the outcome of decisions (Endsley, 2000).

Johnsen (n.d.) has contextualized Endsley’s theory about the connection between SA, decision-making and execution for the Norwegian police, and present the model in Figure 3 on the next page which contains key elements of the decision cycle for a crisis responder (Johnsen, n.d.). The model is described as follows: The decision maker's input is visual or verbal information that is perceived from the environment. Much of the information is conveyed via radio and other technology, and there is a filter where bits of information could be altered or hindered, which is referred to as “system interface” in the model. Information available to the decision maker is stimuli that pass through the filter. Input forms the basis for SA, resulting in a basis for decisions and performance. The decisions can be based on both individual work and teamwork. The result (feedback) of the action serves as new input in the decision cycle. Input can also trigger an automatic response and therefore affect execution (Johnsen, n.d.). Figure 3 shows how crisis responders gain SA through technology, which affects their decision-making and the execution of tasks. However, the model does not include any elements that may disrupt the process of attaining SA, such as barriers for using the system.

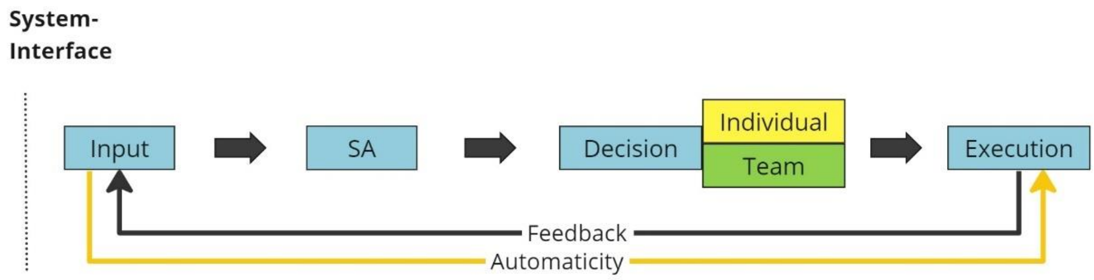

Figure 3 Key elements of the decision cycle (Johnsen, n.d.).

The second idea that shapes the theoretical perspective is that information systems made for crisis situations should be designed so that one can achieve the greatest degree of SA. Endsley (2000) explains that the enhancement of SA has become a major design goal for those developing crisis information systems. Many systems developed today can produce large amounts of data and have few limitations on what features and functionalities are included. Endsley argues that although new systems produce large amounts of data, both in their own components and on the status of the external environment, it does not necessarily display the information that is needed (Endsley, 2000). The systems developed must take barriers into account to maximize the potential SA a crisis responder can attain by using the systems.

Endsley (2000) explains that "*In addition to designing systems that provide the operator with the needed information and capabilities, we must also ensure that it is provided in a way that is useable cognitively as well as physically. We want to know how well the system design supports the operator's ability to get the needed information under dynamic operational constraints*". This shows how the sudden nature and damage that a crisis entails results in the complex and dynamic operational constraints that crisis responders can experience. Despite the operational constraints, crisis responders must manage the crisis to the best of their ability, and the use of information systems has become an essential part of crisis management. However, using such systems in a crisis can be a challenging endeavor if the user experiences barriers.

This brings us to the third and last idea that forms the theoretical perspective of this thesis: there are several factors that are shown to influence SA in the dynamic decision-making cycle (Endsley, 1995). Endsley's SA demons do not cover all the barriers that can be experienced by crisis responders. Situational disabilities are one example of barriers suggested in conceptual research, but empirical data on such barriers have not been mapped out. Additionally, there could be other, undisclosed barriers that may impede the use of information systems to attain SA. The theoretical perspective of this thesis is formed by the fact that there are barriers that disrupt the process of attaining SA through information systems in crisis situations, and uncovering these barriers is the research goal.

2.3 Literature review

Okoli (2015) explains how literature reviews are performed for a variety of purposes: “*They include providing a theoretical background for subsequent research; learning the breath of research on a topic of interest; answering practical questions by understanding what existing research has to say on the matter*”. The purpose of conducting a literature review for this thesis is to identify barriers that has been addressed in existing research and determine whether there is a research gap on mapping out barriers experienced in crisis situations. The literature review also contributes to a greater understanding of the topic, which is important when moving forward with data collection and analysis. Not only does the literature review provide a base for own endeavors, it creates a solid starting point for other members of the academic community interested in the same particular topic as well (Okoli, 2015).

The literature review is inspired by the conceptual approach proposed by Webster and Watson (2002). In addition, the phases used to conduct the literature review is derived from Okoli (2015) as sited and demonstrated in Danielsen et al. (2022) and consists of five phases: 1) Planning the literature review, 2) searching the literature, 3) screening papers, 4) analyzing the selected papers, 5) writing the review.

2.3.1 Search method

Scopus is the database used to search for articles, which was chosen due to the advantages it offers. On Scopus all articles are peer reviewed, conditional search queries are available, exportation of citations is simple, and metadata about the searches are visualized. The search query resulted in over 500 articles from relevant journals and conferences such as ISCRAM, ICIS, AMCIS and more. The search was not restricted to a specific timeframe of publication dates, but the publication date was used as an indicator of relevance when assessing the content of the article. Most of the articles that were ultimately selected are from 2013 to 2022, and the oldest articles are from 2009. The search was restricted to only retrieve relevant subject areas, only retrieve English articles, and exclude articles about the Covid-19 pandemic. The final search query is the result of an iterative review of concepts where the main concepts are *Situational awareness*, *Crisis*, *Information systems* and *Barriers*. The query is shown in Figure 4, and it resulted in 528 articles (last search was in February 2023). The concepts in the query are also shown in Table 4.

TITLE-ABS-KEY (("Awareness" OR "Situation*" OR "Decision making" OR "Operational picture") AND ("Emergency" OR "Crisis" OR "Crises" OR "Disaster" OR "Adversity" OR "First responders") AND ("Information systems" OR "ICT" OR "Digital" OR "Technolog*") AND ("Disabilit*" OR "SA demons" OR "Barrier" OR "Inhibitor" OR "Hinder" OR "Limitation*" OR "Demons of SA") AND NOT ("Covid" OR "Corona" OR "Pandemic" OR "Epidemic")) AND (LIMIT-TO (SUBJAREA , "COMP") OR LIMIT-TO (SUBJAREA , "DECI") OR LIMIT-TO (SUBJAREA , "SOCI") OR LIMIT-TO (SUBJAREA , "PSYC")) AND (LIMIT-TO (LANGUAGE , "English"))

Figure 4 Scopus search query

Table 4 Concepts in search query

Concept	Related concepts
Situational awareness	Awareness, Situation*, Decision-making, Operational picture, Decision support
Crisis	Crises, Emergency, Disaster, Adversity, First responders
Information systems	ICT, Digital, Technology*
Barriers	Disabilit*, SA Demons, Inhibitor, Hinder, Limitation*, Demons of SA

As mentioned earlier, phase three of the literature review is screening papers. For this phase, Danielsen et al. (2022) suggests five steps for screening to remove articles based on the exclusion criteria. This is illustrated in Figure 5 below.

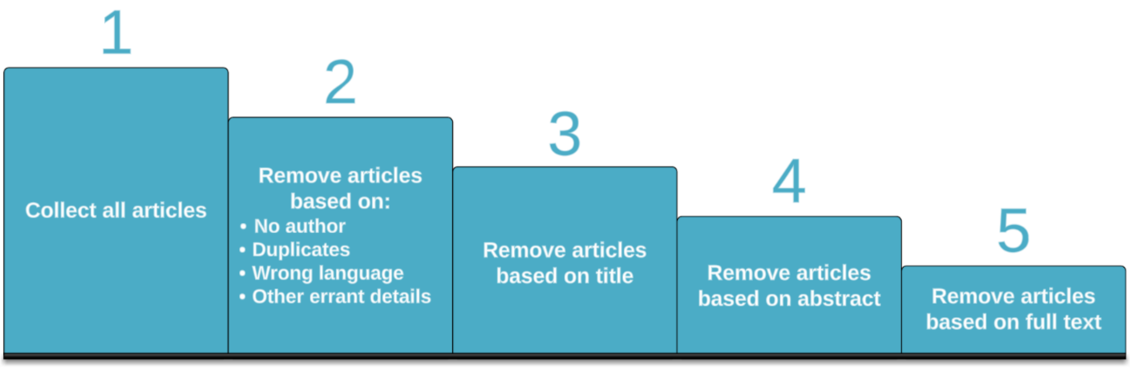

Figure 5 Article screening process

The five phases were used as a basis, but with some modifications. On phase three, we would briefly examine the abstract of the articles if it was difficult to determine relevance solely based on its title, which resulted in the removal of a higher number of articles than what would normally occur in this step. An advantage of this approach was the facilitation of a more thorough evaluation of the abstracts in step four since there were fewer abstracts to read. In phase five, quality assessment was conducted by assuring that all the selected articles were peer reviewed and empirical. A well-defined research method was also a requirement, to ensure transparency when judging the reliability and validity of the findings. Table 5 shows the inclusion criteria for the articles:

Table 5 Inclusion criteria for the articles

Inclusion criteria	Description and reasoning
Empirical	Results should reflect the real world.
Peer reviewed	When the work has been evaluated by other people with competence within the given field, the quality of the paper will probably improve.
Relevant to the research question	The articles should offer input on how information systems are used in crisis situations, and/or contain barriers for using information systems during crisis situations to attain SA.
Well defined research method	How the data collection and analysis was conducted should be transparent in the paper, so that the reliability and validity of the findings can be assessed.

The completion of the five phases resulted in only 13 articles, mainly because several of the promising abstracts belonged to non-empirical articles and had to be removed. Some of these articles did, however, provide a gold mine for new articles when conducting a backward search, which resulted in six additional articles. During our search process, we also attended the Information Technology in Disaster Risk Reduction (ITDRR) 2022 conference, where one of the papers presented was highly relevant for our review, and we obtained a copy from the author. Figure 6 is a graphical representation of the search process:

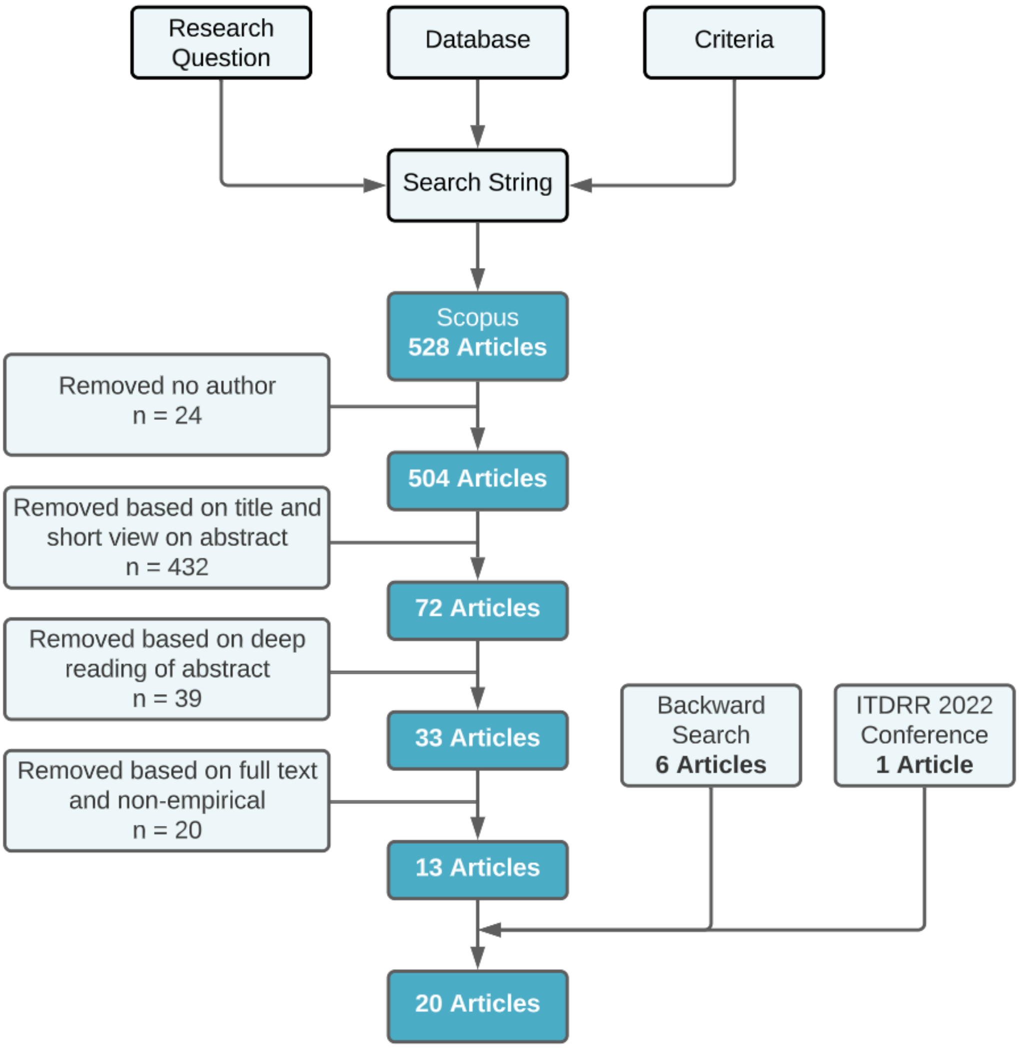

Figure 6 Search process

2.3.2 *Search process results*

This section presents the results of the search process and includes the analysis of 20 articles that passed the inclusion criteria. Some of the articles do not mention barriers specifically, but present how systems should be designed and developed, indirectly showing which barriers they are trying to counteract. At 20 articles we experienced a saturation of barriers that were mentioned. There is a low number of relevant journal articles on the topic which is why most articles in the selection are conference papers. There is also one book chapter included. Table 6 displays all articles used for the literature review.

Table 6 Summary table of articles

Title	Year	Author(s)	Outlet
Cognitive ergonomics applied to the eQRH: Developing an electronic quick reaction handbook for use during aviation emergencies	2017	Crosland M., Wang W., Ray J., Michelson S., Hutto C.J.	Advances in Intelligent Systems and Computing
Understanding past, current and future communication and situational awareness technologies for first responders	2018	Schroeder J.M., Amaya J.P., Bays R.M., Manz D.O., McMakin A.H.	ACM International Conference Proceeding Series
Towards an Indoor Navigation Application for Emergency Evacuations and Persons with Visual Impairments – Experiences from First Responders and End Users	2020	Anthony Giannoumis G., Gjøsæter T., Paupini C.	IFIP Advances in Information and Communication Technology
Universally Designed Beacon-Assisted Indoor Navigation for Emergency Evacuations	2019	Anthony Giannoumis G., Gjøsæter T., Radianti J., Paupini C.	IFIP Advances in Information and Communication Technology
Key challenges in multi-agency collaboration during large-scale emergency management	2014	Eide A.W., Haugstveit I.M., Halvorsrud R., Skjetne J.H., Stiso M.	CEUR Workshop Proceedings
Evaluating accessibility and usability of an experimental situational awareness room	2019	Gjøsæter T., Radianti J.	Advances in Intelligent Systems and Computing
Exploring the usefulness and feasibility of software requirements for social media use in emergency management	2020	Hiltz S.R., Hughes A.L., Imran M., Plotnick L., Power R., Turoff M.	International Journal of Disaster Risk Reduction
Liferescue software prototype for supporting emergency responders during fire emergency response: A usability and user requirements evaluation	2017	Nunavath V., Prinz A.	Lecture Notes in Computer Science
SMS-based real-time data collection for evaluation of situational awareness and common operational picture: Lessons learned from a field exercise	2020	Steen-Tveit K., Radianti J., Munkvold B.E.	Proceedings of the International ISCRAM Conference
Perceivability of Map Information for Disaster Situations for People with Low Vision	2019	Tunold S., Radianti J., Gjøsæter T., Chen W.	Lecture Notes in Computer Science
Adoption, use and diffusion of crisis apps in Germany: A representative survey	2019	Grinko M., Kaufhold M.-A., Reuter C.	ACM International Conference Proceeding Series
Modeling an ontology on accessible evacuation routes for emergencies	2014	Onorati T., Malizia A., Diaz P., Aedo I.	Expert Systems with Applications

Support for Collaborative Situation Analysis and Planning in Crisis Management Teams using Interactive Tabletops	2013	Döweling, S., Tahiri, T., Sowinski, P., Schmidt, B. and Khalilbeigi, M.	ACM International Conference on Interactive Tabletops and Surfaces
Designing Interfaces for Faster Information Processing – Examination of the Effectiveness of Using Multiple Information Cues	2009	McNab A. L., Hess T., Valacich J. S.	Americas Conference on Information Systems (AMICS)
Information Technologies Supporting Emergency Management Controllers in New Zealand	2020	Huggins T. J., Prasanna R.	Sustainability
Situational Disabilities in Information Systems for Situational Awareness in Flood Situations in Nigeria	2022	Ogbonna U.K., Paupini C., Gjøsæter T.	Information Technology in Disaster Risk Reduction (ITDRR)
Guidance for developing human–computer interfaces for supporting fire emergency response	2013	Prasanna R., Yang L., King M.	Risk Management
On-Site Information Systems Design for Emergency First Responders	2009	Prasanna R., Yang L., King M.	Journal of Information Technology Theory and Application
Developing information systems to support situational awareness and interaction in time-pressuring crisis situations	2014	Luokkala P., Virrantaus K.	Safety Science
Analysis of Common Operational Picture and Situational Awareness during Multiple Emergency Response Scenarios	2019	Steen- Tveit K., Radianti J.	Proceedings of the International ISCRAM Conference

Article selection metadata

By analyzing the metadata of the selected articles, it is possible to get a better understanding of their context. 20 articles are not necessarily representative for the entire research field, so the results should be considered tentatively. However, it is still enough to get an indication of their context. The metadata included is the research approach and publication year.

Since all the articles are empirical, the research approach is either qualitative, quantitative, or mixed. The pie chart in Figure 7 on the next page reveals that most of the articles are either qualitative (Crosland et al., 2017; Eide et al., 2014; Huggins & Prasanna, 2020; Luokkala & Virrantaus, 2014; Prasanna et al., 2009, 2013; Steen-Tveit & Radianti, 2019; Tunold et al., 2019) or mixed (Doeweling et al., 2013; Giannoumis et al., 2019; Gjøsæter & Radianti, 2019; Grinko et al., 2019; Nunavath & Prinz, 2017; Ogbonna et al., 2022; Onorati et al., 2014; Steen-Tveit et al., 2020) while there are few articles where a purely quantitative approach has been used (Giannoumis et al., 2020; Hiltz et al., 2020; McNab et al., 2009; Schroeder et al., 2018). Furthermore, the majority of the articles with a mixed method had between 3 and 16 participants in the quantitative part (Doeweling et al., 2013; Giannoumis et al., 2019; Gjøsæter & Radianti, 2019; Nunavath & Prinz, 2017; Steen-Tveit et al., 2020), which is a fairly low amount. This could indicate that there is an immaturity in the research field on this topic because there are few generalizable findings.

Figure 7 Research approach

The distribution of the publication years from the chosen articles is illustrated in the line chart in Figure 8 on the next page. As mentioned earlier, there were no restrictions on publication year when selecting articles, but the year was considered when assessing the relevance of the article's content. The oldest articles were published in 2009, and most of the articles were published between 2013 and 2020. The chart below does not display a trend, which may be because there are very few articles with the sole purpose of addressing barriers specifically, resulting in articles with a broad variety of main topics.

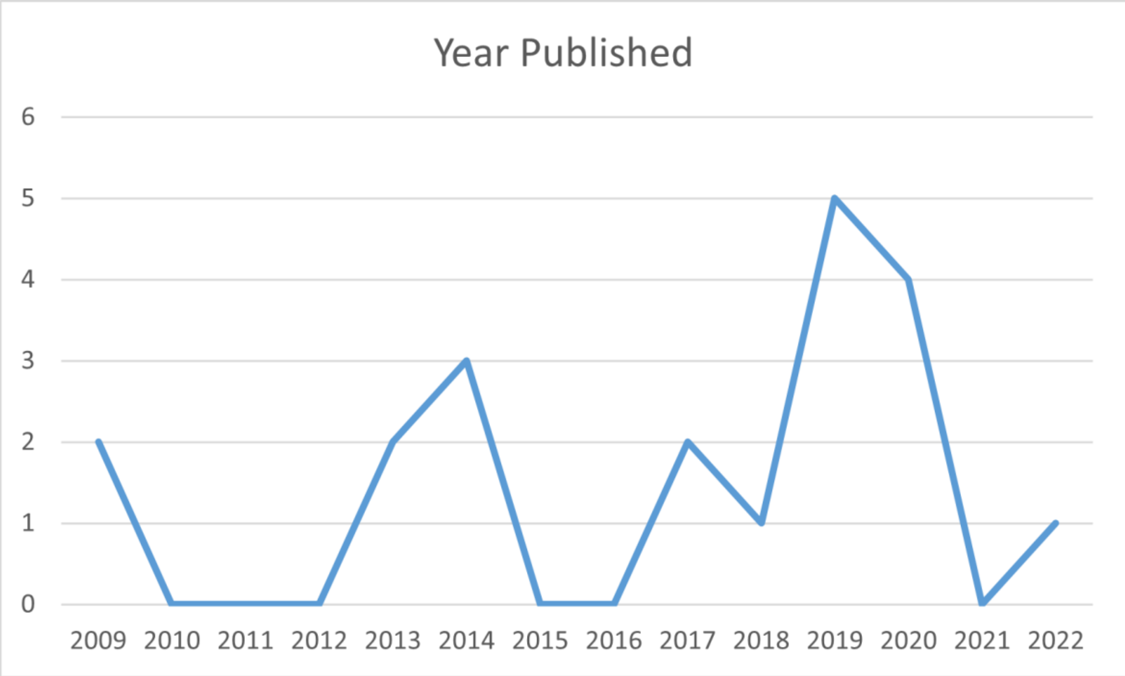

Figure 8 Year published

2.3.3 Concept matrix

Webster and Watson (2002) suggest using a concept-centric approach to a literature review rather than using an author-centric approach. A literature review is all about concepts, and a concept-centric approach is the superior approach for synthesizing the concepts (Webster & Watson, 2002). To achieve this, we created a concept matrix to identify concepts in each article. The concepts were initially based on our current understanding of the topic, and more concepts were added as our knowledge increased. The concepts are based on the research question and theoretical perspective. The purpose of the selected concepts is to attain a deeper understanding of existing research on the topic. Mapping the concepts is also useful in finding gaps in current research. The concept matrix is found in Table 7 and is followed by an explanation of the main concepts in Table 8.

Table 7 Concept matrix

#	Author(s)	Year	Concept: Barrier Types						Stakeholders				IS Technology									SA Type			
			Situational Disability	Permanent Disability	Demons of SA	Cognitive	Physical	Technological	General Public	First Responders	Control Room Workers	Specific Profession(s)	Social Media	Map System	Evacuation System	Alert Notification System	Radio Communication System	Action Manual / Handbook	IoT / Sensors	Control Room Technology	General SA IS	Individual	Team	Common Operational Picture	Decision Making
1	Crosland M., Wang W., Ray J., Michelson S., Hutto C.J.	2017				X	X	X				X						X				X	X		X
2	Schroeder J.M., Amaya J.P., Bays R.M., Manz D.O., McMakin A.H.	2018						X		X									X			X	X		
3	Anthony Giannoumis G., Gjøsæter T., Paupini C.	2020				X		X		X		X			X							X	X		
4	Anthony Giannoumis G., Gjøsæter T., Radianti J., Paupini C.	2019	X	X		X	X		X	X					X							X			
5	Eide A.W., Haugstveit I.M., Halvorsrud R., Skjetne J.H., Stiso M.	2014				X		X		X							X		X				X	X	X
6	Gjøsæter T., Radianti J.	2019						X			X									X					X
7	Hiltz S.R., Hughes A.L., Imran M., Plotnick L., Power R., Turoff M.	2020						X		X			X	X											X
8	Nunavath V., Prinz A.	2017						X		X	X			X						X		X	X		X
9	Steen-Tveit K., Radianti J., Munkvold B.E.	2020				X				X							X					X	X	X	X
10	Tunold S., Radianti J., Gjøsæter T., Chen W.	2019	X	X			X		X	X	X			X								X			
11	Grinko M., Kaufhold M.-A., Reuter C.	2019				X		X	X							X		X				X	X		
12	Onorati T., Malizia A., Diaz P., Aedo I.	2014	X	X			X		X						X	X						X			
13	Döweling, S., Tahiri, T., Sowinski, P., Schmidt, B. and Khalilbeigi, M.	2013				X		X			X			X						X					
14	McNab A. L., Hess T., Valacich J. S.	2009						X	X																
15	Huggins T. J., Prasanna R.	2020				X		X			X									X			X		X
16	Ogbonna U.K., Paupini C., Gjøsæter T.	2022	X			X	X	X	X												X				
17	Prasanna R., Yang L., King M.	2013			X	X		X		X											X	X	X		X
18	Prasanna R., Yang L., King M.	2009				X				X							X		X				X	X	
19	Luokkala P., Virrantaus K.	2014						X		X							X				X	X	X		X
20	Steen- Tveit K., Radianti J.	2019				X		X		X							X						X	X	X

Table 8 Concept topic with description

Concept Topic	Description
Barrier Types	Includes the core concepts of this literature review. Since mapping out every single barrier identified in literature would require too many concepts, they have been divided into subtypes of barriers instead: S*ituational disability, Permanent disability, SA demons, Cognitive, Physical,* and *Technological*.
Stakeholders	Explains the users of technology that the paper is directed at. By identifying the main stakeholders, the target groups of previous research are revealed, along with which barriers the different stakeholders experience. The identified stakeholders are *general public, first responders, control room workers* and *specific profession*.
IS Technology	The main information system technology which is included in the paper. Mapping out the technology gives context to the technology area the barriers are experienced and shows which stakeholders may use certain technologies. Identified technologies are *social media, map system, evacuation system, alert notification system, radio communication system, action manual / handbook, IoT / sensors, control room technology* and *general SA IS.*
SA Type	The SA type shows the focus area intended to be achieved with the technology in the paper. By mapping the SA types, the focus areas for mitigating barriers are revealed. The identified SA types are *individual, team, common operational picture* and *decision-making*.

While the target group of this thesis is crisis responders, the literature review extends the stakeholder scope. Other stakeholders include the general public and other specific professions. This was done based on the assumption that crisis responders can experience the same barriers as the general public in crisis situations. It is common to think of crisis and crisis management in relation to society and publicly planned and trained response organizations. However, it is equally relevant and appropriate to examine these terms in relation to individuals, organizations, and society at large, because they are also stakeholders of a crisis when it occurs (Engen et al., 2016). By including a larger range of stakeholders, it is possible to get a broader, holistic picture of barriers that can arise in crisis situations.

2.4 Literature synthesis

This section includes a discussion of the selected concepts presented in the concept matrix. The main concepts are barriers when using information systems in crisis situations, but it is also interesting to examine the context around the barriers to attain a deeper understanding. The concepts will be presented in the following order: which stakeholders the systems are made for, which technology is implemented or developed, what type of SA the different technologies contribute to, and finally the barriers, which has been categorized into three main themes: *Cognitive*, *Physical*, and *Technological*.

2.4.1 Stakeholders

The stakeholder concept was used to map which stakeholders the information systems are developed for. The identified categories are the general public, first responders, control room workers, and specific profession. From the 20 selected articles, 12 of them deal with information systems used by first responders (Eide et al., 2014; Giannoumis et al., 2020; Giannoumis et al., 2019; Hiltz et al., 2020; Luokkala & Virrantaus, 2014; Nunavath & Prinz, 2017; Prasanna et al., 2009, 2013; Schroeder et al., 2018; Steen-Tveit & Radianti, 2019; Steen-Tveit et al., 2020; Tunold et al., 2019), six articles mention information systems for the general public (Giannoumis et al., 2019; Grinko et al., 2019; McNab et al., 2009; Ogbonna et al., 2022; Onorati et al., 2014; Tunold et al., 2019), while five addresses information systems used by control room workers (Doeweling et al., 2013; Gjøsæter & Radianti, 2019; Huggins & Prasanna, 2020; Nunavath & Prinz, 2017; Tunold et al., 2019). There is one article that only address a specific profession, which is an article about an electronic handbook used by aviation personnel during aviation emergencies (Crosland et al., 2017). These findings indicate that there has been more focus on information systems developed for first responders than any other stakeholders.

2.4.2 IS technology

The IS Technology concept was used to get an overview of what technology has been implemented and developed for the different stakeholders. Mapping the technology provides a deeper understanding of priorities in the emergency management field. Radio and communication systems were mentioned in five articles (Eide et al., 2014; Luokkala & Virrantaus, 2014; Prasanna et al., 2009; Steen-Tveit & Radianti, 2019; Steen-Tveit et al., 2020). Map information systems were mentioned in four articles (Doeweling et al., 2013; Hiltz et al., 2020; Nunavath & Prinz, 2017; Tunold et al., 2019). Control room technology was also mentioned in four articles (Doeweling et al., 2013; Gjøsæter & Radianti, 2019; Huggins & Prasanna, 2020; Nunavath & Prinz, 2017). These technologies are the most frequently mentioned, probably because they are well established technologies that first responders and control room workers, the most common stakeholders, are heavily reliant on. Evacuation systems (Giannoumis et al., 2020; Giannoumis et al., 2019; Onorati et al., 2014), IoT / sensors (Eide et al., 2014; Prasanna et al., 2009; Schroeder et al., 2018) and general SA information systems (Luokkala & Virrantaus, 2014; Ogbonna et al., 2022; Prasanna et al., 2013) were mentioned in three articles each. Alert notification system (Grinko et al., 2019; Onorati et al., 2014) and action manual/handbook (Crosland et al., 2017; Grinko et al., 2019) were mentioned in two articles. The reason why these technologies are mentioned in fewer articles may be because they are not as commonly used as the other technologies. Social media was only mentioned in one article (Hiltz et al., 2020). This may be because it is a relatively new concept in the crisis management field, and the existing articles on social media crisis management may have a different focus than identifying barriers. The findings indicate that the focus has been on technology that is often used by emergency responders such as radios, maps, and control room systems.

2.4.3 SA type

The SA Type concept was used to map out what kind of SA the articles mention in relation to the technology. The main identified categories are individual SA and team SA. Common operational picture is another phrase that is used as a synonym for team SA. Some articles were more concerned with decision-making than SA, and since it is a concept in close relation to SA, it was categorized as an SA type. From the 20 selected articles, 12 addresses team SA (Crosland et al., 2017; Eide et al., 2014; Giannoumis et al., 2020; Grinko et al., 2019; Huggins & Prasanna, 2020; Luokkala & Virrantaus, 2014; Nunavath & Prinz, 2017; Prasanna et al., 2009, 2013; Schroeder et al., 2018; Steen-Tveit & Radianti, 2019; Steen-Tveit et al., 2020) and 11 addresses individual SA (Crosland et al., 2017; Giannoumis et al., 2020; Giannoumis et al., 2019; Grinko et al., 2019; Luokkala & Virrantaus, 2014; Nunavath & Prinz, 2017; Onorati et al., 2014; Prasanna et al., 2013; Schroeder et al., 2018; Steen-Tveit et al., 2020; Tunold et al., 2019). Four articles out of the 12 team SA articles mention common operational picture specifically (Eide et al., 2014; Prasanna et al., 2009; Steen-Tveit & Radianti, 2019; Steen-Tveit et al., 2020). Decision-making was addressed in 10 out of the 20 articles (Crosland et al., 2017; Eide et al., 2014; Gjøsæter & Radianti, 2019; Hiltz et al., 2020; Huggins & Prasanna, 2020; Luokkala & Virrantaus, 2014; Nunavath & Prinz, 2017; Prasanna et al., 2013; Steen-Tveit & Radianti, 2019; Steen-Tveit et al., 2020). The findings show no significant differences between the number of articles addressing team SA and individual SA, which indicates an even coverage of the two SA types in existing literature.

2.4.4 Barrier types

Identifying the barriers for using information systems in crisis situations is the core purpose of this literature review. The review has resulted in three main themes of barriers that could be experienced during a crisis: *Cognitive, Physical,* and *Technological* barriers. Even though the barriers have been categorized into one of the three themes, barriers are sometimes interrelated, e.g., not being able to use the technology as intended due to *Technological* or *Physical* barriers can increase *Cognitive* barriers by adding more stress to the situation. An example is from Ogbonna et al. (2022) where heavy rain (a *Physical* barrier) made it difficult to use the touch screen on the smartphone (a *Technological* barrier) which leads to more stress when trying to call family members (a *Cognitive* barrier) which in turn made it more difficult to hear what was being said and increase SA. It is also worth mentioning that in the literature selection, some of the articles does not mention or discuss barriers specifically, but instead focus on issues with a current system, or how systems can be improved or created to mitigate the unspoken barriers. For example, Giannoumis et al. (2020) discuss the usefulness of an emergency application and some of the issues identified by users. Despite no specific mention of barriers, it is possible to deduce the barriers from the issues mentioned. In this specific system, an issue was that some users did not speak Norwegian when the system was only available in Norwegian. This means a barrier for using the system is *Failure to understand language or terms,* a cognitive barrier.

Despite having mapped out more barrier types than just the *Cognitive, Physical,* and *Technological* barriers in the concept matrix, the following subsections will focus on just these three. The reason is to avoid repetition, as situational disabilities fall under the themes of *Physical* and *Cognitive* barriers, permanent disabilities fall under the themes of *Physical* and *Cognitive* barriers, and SA demons are concerned with the interplay between *Cognitive* and *Technological* barriers. Since these barrier concepts can be categorized within *Cognitive, Physical,* and *Technological* barriers, they will be discussed under their associated concept(s). A description of the main barrier themes and the subthemes that belong to them is shown in Table 9 on the next page.

Table 9 Main barrier types

Main barrier theme	Description	Subthemes(s)	No. of articles
Cognitive	Barriers related to the limitations of a human's mind and mental capacities that impede the use of information systems to attain SA.	Situational and permanent disabilities, SA demons	12
Physical	Barriers related to senses, mobility and environment that impedes the use of information systems to attain SA.	Situational and permanent disabilities	5
Technological	Characteristics of information systems that do not accommodate the needs of humans during a crisis, impeding the human's attainment of SA.	SA demons	15

Cognitive barriers

The most noteworthy *Cognitive* barrier that is experienced during crisis situations and can influence the effectiveness of using information systems, is *Work-related stressors*. It is mentioned in several of the articles concerned with *Cognitive* barriers (Crosland et al., 2017; Doeweling et al., 2013; Giannoumis et al., 2019; Grinko et al., 2019; Ogbonna et al., 2022; Prasanna et al., 2009, 2013; Steen-Tveit & Radianti, 2019; Steen-Tveit et al., 2020). The only article addressing the SA demons directly (Prasanna et al., 2013) found that stress may lead to inappropriate use of the system by firefighters. Another article (Grinko et al., 2019) argues that the need of finding the right crisis app during a crisis situation will add more stress upon the general public on top of the stress induced by the crisis, and suggests a single crisis app to be used in all crisis situations. Another article explains how residents in Nigeria experienced stress during a flood, which contributed to difficulties in perceiving and understanding their surroundings, e.g., by struggling to hear the person on the other end of their phone call (Ogbonna et al., 2022).

Data overload is another *Cognitive* barrier mentioned by many of the articles (Eide et al., 2014; Grinko et al., 2019; Huggins & Prasanna, 2020; Prasanna et al., 2009, 2013). Just like *Work-related stressors*, this barrier is also a part of the SA demons. One of the articles that does not mention *Data overload* specifically, suggests that only the information needed should be displayed on the screen to address the cognitive ergonomic principle; *focus attention* (Crosland et al., 2017). The article about SA demons experienced by firefighters (Prasanna et al., 2013), emphasizes the importance of balancing the need of information with too much information, and suggests a layered system approach where the most crucial information is pushed, and other information can be pulled from the users. Table 10 contains all the identified *Cognitive* barriers in the literature selection:

Table 10 Cognitive barriers from literature review

Cognitive Barrier	Description	Articles mentioned / addressed
Work-related stressors*	“Stress is a state of mental or emotional strain or tension resulting from adverse or demanding circumstances. Some stress factors include time pressure, mental workload and uncertainty” (Endsley et al., 2003).	(Crosland et al., 2017), (Steen-Tveit et al., 2020), (Grinko et al., 2019), (Doeweling et al., 2013), (Ogbonna et al., 2022), (Prasanna et al., 2013), (Prasanna et al., 2009), (Steen-Tveit & Radianti, 2019), (Giannoumis et al., 2019).
Data overload*	“Inability for a human to process the amount of information taken in, leading to lapses in SA” (Endsley et al., 2003).	(Eide et al., 2014), (Grinko et al., 2019), (Prasanna et al., 2013), (Prasanna et al., 2009), (Huggins & Prasanna, 2020).
Attention tunnelling*	“Locking in on certain aspects or features of the environment but neglecting other aspects that could be important to attain SA” (Endsley et al., 2003).	(Prasanna et al., 2013).
Requisite memory trap*	“Inability to keep information in the short-term memory” (Endsley et al., 2003).	(Crosland et al., 2017), (Prasanna et al., 2013).
Out of the loop syndrome*	“Too much automation makes the user more distant from the environment and lowers decision making capabilities” (Endsley et al., 2003).	(Prasanna et al., 2013).
Errant mental models*	“Bad interpretations and projections of the situation. Can lead to cues being misinterpreted” (Endsley et al., 2003).	(Crosland et al., 2017), (Giannoumis et al., 2019), (Doeweling et al., 2013), (Prasanna et al., 2013), (Prasanna et al., 2009).
Lack of training / knowledge	A person has not had sufficient training on using the system or does not have knowledge about how the system can or should be used.	(Eide et al., 2014), (Grinko et al., 2019), (Doeweling et al., 2013), (Huggins & Prasanna, 2020), (Prasanna et al., 2013).
Failure to understand language or terms	The user does not speak the language in the system or is not familiar with the terms used.	(Crosland et al., 2017), (Eide et al., 2014), (Doeweling et al., 2013), (Prasanna et al., 2013), (Giannoumis et al., 2020).

*** Original SA Demon**

Physical barriers

Among the five articles that mentioned any *Physical* barriers, *Visual impairment* was the only barrier mentioned by all of them. Two of the articles (Giannoumis et al., 2019; Tunold et al., 2019) considers visual disabilities such as poor eyesight and blindness as barriers for using technology during crisis situations. Another article addresses the situational disability of smoke from fire when using a fire evacuation system (Onorati et al., 2014). The article about technology for aviation personnel highlights the negative effects of screen light on human vision in the dark (Crosland et al., 2017). The final article mentions how haze from vapor during a flood makes it difficult to see information displayed on the screen of a mobile phone (Ogbonna et al., 2022).

Looking at Table 11, it becomes apparent that only one out of the 20 articles has thoroughly addressed the *Physical* barriers that may be experienced during a crisis. This is because other articles had other focus areas, while the purpose of Ogbonna et al.'s article was to address the situational disabilities that can be experienced during a flood.

Table 11 Physical barriers from literature review

Physical Barrier	Specific examples mentioned	Articles mentioned / addressed
Visual impairment	Eyesight disability, Blindness, Smoke, Haze from vapor, Effects of screen light on human vision in the dark.	(Crosland et al., 2017), (Giannoumis et al., 2019), (Tunold et al., 2019), (Onorati et al., 2014), (Ogbonna et al., 2022).
Hearing difficulties	Background noise, difficult to hear due to stress	(Ogbonna et al., 2022)
Mobility difficulties	Cold hands, gloves impeding use of touch screen	(Ogbonna et al., 2022)
Speech difficulties	Heavy rain, shock	(Ogbonna et al., 2022)

Technological barriers

The most mentioned *Technological* barrier for attaining SA in crisis situations is *Inefficient user interface*. The literature offers several examples of this barrier. Too much interaction required to perform a task, as well as too much distance between the elements that needs to be pressed will cause the user to spend more time than necessary, which is unfortunate in time-critical emergencies (Crosland et al., 2017). A couple of articles mentioned how it would be problematic to use a system that is physically difficult to operate. For example, during a pursuit it could be difficult to dial numbers for a specific radio channel (Schroeder et al., 2018), or performing a "press-and-hold gesture" to expand a screen was difficult to do correctly (Gjøsæter & Radianti, 2019). Furthermore, the usefulness of flexibility and being able to customize the system's user interface was expressed by multiple articles (Crosland et al., 2017; Doeweling et al., 2013; Grinko et al., 2019; Huggins & Prasanna, 2020).

When it comes to salience, two different issues have been identified in the literature: *Misplaced salience* and *Lack of salience*. Within the IS field, salience means denoting/highlighting important information in a system. Despite being similar to the

Inefficient user interface barrier, salience issues were sorted into individual barrier types, firstly because *Misplaced salience* is described as an SA demon by Endsley et al. (2003), and secondly because there were several specific examples of *Misplaced salience* and *Lack of salience* mentioned in the literature selection. Furthermore, being more explicit about the barriers makes them more tangible and easier to grasp. One of the articles investigated how the use of colors and placement of text could influence the information perceived by the user. The results show that both colors and placements matter in terms of what information the user perceives, and that color is particularly important to promote salience (McNab et al., 2009). Poor use of colors (i.e. the colors are confusing or misunderstood) to highlight the important information was mentioned by all articles that included *Misplaced salience* issues (McNab et al., 2009; Nunavath & Prinz, 2017; Prasanna et al., 2013). Similarly, all articles that included *Lack of salience* mentioned coloring of important text to make it stand out from the less important text (Crosland et al., 2017; Huggins & Prasanna, 2020; Prasanna et al., 2013). When it comes to the use of alarms, *Misplaced salience* can occur when alarms are overused (Prasanna et al., 2013), and a *Lack of salience* can occur when there are no alarms (or more specifically; flashing lights) to redirect attention to an important issue (Huggins & Prasanna, 2020).

There were also several mentions of barriers attributed to *Technology vulnerabilities and shortcomings*. The fact that technology is susceptible to being damaged was mentioned as a barrier in a couple of the articles (Crosland et al., 2017; Grinko et al., 2019). Insufficient communication networks were mentioned as a barrier in several articles. For example, poor radio or cellular connection was mentioned in four articles (Eide et al., 2014; Ogbonna et al., 2022; Schroeder et al., 2018; Steen-Tveit & Radianti, 2019). One article also expressed the issue of noise in the radio communication channel when voice activation button is pressed accidentally (Steen-Tveit & Radianti, 2019). Table 12 shows all five of the overall technological barriers we have identified in the literature, with specific examples mentioned by the articles.

Table 12 Technological barriers from literature review

Technological barrier	Specific examples mentioned as barriers	Articles mentioned / addressed
Misplaced salience*	Poor use of colors, poor placement of text, overuse of alarms.	(Nunavath & Prinz, 2017), (McNab et al., 2009), (Prasanna et al., 2013).
Complexity creep*	Difficult to find needed information, too many screens, too many systems, too many layers, inconsistent design.	(Crosland et al., 2017), (Gjøsæter & Radianti, 2019), (Hiltz et al., 2020), (Grinko et al., 2019), (Prasanna et al., 2013).
Inefficient user interface	Too much interaction required, too much distance between elements, physically difficult to operate, inaccurate visualizations, low flexibility and customization, low readability of text, lack of colors and symbols, information not scalable for smaller devices.	(Crosland et al., 2017), (Schroeder et al., 2018), (Gjøsæter & Radianti, 2019), (Nunavath & Prinz, 2017), (Grinko et al., 2019), (Doeweling et al., 2013), (Huggins & Prasanna, 2020), (Prasanna et al., 2013), (Luokkala & Virrantaus, 2014).
Technology vulnerabilities and shortcomings	Low battery life, susceptible to damage, insufficient communication networks, old and incompatible tech, inaccurate GPS positioning.	(Crosland et al., 2017), (Schroeder et al., 2018), (Giannoumis et al., 2020), (Eide et al., 2014), (Grinko et al., 2019), (Ogbonna et al., 2022), (Steen-Tveit & Radianti, 2019).
Lack of salience	Lack of bold text, lack of colors in text, lack of flashing lights, failure to prioritize information to display.	(Crosland et al., 2017), (Huggins & Prasanna, 2020), (Prasanna et al., 2013).

*** Original SA Demon**

2.4.5 Final thoughts and reflections on the literature review

Identifying barriers for using information systems during crisis situations has been the core purpose of this literature review. However, with the current selection of articles that exists, deducing barriers from issues, requirements, suggestions etc. related to technology in the articles has been a necessity. Only two out of the 20 articles focus on specifically addressing barriers (Ogbonna et al., 2022; Prasanna et al., 2013). The others mainly focus on issues with a current system, or how systems can be improved or created to optimally serve the needs of people in crisis situations, which brings barriers to light without mentioning them specifically. There is a clear lack of research specifically on barriers that should be considered before developing crisis information systems. After analyzing the findings from the 20 articles, three main themes of barriers were revealed: *Technological*, *Cognitive*, and *Physical*.

Technological barriers are the most addressed barriers in the selected literature. This makes sense, because when developing information systems, identifying the limitations and improvement areas of the system itself is probably the most obvious approach to develop good crisis systems. The second most addressed barrier theme in the selected literature is the *Cognitive* barriers. An explanation for this could be that the cognitive limitations of humans in crisis situations is the most obvious impediment for using technology from a human-computer interaction perspective, due to the stressful and demanding circumstances of a crisis. Several of the articles had some mention of the *Cognitive* barriers that exist when using information systems in crisis situations, but very few of them go in-depth on these barriers. In most of these articles, *Cognitive* barriers were randomly mentioned by participants during data collection. Finally, *Physical* barriers are by far the most neglected type of barriers in the literature. Only five of the articles mentioned physical barriers for using information systems, and four of these only addressed barriers related to vision. This is probably because physical barriers, such as the situational disabilities conceptualized by Gjøsæter et al. (2019), is a relatively new and immature concept in the research field.

Each of Endsley's SA demons were included in at least one article from the article selection, which illustrates their validity within crisis management. However, some demons were mentioned significantly more frequently than others. For example, *Work-related stressors* is by far the most mentioned SA demon, with a total of nine mentions across all articles. The least mentioned demons are *Attention tunneling* and *Out of the loop syndrome*, which were only included in the article that specifically addressed the SA demons (Prasanna et al., 2013). These demons are not necessarily less relevant for the crisis management field but may be too specific to be mentioned by articles that are not seeking to identify barriers explicitly.

Limitations of this literature review

One limitation of this literature review has been the need to deduce barriers from articles that has other main topics than identifying barriers. This approach is prone to misinterpretations and misunderstandings. However, this has been a necessity, because without interpreting certain issues and problems as barriers, there would only have been two relevant articles for this literature review. We have been aware of this since the beginning, and to counter this limitation we have made sure to thoroughly assess and discuss the identified barriers to ensure integrity in our findings. Another limitation is the fact that the barriers discovered in the literature review could have been included in the search string to obtain more articles that are relevant. This includes the SA demons and other key words related to the barriers discovered during the literature review. Thus, findings from the literature review in combination with findings from our research should be used to improve the search string for any future literature reviews on this topic.

2.5 Research gap and additional motivation

The existing research on information systems used in crisis situations comes short in the consideration of barriers for attaining SA with these systems. Even though there are several articles on the topic of using information systems in crisis situations, there is a scarcity of research that aims to identify these barriers specifically. The articles from the literature review that aimed to identify barriers has been confined to either the SA demons or situational disabilities. Endsley et al. (2003) explains that SA demons arise due to the interaction between complex domains (such as information systems) and humans who all have cognitive limitations. Gjøsæter et al. (2019) argues that situational disabilities can trigger SA demons. This means there is a clear relation between barriers: they can affect each other and create new barriers. This observation highlights the importance of achieving a holistic view on barriers experienced in crisis situations. We have not found any research that has aimed to do this, and the goal of this thesis is to fill this research gap. The literature review has provided a great starting point for identifying barriers within the three themes of *Cognitive*, *Physical*, and *Technological* barriers, which will serve as a basis for data collection and coding. The research gap will be filled by identifying and accumulating barriers through data collection and analysis. There will be no restrictions or confinement on barrier types, as long they can be experienced during a crisis and serve the purpose of answering the research question:

> *What are the barriers that can impede the use of information systems to attain situational awareness during crisis situations?*

Gjøsæter et al. (2019) argues that accessibility and universal design can be a cure for the barriers that arise from situational disabilities. Endsley and Jones (2012) has presented design principles to tackle the SA demons. These findings fuel the motivation for answering the research question, because it means that it is possible to mitigate barriers that impede crisis responders from attaining SA. Empirical data collection on situational disabilities and SA demons experienced by crisis responders could contribute to the understanding of how technology users are affected by these barriers. Furthermore, we are widening the scope of barriers beyond situational disabilities and SA demons to achieve a holistic picture of barriers experienced in crisis situations. These findings could provide important insight and a foundation for further research that could reveal additional remedies for mitigating barriers. In practice, this could lead to crisis information system development that focus on mitigating the identified barriers, ultimately leading to increased SA and better performance in crisis situations, potentially benefiting society and individuals alike with lower casualty rates and decreased material losses.

3 RESEARCH METHOD

The research conducted in this study is characterized by its exploratory nature since the goal is to discover barriers that can impede the use of information systems to attain SA. The purpose of exploratory research is to serve as a tool for initial research and provide a hypothetical or theoretical idea on the research problem (SMstudy, 2016). Exploratory studies are often considered to be inductive in their approach (Casula et al., 2021) which involves "*the search for pattern from observation and the development of explanations – theories – for those patterns through series of hypotheses*" (Bernard, 2011). It is rare to find research that is exclusively inductive, however most inductive approaches do not imply disregarding theories when formulating research questions and objectives (John, 2022), which is also the case for this thesis. By utilizing previous research and establishing a theoretical perspective, a research question was formulated. Thus, this study employs a combination of a theory and data driven approach. Due to the exploratory nature of the research, a qualitative research design with individual and group interviews for data collection and thematic analysis for data analysis was selected.

The timespan of our research stretches over two semesters (from August 2022 until June 2023) and can be roughly divided into three parts as presented in Figure 9 below.

Figure 9 Research progression model.

The first semester consisted of a pre-study where the initial work of understanding the topic was done. This is when the literature review was conducted, alongside pilot interviews with three participants. Both the literature review and pilot interviews have been included in this thesis, with modifications to the literature review. In the first half of the final semester, the main research was done, which included interviews with 11 participants, and analysis of the data collected from all 14 participants. In the second half of the final semester, the results were produced by presenting the findings and discussing them. This chapter describes the research design and the selected target group, in addition to the data analysis and coding process. The chapter ends with a brief description of how validity, reliability and ethicality is addressed in this thesis.

3.1 Qualitative research design

Qualitative research is used to understand how people experience the world (Bhandari, 2020). In this approach, the data is collected in the format of words, images, sound and more, using methods like individual interviews, group interviews, observations, and document research (Jacobsen, 2018, p. 146). Using a qualitative research approach facilitates an understanding of a phenomenon in its context. Recker (2021) explains how the qualitative approach came as a response to the shortcomings of a quantitative approach which fails to consider the wider setting in which a phenomenon occurs. While quantitative research focuses on measurements and identifying regularities, qualitative research looks at a phenomenon in depth and captures real-life point of view (Recker, 2021, p. 114).

A quantitative approach would have been appropriate for this thesis if the purpose was to conduct confirmatory research on whether the barriers from existing literature are generalizable, or by making measurements on the frequency of occurrence and impact of the barriers. This would have aligned well with the strengths of a quantitative approach, which lies in testing theories and hypotheses, finding how often a phenomenon occurs, the possibility of generalizing the findings from the selection to a broader population, and more (Jacobsen, 2018, p. 137). However, the purpose of this thesis is better aligned with the strengths of a qualitative approach, which is useful for obtaining in-depth and detailed information, a holistic understanding of a phenomenon, flexibility in data collection, and more (Jacobsen, 2018, p. 137).

The goal of this thesis is to answer the research question by identifying what barriers crisis responders face when they are using information systems to attain SA. Using a qualitative research approach for this purpose is a great option because it allows for exploration of barriers that occur in different contexts. The factors that influence information system usage in crisis management are virtually endless due to the abundance of crisis scenarios and contexts that crisis responders experience, resulting in a variety of potential barriers that is waiting to be discovered. A qualitative approach is excellent for attaining an in-depth understanding of the barriers and the context they occur in by providing a holistic picture of the situation and associated barriers. Individuals may also have subjective experiences of the same situations, resulting in the occurrence of different barriers. A qualitative approach facilitates the revelation of these differences.

Despite being an apt option for this thesis, the qualitative research method does have some weaknesses. A summary of weaknesses by conducting qualitative interviews by Myers and Newman (2007) and a summary of weaknesses with qualitative data by Jacobsen (2018) are found in Table 13. Most of these weaknesses could potentially affect the validity and reliability of the research. It is therefore important to be aware of these weaknesses since it is possible to mitigate them. Validity and reliability, and how to mitigate the weaknesses related to these concepts are discussed further in Section 3.4.

Table 13 Qualitative research weaknesses

Qualitative research aspect	Weakness
Interview (Myers & Newman, 2007)	Artificiality of the interview
	Lack of trust
	Lack of time
	Level of entry (Management / employees)
	Elite bias (Fail to understand the broader situation)
	Hawthorne effects (Researcher intrude upon social setting and interfere with people's behavior)
	Constructing knowledge
	Ambiguity of language
	Interviews can go wrong (unintentionally offend or insult)
Data (Jacobsen, 2018)	Unmanageable/unorganized and too detailed information
	Too much flexibility can lead to never-ending research
	High costs, particularly during analysis
	Familiarity with the respondent could destroy the capability of analytical distance

3.2 Data collection

As mentioned, the method used for data collection in this study is interviews. Interviews can be done face-to-face or remote via online communication tools. Recker (2021) explains that "*It is a conversation between researcher(s) and key informants where the goal is to get specialist knowledge about a phenomenon that other ordinary people might not have*" (p. 117). Qualitative interviews can have different degrees of openness and structure. In this study, semi-structured interviews have been utilized. Semi-structured interviews include a list of themes to be covered, along with some open-ended questions from the interview guide (see interview guide in APPENDIX A). A benefit of using the semi-structured approach is the possibility to make changes, and ask additional questions depending on the flow of the conversation (Oates, 2006, p. 188). Semi-structured interviews enable more detail and introduction of new topics, viewpoints and issues that may be relevant for the thesis.

In addition to individual interviews, group interviews (focus groups) have been conducted. Group interviews are usually performed with three to six people where the goal is to have the group members interact with each other and present new insight. It is helpful to generate consensus views, get more varied responses and stimulate others (Oates, 2006, p. 194). There are several reasons why group interviews are beneficial for this thesis. For example, one participant may remember a barrier that has slipped the mind of the other participants, and spark a discussion around this barrier, generating more insight than what would occur in an individual interview with each participant. Such discussions could also lead to more interesting findings by putting the participants on a train of thoughts. Thus, group interviews can provide more valuable insight than individual interviews. However, they are more difficult to coordinate and facilitate, and there is a risk of idleness and inactivity among some participants. By conducting interviews individually and in groups, the benefits of both methods are incorporated in this study.

The interview guide used in this thesis has been assessed and changed several times throughout this study to ensure that the data collected is relevant and reliable. Test interviews were carried out before the pre-study, and the participants in the pre-study had the opportunity to provide feedback on the set-up and conduct of the interview. The same interview guide was used for individual and group interviews. The preliminary study indicated this to be a successful approach, and all participants in the group interviews were active and engaged.

Because memory alone is unreliable and prone to bias and error, recordings are needed to capture the contents of the interview. Notes, audio tape recording and videotape recording are some examples (Oates, 2006, p. 190). We have used notes to ask follow-up questions during the interviews, and videotape recording with audio to access the data after the completion of the interview. To ensure privacy for the participants, all interviews were recorded through Microsoft teams, because the recording files are encrypted and stored in the cloud storage owned by the University of Agder.

3.2.1 Participant target group

Crisis management exists in both public and private organizations, and in the event of major incidents, both parties are often involved. To limit the scope of the thesis, the focus is limited to the initial response from the publicly planned and trained agencies: the police, the fire service, and the health service (medical emergencies and ambulance). To get a clearer picture of our chosen subject group, a description of how public crisis management is organized in Norway will be presented in the following paragraphs.

When a crisis occurs, the first step in crisis management will be to respond to an initial message from a caller. Based on the situation, the notification can be made to different emergency services: the police emergency number (112), health emergency number (113), also referred to as AMK (Emergency Medical Communication Center), and the fire emergency number (110), among others. After evaluating the available information from the first message, a level of urgency is set based on the severity of the crisis. Specific operational plans are drawn up for the event in question. This involves a plan for alerting and coordinating additional resources, selecting a plan for rescue and evacuation, etc. When the operative emergency call centers have alerted tactical crisis responders from fire, police, health and/or additional resources, all activities involved in physically handling the incident will be initiated (Solberg et al., 2018).

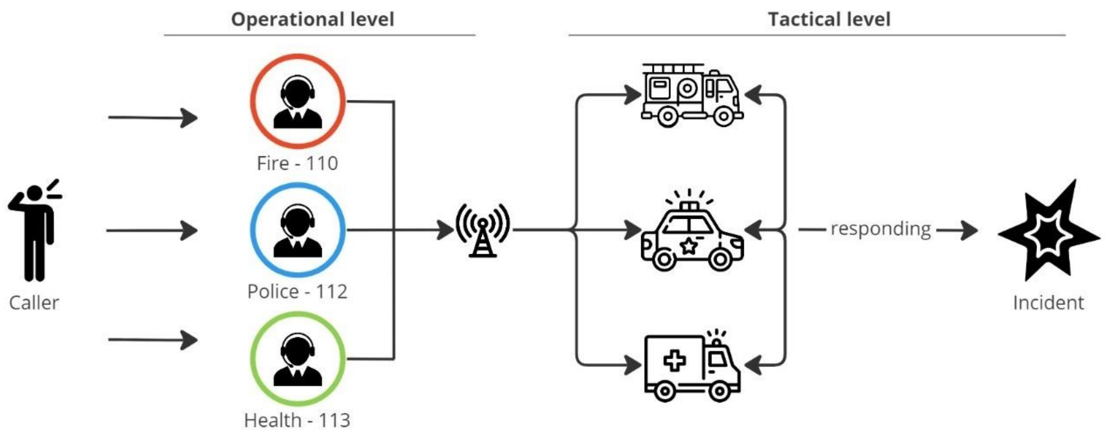

Figure 10 Public crisis management. Adapted from Solberg et al. (2018).

A rescue operation is managed on three levels: tactical, operational, and strategic. Tactical level, often referred to as the first line, is the emergency services and their organization at the scene of the incident. The operational level describes the management apparatus that assigns tasks to and supports the tactical level. The strategic level describes the encompassing management apparatus, focusing on long-term plans for handling future incidents (Solberg et al., 2018). When a crisis occurs, the tactical and operational level are highly dependent on each other to handle the crisis optimally. With the help of technology, crisis responders at each level can share information and create a better SA, potentially improving the outcome of the crisis. Thus, this thesis will uncover barriers for both crisis responders at the operational level who either work in a control room such as an emergency call center, or have another coordinating position in a crisis, as well as crisis responders at the tactical level who are out in the field physically handling the crisis.

When interview participants were selected, it was important to ensure their qualifications to provide the needed information and knowledge. The criteria for participation included experience as a crisis responder and with using technology that contributes to SA in a crisis. It was also specified in the invitation email that the interview concerns uncovering barriers experienced when using technology in crisis situations.

3.2.2 Selection of participants

We first encountered potential interview subjects through the network of CIEM, Centre for Integrated Emergency Management[1] at University of Agder (UiA). From there, the snowball effect was used to get in touch with enough participants to achieve saturation. Utilizing the snowball effect means to request the contact details of potential interview participants from a previously interviewed participant (Schwab, 2022). This resulted in a total of 14 participants, all contributing valuable information. Of the 14 participants, several had experience on both the operational and tactical level. Figure 11 below shows the distribution between operational and tactical level, as well as the various agencies that participated.

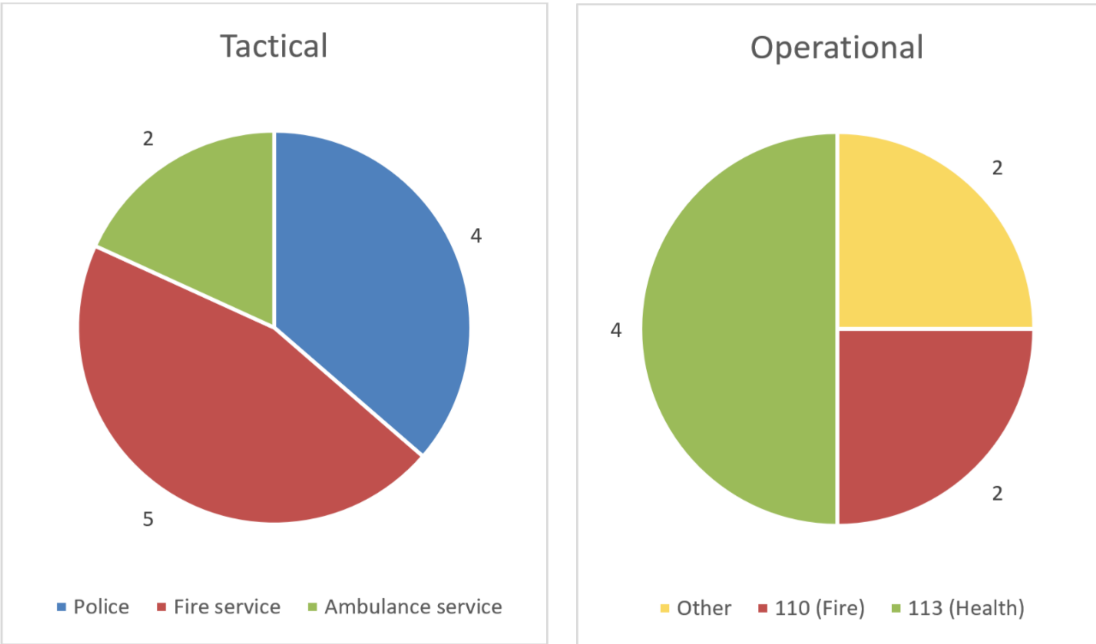

Figure 11 Tactical and operational participants

On the tactical level there are participants with experience from the police, fire service, and ambulance service. On the operational level there are participants with experience from the fire emergency and health emergency call centers, as well as an emergency manager from the health service, and a fire service chief. The number of participants in the figure exceeds 14, because some participants had experiences from multiple operational levels and roles. Several representatives from the police emergency central were contacted, but none were able to participate, in some cases due to confidentiality. This was also the case for one of the police officers who was interviewed (P12), who due to their job position could not answer questions about technological barriers. Table 14 shows current and previous roles and years of experience of the interview subjects. Different

[1] https://www.uia.no/en/research/samfunnsvitenskap/ciem-centre-for-integrated-emergency-management

hierarchical roles within the agencies are represented on both the operational and tactical level, which means there are perspectives from leader roles and subordinate roles.

Table 14 Interview participants

Partici-pant ID	Experience	Operational Level	Total experience
P1	**Police** Officer	Tactical	1 year
P2	**Police** Officer	Tactical	1 year
P3	**Fire** Service Chief	Operational	25 years
P4	**Fire** Incident Commander	Tactical	37 years
P5	**Fire** Emergency Manager	Tactical	25 years
P6	**Fire** Smoke Diver	Tactical	12 years
	Fire Smoke Diving Manager		
P7	**Health** 113 Operator	Operational	23 years
	Health Ambulance Worker	Tactical	
P8	**Health** 113 Operator	Operational	10 years
	Norwegian Rescue Dogs	Tactical	
P9	**Fire** 110 Operator (Shift Leader)	Operational	8 years
	Fire Officer	Tactical	
P10	**Fire** 110 Operator	Operational	3.5 years
	Police Officer	Tactical	
P11	**Health** 113 Operator	Operational	3 years
P12	**Police** Officer	Tactical	6.5 years
P13	**Fire** Incident Commander	Tactical	17 years
P14	**Health** Emergency Incident Com-mander	Operational	40 years
	Fire 110 Operator	Operational	
	Health Ambulance Worker	Tactical	
	Health 113 Operator	Operational	

A total of 11 interviews were conducted. Nine of the interviews were done individually, and two interviews were done in groups. The first group interview was done with participants P1 and P2, and the second group interview was done with participants P3, P4 and P5. The participants have an average experience of ~15 years, ranging from 1 – 40 years of experience. Half of the participants were interviewed digitally through Microsoft Teams; the other half was done in person. The duration of the interviews ranged from 45 to 90 minutes, with an average duration of about 60 minutes. All interviews were audio recorded with the participants' approval and transcribed within a few days of the time of the interview. The transcriptions were used for data analysis.

3.3 Data analysis

After preparing, scheduling, and performing the interviews, the gathered data needs to be analyzed. There are many well established methods and techniques for qualitative data analysis where each has its own focus, advantages, and disadvantages (Recker, 2021, p. 121). In this thesis, the guide by Braun and Clarke (2006) to thematic analysis is used. It is a method for identifying, analyzing, and reporting patterns (themes) within data. Coding is a central part where each theme of analytic interest is tagged with a coding label. The method consists of six phases where one goes back and forth between each phase until a point of satisfaction is reached with the final codes (Braun & Clarke, 2006). The six phases are described below:

1. **Familiarize yourself with your data.**
   After the data collection, the raw data needs to be transcribed. Transcribing is useful to get familiar with the collected data as it forces the researcher to read or hear through the recording of interviews thoroughly (Braun & Clarke, 2006). As described in Subsection 3.2.2 all interviews are recorded and transcribed manually.

2. **Generating initial codes.**
   By generating initial codes, the collected data can be organized into meaningful groups. Codes identify a feature of the data that appears interesting and provides a source of documentation for where and how patterns occur (Braun & Clarke, 2006). The initial codes in this thesis were generated through a theory driven approach since they were adapted from the barriers identified in the literature review. In addition to the codes that were generated from the literature review, we used a data driven approach to coding based on the barriers that were revealed during interviews. This is further described in Subsection 3.3.1.

3. **Searching for themes.**
   After all the data has been coded, the different codes are sorted into broader themes. The initial codes can go into main themes or sub-themes, while some might be discarded (Braun & Clarke, 2006). The initial codes identified in this research fit into the broader themes identified in the literature review: *Technological*, *Cognitive* and *Physical*.

4. **Reviewing themes.**
   After creating themes and assigning codes to them, the themes must be reviewed. Some themes might be too vague, others might collapse into each other or break down into separate themes (Braun & Clarke, 2006). The outcome will be knowledge about how the themes fit together, and the overall story they tell about the data.

5. **Defining and naming themes.**
The reviewed themes are then elaborated in the report. This means including a description of each theme and why it is relevant for the thesis (Braun & Clarke, 2006). For each barrier, a detailed explanation is included. This information is presented in Chapter 4 as well as in APPENDIX B.

6. **Producing the report.**
After defining and naming the themes, the write-up of the report begins. The goal of the report is to tell the story of the collected data in a way that shows validity and reliability (Braun & Clarke, 2006). The results are presented in Chapter 4 and discussed in Chapter 5.

3.3.1 Analysis framework derived from coding

Coding was done in accordance with the description in Section 3.3. We used the qualitative data analysis software NVivo[2] to organize the coding into themes, using statements directly from the documents containing the transcriptions. As mentioned, both a theory and data driven approach was used for coding the data. The theory driven approach to coding was done by using the barriers identified in the literature review as a starting point for coding, see Subsection 2.4.4. The data driven approach was done by supplementing the main barrier themes (*Cognitive, Physical,* and *Technological*) with the additional barriers that were identified from the large amount of empirical data, in addition to refining the existing barriers. No additional main barrier themes that are relevant to our research question were identified in the data because all barriers mentioned conformed to one of the three themes. The coding process resulted in an analysis framework that is used to structure the findings in Chapter 4.

The barrier inclusion criteria for each code were based on the assigned definition of each code. To strengthen the reliability and validity of the coding, we were both equally involved in the coding process. We discussed each statement containing a barrier to determine which code the barrier belonged to. If a barrier did not fit a predetermined definition, a new code would be made or an initial code would be restructured or renamed. The coding process has been an iterative process, and thorough work has been done to ensure that the final codes are accurate representations of the empirical data. Figure 12, Figure 13, and Figure 14 on the following pages displays the analysis framework that contains all barriers that were identified in the data. For the *Physical* and *Technological* barriers, three orders have been identified, while the *Cognitive* barriers only have two orders.

[2] https://lumivero.com/products/nvivo/

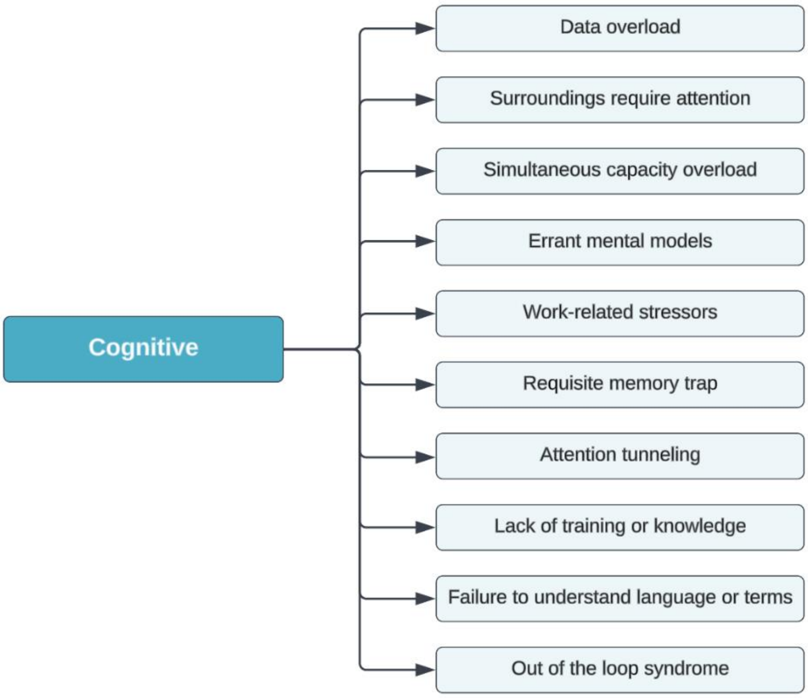

Figure 12 Macro-view of cognitive barriers from data analysis

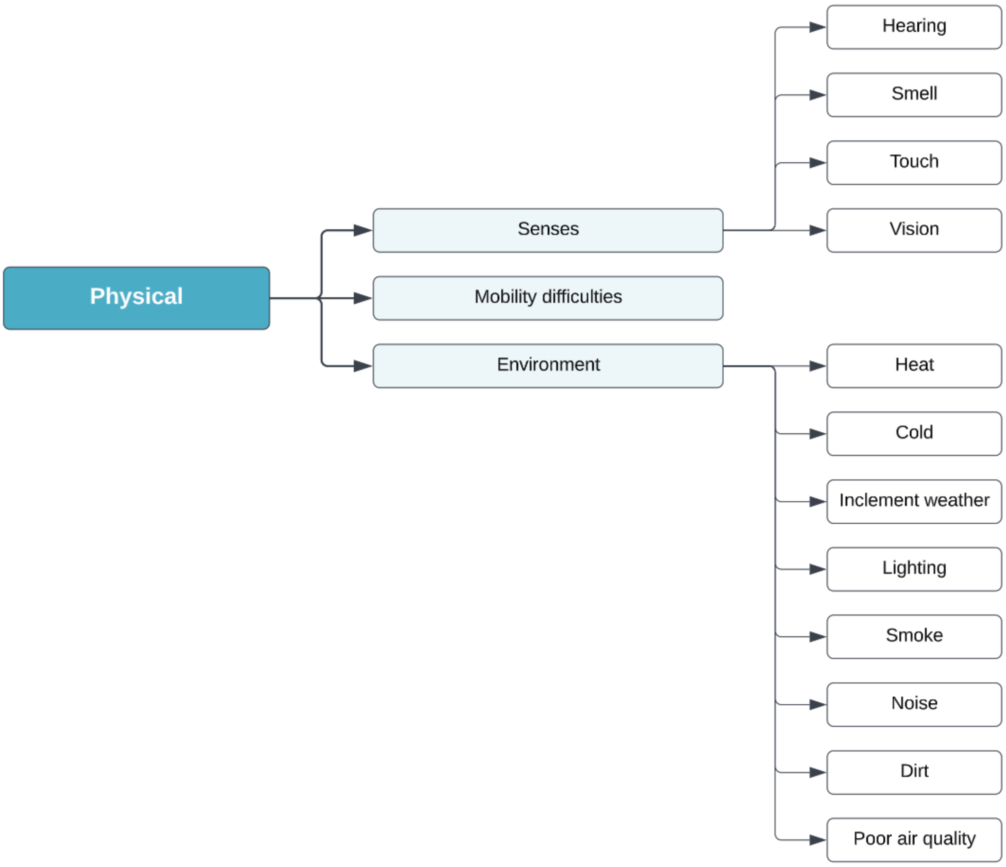

Figure 13 Macro-view of physical barriers from data analysis

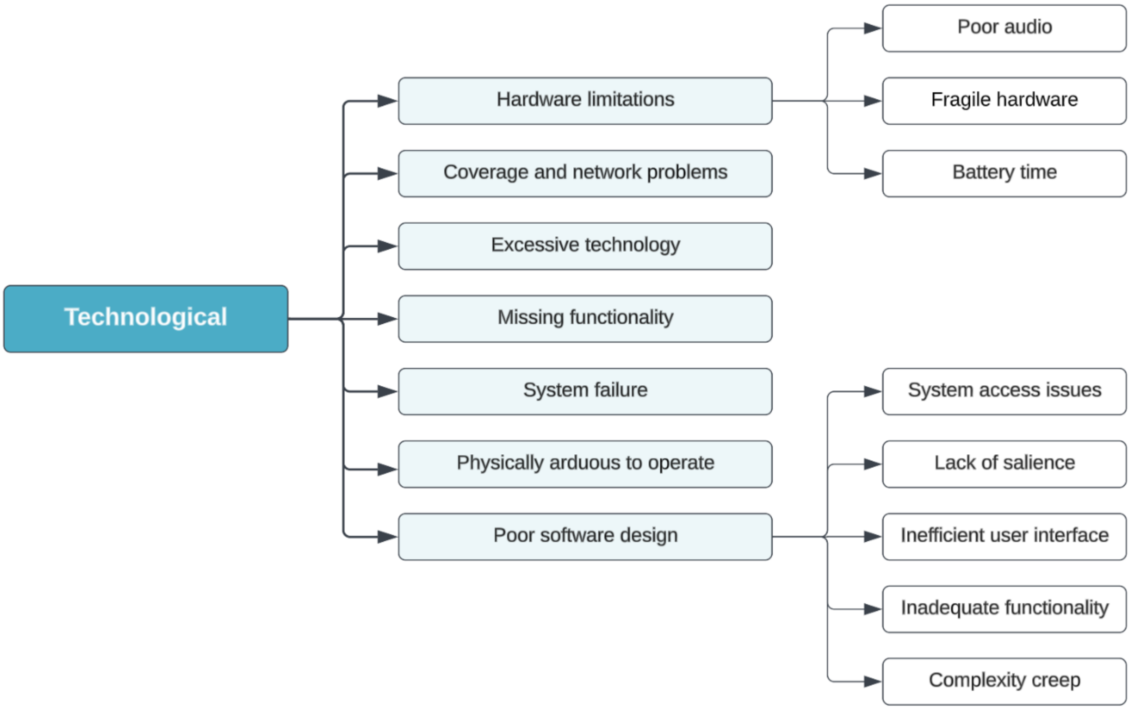

Figure 14 Macro-view of technological barriers from data analysis

A total of 43 themes and barriers were identified in the data collected. *Misplaced salience* is the only SA demon that was not mentioned by any participants. *Speech difficulties* is the only other barrier from the literature review that was not mentioned by the participants. Some of the barriers from the literature review have been restructured to make them more accurate and descriptive. I.e., *Inefficient user interface* has become a barrier in the theme *Poor software design*, and *Technology vulnerabilities and shortcomings* have been broken into several of the other technological barriers that are more accurate. Detailed descriptions of each theme and barrier are included in their associated chapter in Chapter 4 and an overview of each barrier with definition is found in APPENDIX B.

3.4 Validity and reliability

During the data collection and data analysis, validity and reliability have been considered to ensure that the findings presented in Chapter 4 are the truest representation of reality. Validity refers to whether findings from research are true and real. In a pragmatic approach it means to question the compliance between reality and the researcher's descriptions of this reality (Jacobsen, 2018, p. 228). In this thesis we have followed recommendations from Jacobsen (2018) on achieving validity in qualitative research, combined with some of the validation strategies for qualitative research in the report by Johnson (1997). By using these recommendations and strategies we have ensured that there is coherence between the reality of the crisis responders and our description of their reality.

- The first step to achieving validity is to ensure that the interview subjects provide a true representation of reality. This can be done by asking critical questions that provide answers to whether the sources are rightly obtained for the purpose of data collection, as well as assessing the sources' ability to provide correct information about what is being studied (Jacobsen, 2018, p. 229). When conducting the interviews, we questioned the interview subjects about their experience of using information systems in crisis situations to assess their ability to provide this information. Johnson (1997) suggest a Data Triangulation strategy, which involve using multiple sources in a method, to help understand a phenomenon and to validate findings.
- The second step is to ensure that the researchers give a true representation of data. In the process of simplifying and systematizing data, the data becomes more distant from its original source. To prevent the introduction of own opinions and prejudices, Jacobsen (2018) suggest critical review of results and response validation. Johnson (1997) presents the Reflexivity strategy, explaining how researchers should strive to be critically self-aware of his or her potential biases. This thesis is produced by two people who have worked together and evaluated each other's work continuously. Additionally, dedicated supervisors from CIEM have provided critical assessments to ensure validity.
- The last step is to determine the extent to which the findings represent a reality outside both the researcher and those investigated. This can be done by comparing the findings with previous research, i.e. comparing other researchers' findings with ours (Jacobsen, 2018). Johnson (1997) presents Peer Review as a strategy, which includes discussions with a "disinterested peer", who will critically examine if the research provides solid evidence for all conclusions. Again, we have used our supervisors from CIEM, who have expert knowledge on the topic presented in this study.

In addition to addressing the validity of the study, we have strived to ensure reliability. Reliability refers to whether there are factors about the research process itself that has created or influenced the results (Jacobsen, 2018, p. 241). Strong reliability can be ensured by questioning whether the research design, data collection and analysis have influenced the results to deviate from reality. For example, the interview participant could be influenced by the interviewers to give abnormal answers, or by the context they are in when the interview is conducted (i.e., artificial vs. natural setting). Another example could be if the interviewers are sloppy in the recording and analysis of data (Jacobsen, 2018, p. 245). In this thesis, ensuring reliability has been done by following best practices for conducting interviews, avoid leading questions, ensure good quality in audio recordings and transcriptions, thorough evaluation of reliability throughout each step of the research process, and by paying attention to potential reliability pitfalls so that they can be avoided.

3.5 Ethical considerations

Since data is collected from people, it is important to consider whether there are any ethical issues that may arise. There are several theories to define ethical behavior, such as consequentialist theories (the outcome of the action determines whether the action was ethical if it produces more good than evil), non-consequentialist theories (the action itself determines if it is ethical, such as keeping a promise, showing gratitude or demonstrating loyalty) and virtue (focused on the character of the person, a good person will perform good actions) (Israel & Hay, 2006). To ensure ethical behavior when doing research, we have kept the ethical theories in mind. The goal of our research is to help decision makers in crisis situations, which in turn could mean increased chances of fewer casualties and less materialistic loss. Fabrication and falsification of data in research is always unethical, but when the results can influence situations where lives are at stake, one could argue that the gravity of falsity is even more severe. That gives us an ethical responsibility of conducting our research with honesty and integrity. It is important to convey this understanding to the interview participants, which is why informed consent has been a prerequisite for participating in the interviews. Informed consent means that "*participants need first to comprehend and second to agree voluntarily to the nature of their research and their role within it*." (Israel & Hay, 2006). The participant consent form used in this study is found in APPENDIX C. Some participants may also find their behavior in crisis situations to be a sensitive topic, which is why we have ensured confidentiality. This means the information we obtain from them will only be used by us, and only be used for the research as explained (Israel & Hay, 2006). Anonymity and privacy have also been ensured by not revealing any characteristics about the participants that could make them identifiable, as well as handling data with care on secure servers owned by the University of Agder. Furthermore, our application for data collection has been approved by Sikt[3], previously known as NSD[4].

[3] https://sikt.no/
[4] https://www.nsd.no/index.html

4 FINDINGS

This chapter contains a presentation of the results from the thematic analysis derived from the empirical data obtained through interviews. A total of 43 themes and barriers were identified in the data collected. The barriers have been divided into three overarching themes: *Cognitive*, *Physical* and *Technological* barriers, and the chapter is structured accordingly. Within each overarching theme, all barriers identified are defined and described, and quotes from the interviews describing the barriers have been added. The definition for each barrier either comes from previous literature which is shown by the source reference at the end of the definition, or the definition has been made by us and does not have a reference. A summarizing document of all barriers with definitions has been added to APPENDIX B. Our findings indicate differences in barriers experienced at different operative levels, and these differences are explained under the relevant barriers, and discussed in Chapter 5.3. Furthermore, some participants were more specific than others regarding the technology used, which is why the specific type of technology is not always specified in the descriptions of barriers. We have also included brief explanations of higher-level barriers that are outside the scope of this thesis (Chapter 4.5). These barriers are mentioned because they are significant underlying factors that should be considered when addressing barriers for using technology to attain SA.

4.1 Findings of main themes

Table 15 Overview of main themes

Barrier Main Theme	Participants Referenced	Times Referenced
Cognitive	14	135
Physical	14	93
Technological	14	139

The findings from the main themes reveal that all three themes have been mentioned by all participants. The technological barriers are most frequently referenced with 139 references, closely followed by cognitive barriers with 135 references, and lastly the physical barriers with 93 references. All references in each theme belong to a barrier within the given theme, there are no references that are found solely in the main themes. The numbers shown are an aggregate of all references given in the corresponding subthemes.

4.2 Findings from cognitive barriers

Table 16 Overview of cognitive barriers

Cognitive barrier	Participants Referenced	Times Referenced
Lack of training or knowledge	10	30
Work-related stressors	11	26
Data overload	9	16
Simultaneous capacity overload	7	14
Surroundings require attention	8	12
Errant mental models	6	13
Out of the loop syndrome	4	6
Language or terms	5	7
Requisite memory trap	4	5
Attention tunneling	5	6

The cognitive barriers were referenced frequently (135 times), despite having the fewest number of barriers (10). Most participants had a good understanding of how crisis situations influenced their cognitive workload and were able to reflect on the negative impact it has on attaining SA. For many participants, the cognitive barriers were the most obvious because time pressure, danger, and complexities of crisis situations are major characteristics of their profession. This is probably why cognitive barriers were referenced so frequently. However, the cognitive barriers were mostly referenced by the participants with less experience in crisis situations, and not as much by the most experienced. This could explain why *Lack of training or knowledge* is the most referenced barrier.

4.2.1 Lack of training or knowledge

Lack of training, experience, or knowledge on how to use the crisis information systems, and on how to handle crisis situations altogether.

The fact that *Lack of training or knowledge* was referenced 30 times, is because it is an essential indication of the number of barriers, particularly cognitive, that the individual will experience during a crisis. This barrier refers to general training on handling crisis situations as well as training on using information systems, which provides experience and knowledge required to handle crisis situations efficiently. Many participants (P1, P6, P8, P10, P11, P12, P14) stated the important *Lack of training or knowledge* has on influencing other barriers, especially stress:

> *"Stress and the mental capacity you have will improve with experience, and if you have done the same thing before." – P1.*

> *"It is about minimizing the other stress factors. You have a certain level, or a certain supply of [mental] capacity. If you spend all this capacity on things you could have trained on beforehand, you will lose a lot of this capacity, which could lead to a loss of hearing, tunnel vision or other physical and cognitive barriers." – P12*

Several participants (P7, P8, P10, P12, P13, P14) mentioned the importance of becoming familiar with, and training on using the information systems daily and in smaller crisis situations to make them useful in larger crisis situations. The specific technologies mentioned were complex support systems used in emergency call centers, especially map systems with many advanced functions.

> *"For something to work in a large incident, you must use it in the smaller incidents, because what you lay a foundation for daily in small incidents is what you will get good at. If you do not use the technology in small incidents, you probably will not use it in the large incidents either. [...] I think it is hard to get good at using advanced systems if you only use them at the most critical times. You won't be good at them. Even if you practice a lot it will be very difficult to get good at something you don't use in the regular job." – P13.*

> *"What [information systems] you use [often] is what you are able to use in a crisis. Software that you rarely use can suddenly become a barrier when a crisis occurs." – P14.*

4.2.2 Work-related stressors

Stress is a state of mental or emotional strain or tension resulting from adverse or demanding circumstances. Some stress factors include time pressure, mental workload, and uncertainty (Endsley et al., 2003).

In the collected data, *Stress* is commonly mentioned in context with other barriers. In the previous subsection (4.2.1), it was often mentioned that *Lack of training or knowledge* could amplify stress levels. This illustrates how other barriers could lead to *Work-related stressors*. Similarly, stress could be responsible for the creation or amplification of other barriers:

> *"When humans are put into a demanding situation, they will often turn off [cognitive] functions. If you are very stressed, the brain can shut down your hearing or cause tunnel vision, so it is important to keep your cool and*

> *absorb relevant information. It could be useful to have knowledge on how the body responds to stress. It could definitely happen that you aren't able to take in [information] [...]." – P13.*

There are also examples of how stress can lead to lapses in SA by giving a false perception of the situation:

> *"The more audio logs I listened to, the more I realized that it was me who was inducing stress [to the conversation], not the caller I was talking to. [...] [Multitasking makes] you forget to focus on your own stress management. [...] This can cause me to perceive the situation as much more critical or less critical than what it really is." – P10.*

Another example mentioned was how *Work-related stressors* can take its toll on the mental capacity when uncommonly used information systems needs to be used. For example, when the backup system (a regular phone with many lines) must be used because the main systems are offline:

> *"It was my stress that rendered me incapable of using the backup systems. I was frantic. [...] I am very happy nobody called in with a cardiac arrest." – P8*

4.2.3 Data overload

Inability for a human to process the amount of information taken in, leading to lapses in SA (Endsley et al., 2003).

The interviewed crisis responders use face-to-face communication, radio communication, map systems, information databases, logging systems, infrared cameras, live video sharing and other technology displayed on screens such as mobile phones or laptops to obtain external information during a crisis. Any of these communication channels could create *Data overload* when the information emitted exceeds the capacity a human has for taking the information in. It is not uncommon that during a crisis, all these communication channels will emit information simultaneously. *Data overload* is the third most referenced cognitive barrier, both in total number of references (16) and in number of participants referenced (9). There are several examples from the interviews of how *Data overload* can be detrimental to attainment of SA:

> *"Being multiple places at once, both on radio, a mobile calling, in larger cooperations with multiple channels at hand. [...] Having a lot of things, and multiple places to listen for [information], could cause the information to become fragmented and fall out." – P7*

> *"I have communication over the radio, where I must listen for important information. For example, I heard [a person in need] was found, and that is important. But there was also other blabber that I didn't need to know. That makes it hard to have this communication happening on the radio all the time and pick up what is important and what isn't important. [...] Information slips all the time." – P8.*

It was also mentioned that information written in the systems could be hard to sort out, which could consume valuable time during a crisis. For example, in the radio logs used to catch up on the latest information of a crisis incident:

> *"If there is a lot of information [in the radio logs] you may have to spend more time looking and look at the timers to find the order in which the messages came in." – P2.*

4.2.4 Simultaneous capacity overload

Occurs when a human is supposed to use multiple information systems simultaneously to attain SA but fails to do so due to cognitive overload.

The interviewed crisis responders, particularly at the operational level in emergency call centers, are supposed to use a variety of different technologies and information systems. They must operate the phone, type the address of the incident, locate it in the map system, convey information to the relevant agencies, be available on the radio, sometimes use external tools like Google and external support systems like video sharing software, utilize the software on several different screens and sometimes by using different mice and keyboards. The empirical data collected suggests that this usage of multiple systems simultaneously could lead to a cognitive overload, impeding the attainment of SA.

> *"[...] You need to have a high simultaneous capacity. I must answer a phone, get sensory impressions over the phone, concurrently while I'm supposed to see where you are [in the map system], input an address, manage to ask questions, get a situational awareness, everything at once. One must keep one's cool. And it could also be a chaotic shift where there are many callers simultaneously. You need to remember or have good systems to remember who belongs to who, what name and… To send the right vehicle to the right location." – P11.*

> *"[...] You're supposed to lead a conference with the person in need, the police, the health responders and maybe the road traffic center. In addition, you must note some necessary keywords from the conference that will be available in the display in the [responder's] cars. And [communicate] to my colleagues beside me who must convey this in either joint radio*

communication channels or internal communication channels. My hypothesis is that you forget to think about your own stress levels." – P10

4.2.5 Surroundings require attention

Occurs when a situation requires a human to shift their attention away from the crisis information system to deal with the surroundings, causing loss of SA that could have been attained from the technology. This does not include shifting attention towards surroundings that provide better SA than the technology.

This barrier is somewhat similar to *Simultaneous capacity overload*. The difference is that *Surroundings require attention* refers to the cognitive workload spent on anything except technology used for attaining SA, such as radios and map systems, which is more commonly experienced on the tactical level. *Simultaneous capacity overload* refers to the cognitive workload spent on multiple technologies, which is more commonly experienced at the operational level. There are several examples of how *Surroundings require attention* is experienced by first responders at the tactical level:

> *"[P2]: I think we are completely reliant on radio communication, but for various reasons we can't catch everything that's said, especially not details. [P1]: For example, the one driving on an emergency response must be focused on driving if there are many cars, and then it is very rare to catch everything being said because of all the noise." – P2 & P1.*
>
> *"If you arrive alone on a mission where there is a cardiac arrest for example, and you must interact with both health personnel and your own, and you don't have the opportunity to use the [communication] device anymore. That is a loss of information to the people who comes later." – P4.*

Some participants (P4, P8, P10, P13) provided examples of how *Simultaneous capacity overload* and *Surroundings require attention* could be experienced concurrently at the tactical level. For example, when map systems and multiple radio channels are supposed to be used while driving to the scene of the crisis, which occurs early in the crisis at a time when it is critical to attain SA:

> *"When I respond to an incident [...], the screen in the car shows where the incident is, so I drive to the incident [...] and you must communicate in two radio channels simultaneously. And you're thinking about which measures to focus on when you arrive. [...] So, there are many things to juggle on the way out, but it's about getting the right situational awareness to implement the correct measures and request extra resources if necessary." – P13.*

4.2.6 Errant mental models

Bad interpretations and projections of the situation from information received through technology. Can lead to cues being misinterpreted (Endsley et al., 2003).

Suffering from *Errant mental models* during a crisis could be detrimental. When there is a discrepancy between reality and the crisis responder's SA, the severity of the situation could be misinterpreted. Participant P10 even mentioned that the location of the crisis could be errant:

> *"There are many solutions with telecom and subscription solutions that show a completely different location than where they actually are. [...] An example from reality is when I sent a fire response [to store in municipality A] when in reality it was [store in municipality B]. I didn't ask the control question "What municipality are you in?". Everything was correct with the highway and placement on the map. A lot of vehicles were sent to the wrong municipality, that is a pretty big deal." – P10.*

Errant mental models could also be experienced due to human error and misunderstandings when information is conveyed through information systems, such as verbal information from an emergency phone call:

> *"It's about how you interpret the information that comes in. The information you get from the caller: "Is it a lot of smoke there?" "Yes!". For the two of us it could be different. For most people it will be different. You must try and get a good enough description without creating a false picture. You can ask the questions but still be left with two different pictures. Especially when asking yes/no [questions]. In a crisis, the caller doesn't have to answer rationally. If you ask if the building is made of wood, he could answer "yes" even though it is made from bricks.". – P9.*

On the tactical level, crisis responders can find themselves in dangerous situations because of errant mental models. During a mission in a smoke-filled parking garage, P6 relied on the infrared camera too much, and a necessary mental model of the surroundings was never created which became detrimental when the camera stopped working:

> *"Before I was a smoke diving manager, I used to be a smoke diver, and I was inside a parking garage, smoke diving. I trusted the [infra-red] camera 100 percent. You're supposed to take it slow to create a picture inside your head about the surroundings. I may have gone a little too fast, I trusted the camera too much, and then it stopped working in there, and I realized how blind I was because I trusted the technology. [...] I got stressed when I lost visibility and had to orient myself. I had to start from scratch inside the*

building. Normally I would walk slowly into the building to create a track inside my head about the way out." – P6.

4.2.7 Out of the loop syndrome

When automation does not behave as expected, understanding the system, or taking back manual control may be difficult (Endsley et al., 2003).

The empirical data suggests that crisis responders at the operational level are particularly vulnerable to experiencing *Out of the loop syndrome*, because they use a variety of complex information systems. Particularly in emergency call centers where the routines of obtaining information through the phone, identifying the location in the map system, and conveying this information to tactical crisis responders is an ingrained process. This is how they contribute during a crisis, they cannot provide physical help, which is why it is essential to be available to assist the responders on the tactical level. *Out of the loop syndrome* was expressed by P6, P7, P8 and P14. They explained that when the workflow is disrupted by a system's unexpected behavior, regaining control of the situation could be a challenge:

> *"I have experienced that all the systems at the emergency call center went down. Then I had to use the regular phone. I had not practiced for that. There were many lines, and a miracle that everything went alright. […] It was a disaster, I had no understanding about what was happening, I just forwarded everyone over to the emergency room, because I knew what that button did. I was really stressed." – P8.*

> *"The more data and technology we use, the more vulnerable we become when it goes down. It's not bad for me who is used to pen and paper, but for the new ones who are used to technology, it becomes a much larger threshold for dealing with the manual routines than it is for me who is used to it since the beginning." – P14.*

4.2.8 Language or terms

Inability to understand the language spoken or written, or inability to understand terms used.

There are several examples from the collected data of how *Language or terms* can influence a crisis responder's ability to attain SA. For example, the person reporting in an emergency call may speak a different language (mentioned by P8, P9, P10, P11), the map system is not available in the crisis responder's first language (mentioned by P8), or terms used across the different emergency agencies could be different (mentioned by P7). This barrier has been experienced on both operative levels, but was mostly mentioned at the operational level:

> *"When it comes to language, it could be challenging. We've seen that many times. It doesn't necessarily burn in the kitchen as we thought, or even burn in the building at all. Language has caused us to get another situational awareness than what the reality is." – P9.*

> *"There are cultural and normative challenges here and there with subject-specific terminology. For example, you could have challenges with coordinates presented differently. For example, if we are looking for someone in the wilderness, the health response controlled by the aerial ambulance uses longitude and latitude references, while the police use a series of numbers with UTM, which could potentially pose a challenge with standardization. And there is a military system closely linked to UTM, but a little different, and this could cause a massive blunder if one were to mess it up." – P7.*

4.2.9 Requisite memory trap

Inability to keep information in the short-term memory (Endsley et al., 2003).

The empirical data suggests that under demanding circumstances, it could be difficult to keep important information in the short-term memory, which could lead to lapses in SA. Four participants mentioned this barrier where three (P10, P11, P14) had experienced it on the operational level, and one (P2) had experienced it on the tactical level.

> *"One could forget to have asked about something or said something on the radio" – P2.*

> *"[The systems] could stop working for me, suddenly everything is gone. That is a challenge because there is so much information there that you suddenly miss out on. If you haven't written it down manually you will lose a lot, only the memory is left, and we are different regarding how much we can remember". – P14.*

4.2.10 Attention tunneling

Locking in on certain aspects or features of the environment but neglecting other aspects that could be important to attain SA (Endsley et al., 2003).

The empirical data suggests that *Attention tunneling* will typically occur in stressful situations and when attention is directed to a certain event or area in the situation that is considered important:

> *"You're using a lot more capacity to get sensory impressions when it's dark. There is more focus and more tunnel vision towards where the light is." – P12.*
>
> *"When the situation intensifies you could experience tunnel vision. You're very fast to focus on this one thing, but all your focus is on this one event. You must always ensure that the team has the mental capacity to deal with the next incident." – P7.*

4.3 Findings of physical barriers

Table 17 Overview of physical barriers

Physical barrier		Participants Referenced	Times Referenced
Environment	Cold	5	8
	Inclement weather	11	18
	Noise	8	13
	Lighting	5	5
	Smoke	3	6
	Dirt	2	5
	Heat	2	3
	Poor air quality	1	1
Senses	Hearing	6	10
	Vision	6	8
	Touch	6	9
	Smell	1	1
Mobility difficulties		5	6

Out of the three main barrier themes, *Physical* barriers had fewest references (93). The number of references is not necessarily low, but lower than the other main barrier themes. *Physical* barriers were particularly interesting to investigate because the findings from the literature review were quite limited. From the literature review, many *Physical* barriers were mentioned in the context of being outdoors, but not all. What we wanted to investigate was whether *Physical* barriers are as big a problem for crisis responders at an operational level as they are for crisis responders at a tactical level. The crisis responders working in the field mentioned some expected barriers, such as *Inclement weather* and

Smoke. The crisis responders working in emergency call centers did in fact confirm that *physical* barriers do exist inside a controlled environment, where barriers such as *Noise* and *Poor air quality* was mentioned. The findings include *Physical* barriers related to *Environment* and *Senses,* and the barrier *Mobility difficulties*. Barriers related to the *Environment* were referenced most frequently (59 times).

4.3.1 Environment

Attributes related to the surroundings that undermine attainment of SA through technology.

The working environments crisis responders experience differ depending on what operating level and job position they have. Crisis responders at the tactical level will have different environments for each crisis since they move out to the location of the crisis. Crisis responders on an operational level often have a controlled environment inside an office or call center, where they provide crisis support from a distance. Depending on the environment they are in, different barriers can arise. The findings contain eight different *Environment* barriers: *Cold, Inclement weather, Noise, Lighting, Smoke, Heat, Dirt,* and *Poor air quality.*

Cold

Low temperatures in the environment impeding the use of technology.

Cold was referenced eight times, and only by participants working on a tactical level. Experiencing cold conditions is out of the crisis responder's control, and participants P2, P5, P7, P12, and P13 pointed out that the cold made it difficult to use technology, for example when typing on a small screen or when using touch screens on smart phones:

> *"We have some winter exercises where it has been negative 30 degrees [Celsius], that makes your hands cold! [...] You don't have the sensation to put your finger down on the iPhone. Having to use touch or type something then isn't easy." – P12*

> *"Rain and cold can affect the use of the mobile phone. Having to write on a small screen when you are either cold or very stressed can be difficult." – P13*

The empirical data indicates that when technologies like radios and smartphones are not designed to handle cold conditions, their usability and reliability declines:

> *"The buttons that are soft to press and easy to press becomes very hard, and you can barely feel your fingers, so it becomes difficult to use the technology." – P12*
>
> *"[...] the fragility of mobile phones in general. In the cold, the battery is not so good." – P12*

Inclement weather

Harsh weather conditions like storms, heavy rain, and/or heavy snowfall that impedes the use of technology.

Inclement weather is the most referenced *Environment* barrier (18 references). Even though *Cold* could have been included as part of *Inclement weather*, we decided to separate the two barriers. This is because there were many explicit mentions of coldness and how it affects the use of technology, without the context of other weather conditions associated with *Inclement weather.* Additionally, *Cold* affects the use of technology differently than precipitation and strong winds, and the distinction provides meaningful context and emphasizes the different challenges derived from each barrier. Several participants (P4, P7, P9, P14) mentioned how *Inclement weather* caused loss of radio and emergency network connection:

> *"We have an area where a lot of snow can fall. There has been an outage of both the emergency network and mobile telephony. When this happens, you will not be notified. We need systems that can handle it." – P4*
>
> *"We had a major storm and flood where we lost emergency network in some places, mobile network in other places and had no contact. This applied to all the emergency services." – P14*

Crisis responder P8 who works in an emergency call center explained how windy conditions could cause loss of SA due to difficulties in hearing:

> *"[...] if, for example, there is bad sound on the phone. [...] I can't hear them well if they're standing outside and it's windy while they're talking." – P8*

Noise

Disturbances such as loud or unpleasant sounds that impedes the use of technology.

Noise was referenced 13 times, making it the second most referenced *Environment* barrier. It was mainly mentioned as a barrier that affects verbal information sharing through phones and radio. The empirical data suggests the barrier affects crisis responders working on a tactical and operational level.

> *"[...] noise at incident areas can also be quite a disturbing factor when you must give a contact report. If there is, for example, a traffic accident in a tunnel, you will get an extremely loud noise. From either passing traffic, or for example the fan system in the tunnel that starts when the vehicle stops to ventilate in the event of a fire." – P10*

P10 who works in an emergency call center mentioned that loud noises from the incoming emergency calls could lead to hearing damage and tinnitus, and was therefore mentioned as a very serious barrier that they are currently trying to solve:

> *"Noise is a huge problem. It's an ongoing area of investigation for us. We have had an extremely large number of people with hearing damage and diagnosed tinnitus at an increasingly young age, and after a shorter period [of time at work]. It is related to the suitability of the premises for our use. For example, ceiling height, materials, technology solutions. Especially the sound into the ear. It goes from 0 – 100 when you pick up the phone. When you answer the call, it may be that the person you are talking to is standing next to the fire alarm. There is a lot of noise with automatic alarms that come on very suddenly with a very high treble. The technology has probably not been completely on our side when it comes to active noise filters in the telephony solution." – P10*

Another example mentioned by P8 and P11 was when travelling patients was put in the same room as the crisis responders in an emergency call center which caused the control room workers to get drained of energy, or have their attention drawn other places because of the *Noise*, making it harder for them to operate the call center technology effectively:

> "*The only physical barrier I can think of at the 113-central is noise. They put traveling patients in the same room as the 113-central. There was a lot of noise and things happening that took our attention away." – P8*

> "*During the day until 4-5 o'clock, there is a lot of noise inside the 113-central. You notice that your head gets tired when there is constant background noise. The job itself involves talking all the time. You don't get peace of mind in a way." – P11*

Lighting

The absence or presence of light impedes the use of technology.

The participants had only experienced *Lighting* as a barrier at the tactical level. P1, P8 and P12 explained the absence of light as a barrier. This is particularly apparent when trying to use technology that is not adapted for use in darkness, such as a small digital code tag that generates a password required to log in to the crisis information systems:

> *"[...] and it's really annoying because you have to type in the password very often and use the [digital] code tag that you wear around your neck. And standing in the dark, looking at a very small code... That's annoying!" – P1*

Bright light hitting the screen of a mobile phone was also mentioned as a barrier by one of the tactical crisis responders:

> *"[...] if you use a map or Incident Share on your mobile phone for example, and if there is a very bright light outside, it may not be that easy to see [the screen]." – P13*

Smoke

Particles in the air caused by fire impedes the use of technology.

Smoke is a barrier only mentioned by crisis responders at the tactical level in the fire service. This barrier impedes the use of technology due to loss of vision:

> *"The fire officer has an infrared camera that makes it possible to see even when there's a lot of smoke. But it has its limitations if there is too much smoke, because they can't see the screen on the handheld camera." – P13*

Another example of *Smoke* is closely linked to the barrier *Dirt*, explaining how soot from the *Smoke* disrupts the use of technology like infrared cameras in fire situations:

> *"All the equipment we use is greatly influenced by the environment in which we work [...] the atmosphere in which we smoke dive is full of soot particles, it flies in all over and sticks to everything, so everything gets covered in soot [...] All displays are bad in a fire situation. Or in a smoke diving situation." – P6*

Dirt

Any type of dirt, grime, soot, dust, or spillage that could contaminate the technological equipment, impeding its use.

Dirt is another *Environment* barrier that was only experienced by tactical crisis responders. The type of *Dirt* that can become a barrier depends on the environment. One example mentioned was how *Dirt* caused an infrared camera to stop working, which triggered the errant mental model that was described in Subsection 4.2.6, where P6 was smoke diving in a parking garage, leaving the crisis responder in a hazardous and critical situation:

> *"[...] there were insulation mats hanging from the ceiling that had fallen down due to the sprinkler system being triggered. A small fiber fell on the*

lens, and even though I wiped and wiped, I couldn't get it off. So, it was simply something that covered it up so that it didn't work." – P6

According to P7, the consequence of *Dirt* could be that technology becomes more difficult to use, or there is a reluctance to use the technology.

"[...] and then it becomes contaminated simply because you are exposed to blood. You can get it on equipment, or experience a reluctance to touch equipment because you have to wash it again afterwards." *– P7*

Heat

High temperatures in the environment caused by fire, impeding the use of technology.

Heat is one of the *Environment* barriers that was only mentioned by the fire service participants on the tactical level (P5 and P6). In some situations, *Heat* from a fire makes it impossible to use technology because it is vulnerable to the *Heat* and could be destroyed.

"[...] or that things melt. It is always the physical barriers that make it difficult for us, at the operative level we are at. [...] Where we work it is always dirt and smoke. All the equipment we use is highly affected by the environment we work in. It's very hot, there's smoke, and it's dirty. It's no place for technology really. So that's part of the reason why we don't have a lot of cool gear. I think it's because it's hard to make gear that can withstand our use. Because the technology must be robust. When we get equipment, it is often lumps of rubber that have some thick buttons, because it must withstand our use. There is no fancy equipment." – P6

Poor air quality

Lack of fresh air, causing loss of concentration when operating technology.

Poor air quality in a controlled working environment was mentioned by one participant working in an emergency call center. It is an environmental barrier because it affects concentration when using the call center technology:

"It affects the ability to concentrate. [...] You have long shifts. I work in an older building where the air is bad.... You must be good at opening windows to get ventilation. It's a little worse in winter when it gets very cold again. The air conditioning fan only works when it wants to. So, it is poor air quality and noise that are the biggest influencers inside." – P11

4.3.2 Senses

Barriers related to perception through hearing, vision, touch, and smell.

Barriers related to *Senses* is concerned with how crisis situations influence perceptions, and the adverse consequences this has for attaining SA through technology. In addition to the natural conditions of a crisis, the senses are influenced by the surroundings. This could have a negative impact on attaining SA through technology if the influence comes from an *Environment* barrier, which means there often is a relation between *Senses* and *Environment*. Findings from the interviews indicate that crisis responders experience barriers related to *Hearing, Smell, Touch* and *Vision*. Definitions of these barriers are excluded because it is unambiguous. Instead, the following subsections include explanations of how these *Senses* become barriers when they are impaired or affected.

Hearing

This barrier refers to the loss or weakening of hearing which has a detrimental impact on the use of phones and radios to attain SA. An interesting finding about the *Senses* that emerged in the interviews was how several of the participants (P1, P2, P12, P13) explained that *Hearing* was one of the first senses to fail due to the demanding circumstances of a crisis:

> *"Of the physical reactions that can make it more difficult to use technology, it is quite clear that in major crisis situations, many people, me included, notice that the hearing is one of the first things to fail. So, in exercises with a lot of impact, where there is shooting and so on, you don't hear [the shooting] because you zone out completely. In the same way, all information that comes in verbally will also be difficult to take in." – P12*

Noise is a barrier in the *Environment* that is strongly related to *Hearing*. This is because *Noise* directly affects a human's ability to hear.

> *"Incidents can happen anywhere. In the machine room in a cargo boat where there is a lot of noise, in a bar or night club where people are shouting and yelling. All of this affects your senses. Having to go in and out of these environments could be a challenging barrier to use or have access to the information you receive through the technology." – P7*

Vision

Vision refers to perception of the surroundings through seeing. This sense becomes a barrier if it is negatively influenced by other factors, especially *Environment* barriers. This barrier was only mentioned for crisis response at the tactical level. Seven out of the eight references that addressed *Vision* as a barrier had an *Environment* barrier as a catalyst, most mentioned was *Smoke* and *Lighting*. P13 emphasizes the impact *Smoke* has on *Vision* as he explains for the second time the difficulties of seeing the screen on the infrared camera if there is enough black smoke:

> *"In relation to the infrared camera I mentioned earlier that the fire officers use during smoke diving. It is supposed to help them read temperatures and help them find missing people or find the way out, but if there is enough thick black smoke, they are unable to see the screen on the camera." – P13*

Besides factors of the *Environment* impairing *Vision*, there are also factors related to the permanent or temporary disabilities of the eyes that can cause impairment:

> *"Small text makes it hard to get information and can depend on the age. Personally, I have felt the need to use reading glasses. […] Glasses can get foggy; you are in and out of different environments that can impair your vision. Contact lenses can also impair [the vision], if you sleep with 24-hour lenses because that makes your eyes crisp dry for a small period until you have your vision back the way it should be." – P7*

Touch

Touch refers to a loss of perception through physical contact, which impedes the use of technology due to the physical trouble of operating it. This also includes a loss of dexterity. *Touch* is the most referenced barrier related to *Senses* (9 references), and it was only mentioned by participants with experience on the tactical level (P1, P5, P7, P12, P12, P13). *Mobility difficulties* caused by gloves were mentioned as a barrier that disrupts the sense of touch, making it difficult to use necessary technology like mobile phones and radio.

> *"[Ambulance personnel] have 2 sets of gloves to work with the patient and then take the first pair off to use the second pair to have a clean pair of gloves when moving to another patient and another environment. But anyway, it's your hands that can make things a little clumsy. This can make it difficult, for example, to press buttons or unlock a mobile phone if you have a smartphone." – P7*

The empirical data suggests that barriers concerning *Touch* are closely linked to other *Cognitive* and *Physical* barriers. For example, *Cold* often have an adverse effect on the sense of touch and dexterity when using technology. Demanding situations and stress were mentioned as something that negatively affect the dexterity of the crisis responders:

> *"You also lose parts of your fine motor skills if you are stressed enough, or if you are placed in a very demanding situation." – P13*

Smell

The barrier *Smell* was mentioned only once, but it brings up an interesting point of view on barriers that is worth mentioning. One participant (P12) mentioned that *Smell* could put your mind in high alert, resulting in a higher cognitive workload. The consequence is that other senses needed to attain SA are weakened, for example hearing which is needed to obtain information from radio.

> *"In extreme situations, it can be anything from the smell of gunpowder from weapons, or something as grotesque as the smell of corpses, blood, etc. It has a very distinctive smell that tells you that you are in a situation that is serious. It sharpens the senses enormously, but then something else [other senses] disappears so that you can take in what you think is important." – P12*

4.3.3 Mobility difficulties

Inability to move freely and use hands to operate technology.

Mobility difficulties occur when circumstances of the crisis render someone incapable of operating technology due to impaired movement. This barrier was only mentioned by participants at the tactical level and is often a consequence of something happening in the environment around the crisis responder. An example mentioned was the necessity to carry out life-saving efforts on an injured person, which prevented them from using the radio to call for assistance:

> *"There are also examples of when we do not have the opportunity to use the technology at incidents as well. For example, when performing life-saving efforts. There was one time when I had to hold someone steady, and when I was going to call the others, I couldn't because I couldn't let go of the person. So I couldn't use the radio because I was stuck in a position where I couldn't do it." – P5*

Another example mentioned was how a shaking environment on a boat caused difficulties when using the radio due to the need to hold on to something for balance:

> *"If we are out in a boat, holding on [to something] because of waves will be a barrier that can cause delay. You are not standing in peace and can't use the radio continuously." – P3*

Gloves was mentioned by several participants (P1, P2, P5, P7) as something that caused *Mobility difficulties*, such as protection gloves used by fire responders:

"[...] you're wearing gloves, because you have to wear them to protect yourself from the heat, so you can't take them off in there [to operate the technology]." – P5

4.4 Findings of technological barriers

Table 18 Findings from technological barriers

Technological barrier		Participants Referenced	Times Referenced
Poor software design	Inefficient user interface	9	21
	Complexity creep	7	10
	Inadequate functionality	5	8
	System access issues	3	6
	Lack of salience	5	7
Physically arduous to operate		9	15
Coverage and network problems		12	23
Missing functionality		10	21
System failure		7	7
Excessive technology		3	5
Hardware limitations	Poor audio	4	4
	Fragile hardware	4	6
	Battery time	5	6

Technological barriers consist of a total of 15 barriers and themes, and were referenced a total of 139 times, making it the most referenced barrier theme. A reason for so many references could be that the *Technological* barriers often overlap with *Physical* barriers when technology is not adapted to deal with the environment and surroundings. It also overlaps with *Cognitive* barriers when technology is poorly adapted to alleviate the cognitive limitations that humans experience during crisis situations. The participants were generally both eager and capable of describing technological barriers, however one participant (P12) could not disclose many technological limitations due to the duty of confidentiality that comes with their position in the police. Furthermore, differences in technological competence among the participants resulted in a variety of answers in terms of detail. I.e., some participants were reflective and could point out specific flaws and improvement areas in the systems, while other participants provided very limited descriptions. However, the variety of technological competence could be beneficial because it entails the perspectives of different technology user groups.

4.4.1 Poor software design

The software is designed in a manner that impedes its usefulness for attaining SA. This includes a low degree of usability and poor functionality.

The barriers that belong to *Poor software design* have been referenced a total of 52 times. The barriers included in this theme are *Inefficient user interface*, *Complexity creep*, *Inadequate functionality*, *Lack of salience* and *System access issues*.

Inefficient user interface

The user interface is designed unfavorably for acquiring or providing information quickly and efficiently, or for completing other tasks related to attainment of SA.

Inefficient user interface was mentioned in reference to the logging systems, map systems, external systems when they are not integrated in the main system, address searching and destination locating, and an information support database. Additionally, it includes general comments from participants about technology that is hard to use, has small text, is susceptible to errant button presses, etc. Participants P8, P9, P10, and P13 explained that when information systems used for attaining SA has an *Inefficient user interface*, valuable time could be wasted:

> *"Since [the video sharing solution] isn't integrated in our crisis management system, it becomes a time-consuming process. [...] It isn't readily available to us, but in its own browser behind the systems. That means you must use a screen to try and send an SMS that takes an eternity to get through. Worst case the user is on battery save mode or doesn't have coverage, and it turns into, in lack of a better word, a real [trainwreck], and you've lost a lot of time that isn't yours." – P10.*

P11, who works in an emergency call center, explained that an *Inefficient user interface* could result in adverse consequences by accidentally sending the ambulance to the wrong location:

> *"One button-click wrong from me if I'm writing the address, and I jump down one row too much and choose the wrong address. Unless I notice it myself, I could send the ambulance to the wrong location. The technology could be more secure in that regard." – P11.*

Complexity creep

Systems with too many features make it difficult for a person to develop an accurate mental model of how the system works (Endsley et al., 2003).

The empirical data suggests that when a system is too complex, it could lead to loss of focus on other important factors, or even lead to the system being discarded altogether:

> *"The [emergency call center] system lacks a few things that would have made it easier to use. […] Today we have three keyboards and three computer mice, and we operate three different systems with three different support systems. That will clearly cause you to focus on something else if you access another PC." – P9.*

> *"It's so much technology which makes it very complicated, and we fall short because our brains have limitations. […] Many people choose not to use the map application because it is too complicated. It's not very intuitive, there are a lot of functions, and some people struggle with the language because it's only in English." – P8.*

Some important functions may be hidden from the user due to *Complexity creep*. For example, in one group interview, it was revealed that a participant was unaware of the possibility to change channel and communicate when the radio is active:

> *"[P2]: You can't do anything if someone else is talking on the radio. You can't change the channel or turn on and off the speaker if the radio is active. [P1]: But there are shortcut buttons, if you have saved the previous channel as a shortcut, you can just press and hold the square [to get back to the previous channel]. – P1 & P2.*

Inadequate functionality

Functionality that currently exists in the system is flawed and impedes the attainment of SA.

Two participants (P2 and P13) mentioned that the current radio solution is suffering from *Inadequate functionality* due to the difficulties of getting information through to a busy radio channel, or because it is difficult to operate multiple radio channels simultaneously:

> *"There is something we may experience when a lot of people are moving out to the same incident. If someone talks a lot on the radio, people with critical information may not get through because the radio channel is always busy. […] During a fire that was close to spreading to four cabins I needed to contact the one controlling the water pump to get water on the fire. It was time critical, but it was impossible to reach him because someone else on their way to the incident was talking on the radio about something that was far less important than what I needed to say." – P13.*

> *"There was an exercise last year where we had to be on multiple [radio] channels at once, and we needed to have it on speaker mode. It was hard*

to solve how to be a part of both channels. There were disturbances. It is unpractical, more things to pay attention to." – P2.

One participant (P7) mentioned that when there are many calls coming into the emergency call center, the systems suffer from *Inadequate functionality*:

"The systems aren't adaptive. That means the systems have no agility in terms of dealing with incoming traffic. The emergency call center uses the same static system if there are 200 incoming calls or just one. It doesn't matter how many people are working either. The system doesn't catch this in a good way. One could happily imagine a system with extended functionality that gives more support from the technology." – P7.

System access issues

Problems that arise when accessing the systems, increasing the time it takes to start using the system.

In time-critical situations, spending valuable time just to get access to the system is unfavorable. It was solely the participants at the tactical level (P1, P2, P13) who mentioned this barrier, and they explained that *System access issues* could occur due to difficulties when logging in to a map system or an information support database, or because the log system cannot be opened:

"[P2]: Sometimes it just doesn't work to open the application. There's an error message or... [P1]: Yeah, if there is a new update and you haven't updated yet. The phone must be 100% updated at all times". – P2 & P1.

"You shouldn't have to log in [to the information support database], you should use as little mental capacity as possible to get started. Usually, you will be pressured by the time critical circumstances, you must make a quick decision, and then you need to retrieve information fast. If you must type in username and password and wait five minutes before you log in and search for what you need, too much time may have passed. It should be easy to access and orient." – P13.

Lack of salience

Important information does not get highlighted.

The empirical data suggests that *Lack of salience* has a strong relation with the *Cognitive* barrier *Data overload* because when important information gets mixed in with information of lesser importance, it becomes difficult to filter out what is important. Consequently, it becomes harder to attain SA. *Lack of salience* was mentioned in relation to the text in logging systems, emergency callers with important information who cannot get through, and important information mentioned in the radio that is not highlighted.

> *"I remember an incident where we had a rescue mission with a person lost at sea. It was suddenly reported that the person was found, and I remember I had to really look back and forth [in the logging system] to find when this information came in versus what the latest information is." – P2.*

> *"At the emergency call center, you can monitor multiple calls at once [...] and it is a recurring problem that there is too much information there. It's hard to pick out which information is important to receive." – P8.*

4.4.2 Physically arduous to operate

The technological device has a poor physical device design that does not accommodate and adapt to user needs, resulting in difficulties in operating the technology to attain SA.

Even though there are several barriers related to the technology's software, *Physically arduous to operate* could also impede attainment of SA. Nine participants (P1, P3, P4, P5, P6, P7, P9, P12, P13) had experiences with this barrier, and it occurs when technology is difficult to operate efficiently because of the exterior device design, often due to circumstances that may arise in a crisis. This barrier was mentioned in reference to radios, mobile phones, infrared cameras, and call center technology due to the requirement to use several computers at once.

> *"Usually we have the mobile phone, we don't have the PC when we're on duty. Standing there typing on a mobile phone is one notch harder than typing on a PC." – P13.*

> *"The more technology you use, the more barriers you could experience. For example, if you have three radio channels [that you need to listen to] you have three radios. That isn't easy to operate." – P4.*

4.4.3 Coverage and network problems

Technology loses coverage or network connection, causing disruptions or discontinuation of communication.

Coverage and network problems is the barrier that was mentioned by the highest number of participants out of all barriers (12), and many of them presented it as a major issue. This barrier could affect any technology that requires internet, telephony, or a connection to the base stations that supply the radio communication network. For crisis responders working in emergency call centers, maintaining communication until the location of the crisis is determined is an absolute necessity, and the most essential part of their SA. Without a location, there is no place to send help to:

> *"[...] There could be poor coverage on their location. If they're in the mountains, in the valley, or if the weather is bad, it could affect the base stations and the coverage. It is a dire situation if they present a serious or acute problem or emergency, and then the connection is lost." – P11.*

For crisis responders at the tactical level, experiencing *Coverage and network problems* could be detrimental to SA as well:

> *"We are struggling very much with the map system because of coverage. If you don't have coverage, you don't have the map. Then you're just standing around there [without purpose]." – P8.*

> *"When it comes to barriers outside, it is coverage. We are becoming more and more dependent on being able to send [information]." – P5.*

4.4.4 Missing functionality

Technology lacks functionality that would have been helpful for attaining SA.

The barrier *Missing functionality* occurs when crisis responders lose potential SA because functionality required to attain SA does not exist in the system. This barrier differs from *Inadequate functionality* because it concerns non-existent functionality, not flaws in existing functionality like *Inadequate functionality* does.

> *"Today we have no system for closed roads. If we set the location for an incident and send the closest vehicle to this location, it may not be the closest after all since the roads are closed." – P9.*

> *"I wish there was a tab [in the logging system] you could open to choose what [type of information] you would see. [...] So you could close fire warnings and road traffic and so on, we don't need to know this. You should be able to select what you want to know." – P1.*

Due to *Missing functionality*, crisis responders sometimes need to use external systems to obtain the desired information:

> *"The last thing they removed in the map is the direction of the roof ridges, the line that shows the direction of the house, because it caused the map to crash. It's getting incredibly bad and helps very little. We must use Google solutions [instead] to explain to the fire responders what it looks like." – P9.*

Even though external systems could alleviate *Missing functionality*, many participants (P3, P4, P7, P8, P9, P10, P11, P14) expressed dissatisfaction with the missing interoperability and lack of integration between systems used both within and across agencies, indicating that external systems are a suboptimal solution:

> *"I wish the systems could communicate more. […] For example, when it comes to address, that it would pop up so that I could just click accept if it is the correct address, instead of searching and typing the address." – P11*

4.4.5 System failure

A system failure can occur because of a hardware failure or a severe software issue, causing the system to freeze, reboot, or stop functioning altogether (Computer Hope, 2021).

The empirical data suggests that when the system stops working during a crisis, the consequences could be detrimental, particularly if *System failure* occurs at a critical point. Five participants (P7, P9, P10, P11, P14) who mentioned *System failure* work at the operational level, and two (P2, P13) worked at the tactical level. When this barrier occurs, the crisis responder's ability to attain SA through the system is disrupted.

> *"It is a danger that the system can freeze. Suddenly the desktop freezes, and I must park the emergency call so that my colleague can pick it up until I fix the software." – P11.*

> *"Computer based tools could crash when you need them. That's a regular occurrence. You bring the computer to a forest fire and need to access the map, and there is a windows update that needs to happen right then and there." – P13.*

4.4.6 Excessive technology

Unnecessary technology that does not increase SA, but on the contrary becomes a liability for attaining SA.

Despite the many benefits of using technology to attain SA, it could become excessive if technology that is deemed unnecessary by the crisis responders are forced upon them. Participants explained that when a lot of technology is already in use, adding another technological solution could become a liability instead of an asset.

> *"We had a municipality form at the emergency call center that I forgot to mention. We were supposed to always use it in the procedures, but we never*

did because it wasn't 100 percent necessary. […] It became a disturbance." – P8.

"When I started working here there was a physical book that you could use [to obtain information]. I thought this book was great. Then we got a screen, a touch screen. Personally, I preferred the book because I already had 4 screens. I think my eyes are more relaxed with a physical book I can flip through down there." – P11.

4.4.7 Hardware limitations

Barriers related to the tangible components of technology that could compromise or terminate its usage.

The hardware of technology used during crisis situations should have the quality that is required by crisis responders to perform their tasks effectively. *Hardware limitations* could cause disruptions in attaining SA due to failure in essential information systems. We have identified three barriers related to *Hardware limitations: Poor audio, Fragile hardware,* and *Battery time*.

Poor audio

Poor sound quality caused by audio components in the technology.

The empirical data shows that *Poor audio* could occur when the microphones and speakers of the communication systems are not adapted to handle the environment of the crisis. For example, *Environmental* barriers such as *Noise* and *Inclement weather.* One example mentioned by a firefighter (P4) was how moisture from the environment disrupted the audio of the technology used:

"Smoke divers have Bluetooth and a microphone in their helmets. […] Moisture [on the microphone] could cause sound distortions." – P4.

Fragile hardware

Technology is not adapted to endure harsh conditions and becomes damaged or unusable.

Crisis responders who work at a tactical level out in the field often experience tough and demanding conditions. Technology used under these conditions, such as infrared cameras, laptops, and tablets, should be robust enough to endure. From the empirical data, *Fragile hardware* is a barrier that was only mentioned by fire responders in the tactical context (P3, P4, P6, P13).

> *"We should have had a rougher PC that can withstand shock, water and different temperatures when we are on duty, rather than using the cell phone." – P13.*

Battery time

Technology runs out of power because of too low battery capacity.

The empirical data suggests that in a crisis, running out of battery on technology that is important for attaining SA could be problematic. P1, P9, P10, P12, and P13 explained issues with battery running out on mobile phones and radios.

> *"[The radios] have a battery capacity, so they last for a while, but you need to change the battery after some time if it's a longer or bigger crisis. It could be a challenge when the radio runs out of power". – P13.*

4.5 Barriers at the higher level

By openly asking questions about barriers, several of the participants (P3, P4, P5, P6, P7, P8, P9, P11, P13) mentioned barriers on a higher level. Higher-level barriers are problems with fundamental systems and organizational structures that can have a detrimental effect on crisis responder's use of information systems in crisis situations. These barriers are initially outside the scope of this thesis since they are not experienced *during* a crisis, but it is necessary to mention them because several of the *Cognitive*, *Physical* and *Technological* barriers that have been uncovered cannot be fully alleviated without mending the underlying problems. The empirical data revealed higher-level barriers related to cooperation between agencies, laws and legislation, economics, and organizational structure.

Cooperation between agencies is limited by several factors. There is a lack of interoperability between information systems, which creates barriers for interaction and communication. This applies both across departments within an agency, but also across agencies:

> *"We use our system [at the health emergency call center], while the ambulance that is outside uses its own system. And if their system crashes and they call in for help, I can't do anything because I don't have that system. And that's too bad, because I would have loved to help you and explained what you must do and what to click on, but there's nothing I can do." – P11*

> *"One can hope that it will become easier to share between the agencies over time. Imagine if you could work in one system in all 3 agencies? Today we do not have the opportunity to share the position with each other. So, if we have found a position that does not have an address but is far out in the*

forest, then we must explain that position to the police and the emergency call center, then they must search until they find it." – P9

Another factor that prevents interaction between agencies is confidentiality obligations and other laws. Although there is a desire to interact and use a collaborative system, many believe that security and sensitive data is a barrier to achieving it.

"The problem is that in a national system, there are some security criteria that needs to be addressed, which means that it may not be possible to achieve all the desired functions." – P9

"Confidentiality can be a barrier to getting enough information. For example, if you are on your way to assist the ambulance […], confidentiality may prevent us from knowing things that are very important for us to know." – P6

Participants also pointed out that the emergency services are ready for more technology, there are barriers related to the economic constraints of acquiring such resources. From a manager's perspective, the cost-benefit value of implementing new technology must be carefully considered.

"The emergency services are ready to use quite a lot more technology I think, but what is holding it back is primarily economics. […] The fire services in Norway are municipal, and financial resources are often limited. And in our fire service, I think approximately 90% of the budget goes to salaries." – P13

"One of the biggest barriers is about resources. The cost-benefit value of being able to carry technology beyond what we have in our standard setup is constantly being balanced. If we would have a man who is only dedicated to operating the drone, the cost needs to be considered. […] Resources are a specific barrier when we think of technology, which is extremely important." – P3

Finally, it was also pointed out that even if the emergency response agencies had enough money to be able to acquire information systems that would make emergency response more efficient, barriers related to organizational structure could impede the value of the new systems.

"Another challenge is that we are very similarly organized as we were several decades ago. When you get new technology, you have the opportunity to do things differently. But barriers can arise because you often drive in the same lane as you have always done. […] The question then becomes, should we keep it like this, or should we be organized differently?" – P4

5 DISCUSSION

The purpose of this study has been to explore what barriers are experienced by crisis responders in crisis situations that can impede the use of information systems. Due to a lack of systematic uncovering of barriers in previous literature, the research question was formulated as follows:

> *What are the barriers that can impede the use of information systems to attain situational awareness during crisis situations?*

This thesis is characterized by an exploratory research approach due to the purpose of uncovering barriers that have been neglected in previous research on crisis information systems. A systematic literature review revealed that barriers do exist but have seldom been addressed directly, and none of the identified research has addressed barriers with a scope that encompasses *Cognitive, Physical* and *Technological* barriers. The research question was answered by presenting the identified barriers in Chapter 4. To elaborate on the findings and provide more detailed answers to the research question, this chapter includes comparisons and discussions of our findings to previous literature, in addition to an analytical view on the relations of barriers and factors that influence their occurrence. Furthermore, the theoretical perspective is supplemented with the empirical data, and contribution to practice and implications for further research is presented.

5.1 Findings compared to previous literature

By comparing the barriers uncovered in our qualitative research to the barriers uncovered in the literature review, it is apparent that previous literature does not cover all barriers and their nuances that can impede the use of information systems to attain SA during crisis situations. Our analysis of the collected data resulted in a total of 43 themes and barriers, compared to the 20 themes and barriers that were identified in the literature review. However, some of the barrier names in the literature review were altered and broken down into multiple barrier names in our findings. The purpose of this was to improve the descriptions and account for nuances, which produces more accurate and tangible results.

Lack of training or knowledge is the barrier that was mentioned most frequently by the participants (30 references) but did not distinguish itself as frequently mentioned in the literature review (five articles). A reason could be that *Lack of training or knowledge* is considered outside the realm of barriers in some of the previous literature. For example, Endsley (2000) describes *Abilities, Experience* and *Training* as individual factors influencing the process of attaining SA, but not as SA demons. A reason for this distinction may be because the SA demons are concerned with the relation between humans and information systems, and Endsley views *Abilities, Experience* and *Training* as separate entities. In our research we have included *Lack of training or knowledge* as a *Cognitive* barrier. There are several reasons for this. Firstly, the barriers included in this thesis are not constrained by direct human-computer interactions but involve anything that can impede the use of information systems to attain SA during crisis situations, both directly and indirectly. Secondly, based on data from the interviews, a first responder's level of training, experience and knowledge plays an important role in the cognitive capabilities they have in a crisis, which supports its placement under *Cognitive* barriers. Finally, we consider *Lack of training or knowledge* as a barrier because it has been described as a factor with great impact on other barriers, such as *Work-related stressors*. Such relations between barriers are elaborated in Section 5.2.

Despite the high number of references, *Lack of training or knowledge* is not the barrier that was mentioned by the highest number of participants. It was mentioned by 10 participants, which is less than *Coverage and network problems*, *Work-related stressors,* and *Inclement weather* which were referenced by 12, 11 and 11 participants respectively. Our findings on *Work-related stressors* correlate well with previous research, because it is one of the barriers that were mentioned most frequently in the literature review (nine articles). *Inclement weather* and *Coverage and network problems* were often mentioned concurrently in the interviews because *Inclement weather* may lead to *Coverage and network problems*. Even though *Coverage and network problems* was mentioned in previous literature (under the barrier called *Technology vulnerabilities and shortcomings* with a total of seven article references), it comes across as more noticeable in the interviews. However, *Coverage and network problems* was still mentioned in four articles (Eide et al., 2014; Ogbonna et al., 2022; Schroeder et al., 2018; Steen-Tveit & Radianti, 2019). *Inclement weather* was not mentioned frequently enough to be denoted as a barrier in the literature review, but was mentioned in one article (Ogbonna et al., 2022).

Despite the greater number of barriers identified in the qualitative research, there are two barriers from previous literature that were never mentioned in the interviews: *Misplaced salience* and *Speech difficulties*. *Misplaced salience* is one of Endsley's SA demons. There could be several reasons for why it was never mentioned. One reason being that the SA demons were discovered in the context of aviation. The cockpit of the aircraft is characterized by a substantial number of instruments and controls that must be monitored, and salience is used to redirect attention when required (Endsley & Rodgers, 1996). Since the user interface is different in aviation than crisis systems used by first responders, *Misplaced salience* may not be as relevant. However, previous research has found *Misplaced salience* as a barrier for first responders, even at the tactical level. For example in Prasanna et al. (2013), where an overuse of alarms became a barrier for fire officers. However, it is possible that the information systems used by Norwegian crisis responders does not have much salience. This could explain why *Misplaced salience* was never mentioned, but *Lack of salience* was mentioned by five of the participants. When it comes to *Speech difficulties,* it was only mentioned in one article from previous literature (Ogbonna et al., 2022). This article only includes data from crisis victims who experienced *Speech difficulties* due to shock and stress, but no data from first responders. Crisis responders are trained to handle stressful situations and a loss of speech would be detrimental to solving the crisis. This could explain why it was only mentioned in one article and not in the interviews. To conclude, our findings correlate well with existing literature, which strengthens the validity of our findings. The deviations could be explained by contextual factors of the research, and most of the differences from previous research within a similar context are extensions of existing literature, not divergence.

5.2 Relation between barriers

The barriers presented in the findings could mistakenly be interpreted as nothing but individual entities that influence attainment of SA independently. It is true in some cases that a single barrier is experienced and affects SA independently, but the collected data suggests regularities of multiple interplaying barriers that in conjunction causes impediment to attainment of SA. This is supported in previous conceptual research, i.e., Gjøsæter et al. (2019) suggests that situational disabilities could trigger SA demons. Additionally, findings from empirical research indicate similar relations. Ogbonna et al. (2022) revealed that heavy rain compromised the touch screen of a mobile phone which induced stress. Our data indicates that relations between barriers could occur both inside and transversely between the overarching barrier themes. For example, multiple *Physical* barriers could occur if there are barriers in the *Environment* that influence the *Senses*. This could cause a *Technological* barrier such as *Physically arduous to operate* if the technology used is not adapted to handle the *Physical* barriers. Consequently, the mental capacity required to deal with these barriers could create or amplify *Cognitive* barriers. The purpose of this section is to illustrate different relations of barriers with examples based on the findings from interview data. It is important to explain these relations because it offers the holistic view and depth required to understand an intrinsic part of how attainment of SA through information systems is impeded due to barriers.

5.2.1 An example of barrier relations

A great example of a barrier that is related to other barriers, is *Work-related stressors*. The findings indicate that this barrier is a recurring impediment for attaining SA, and it is frequently mentioned in conjunction with other barriers. In the order in which barriers occur, *Work-related stressors* is often positioned as either a consequence or an antecedent. That means other barriers could cause or amplify *Work-related stressors*, and *Work-*

related stressors could cause or amplify other barriers. These relations are illustrated in Figure 15 below. The antecedent and consequent barriers in the figure are the barriers that were mentioned in conjunction with *Work-related stressors* during the interviews, but due to the intricate nature of the relations, there are probably many other factors and barriers that could be related to *Work-related stressors* that was not mentioned in the interviews. Thus, the purpose of the figure is not to capture the totality of the real world, but to serve as a facet of it.

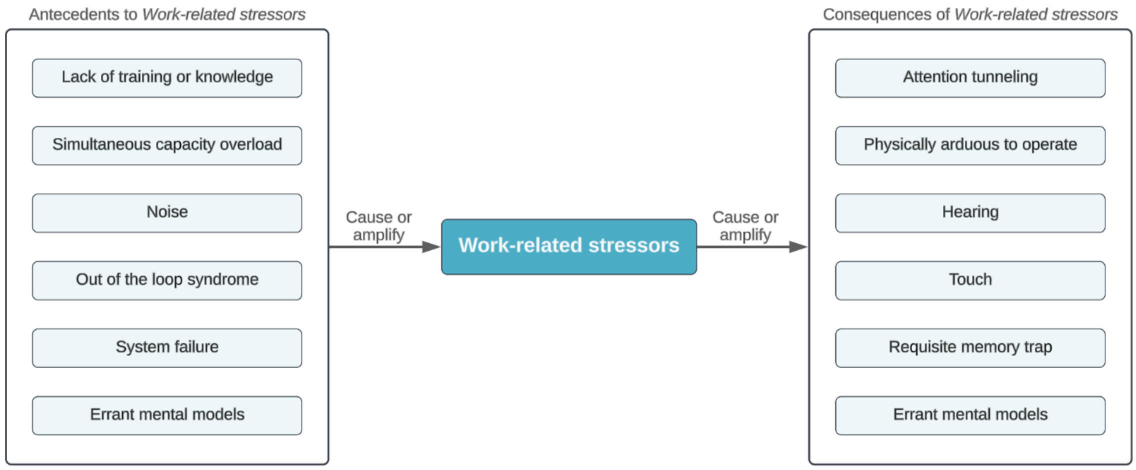

Figure 15 Work-related stressors related to other barriers

Lack of training or knowledge is the antecedent to *Work-related stressors* that was mentioned most frequently. Participants P1, P6, P8, P10, P11 and P12 all mentioned that training or experience will alleviate the impact of *Work-related stressors*. Their reasoning can be summarized as follows: *When routine tasks are ingrained from training and experience, the cognitive workload required to perform them is reduced*. This indicates a connection between low cognitive workload and low stress levels. As a result, more mental effort can be spent on handling the situational complexities of the crisis, which could increase SA.

It is also interesting to note that antecedent and consequent barriers are not necessarily mutually exclusive in relation to the barrier they affect or are affected by. *Errant mental models* has been mentioned as both an antecedent and consequence in relation to *Work-related stressors*. This finding may be interpreted as a vicious circle where *Work-related stressors* and *Errant mental models* affect each other perpetually, but this claim is not supported in our findings. *Errant mental models* as an antecedent and as a consequent barrier to *Work-related stressors* originated from two very different experiences. *Errant mental models* as an antecedent was mentioned by P6 when the mental model provided by the technology evaporated due to a sudden technological failure, which caused stress. *Errant mental models* as a consequence was mentioned by P10 when the stress induced by an emergency caller caused P10 to create a mental model of the situation that was more severe than reality.

5.2.2 Sometimes barriers are a part of a dynamic barrier network

Based on the data collected from interviews, there are many factors that determine what barriers are experienced during a crisis. Some of these factors include crisis location, type of crisis, technology used, operative level, role, position, and individual characteristics. Additionally, the barriers experienced during a crisis are not necessarily static: *Inclement weather* could arise and subside, *Noise* may last for a brief amount of time, the intensity of *Work-related stressors* may fluctuate, etc. This dynamicity is particularly evident for crisis responders at the tactical level due to the change in surroundings and types of labor required to solve a crisis. Furthermore, the relation between barriers experienced during crisis situations can be viewed as a network of cause and effect, which means that the occurrence of one barrier could cause the creation of new ones, increasing the potential for additional barriers to occur. This is illustrated in Figure 16 below.

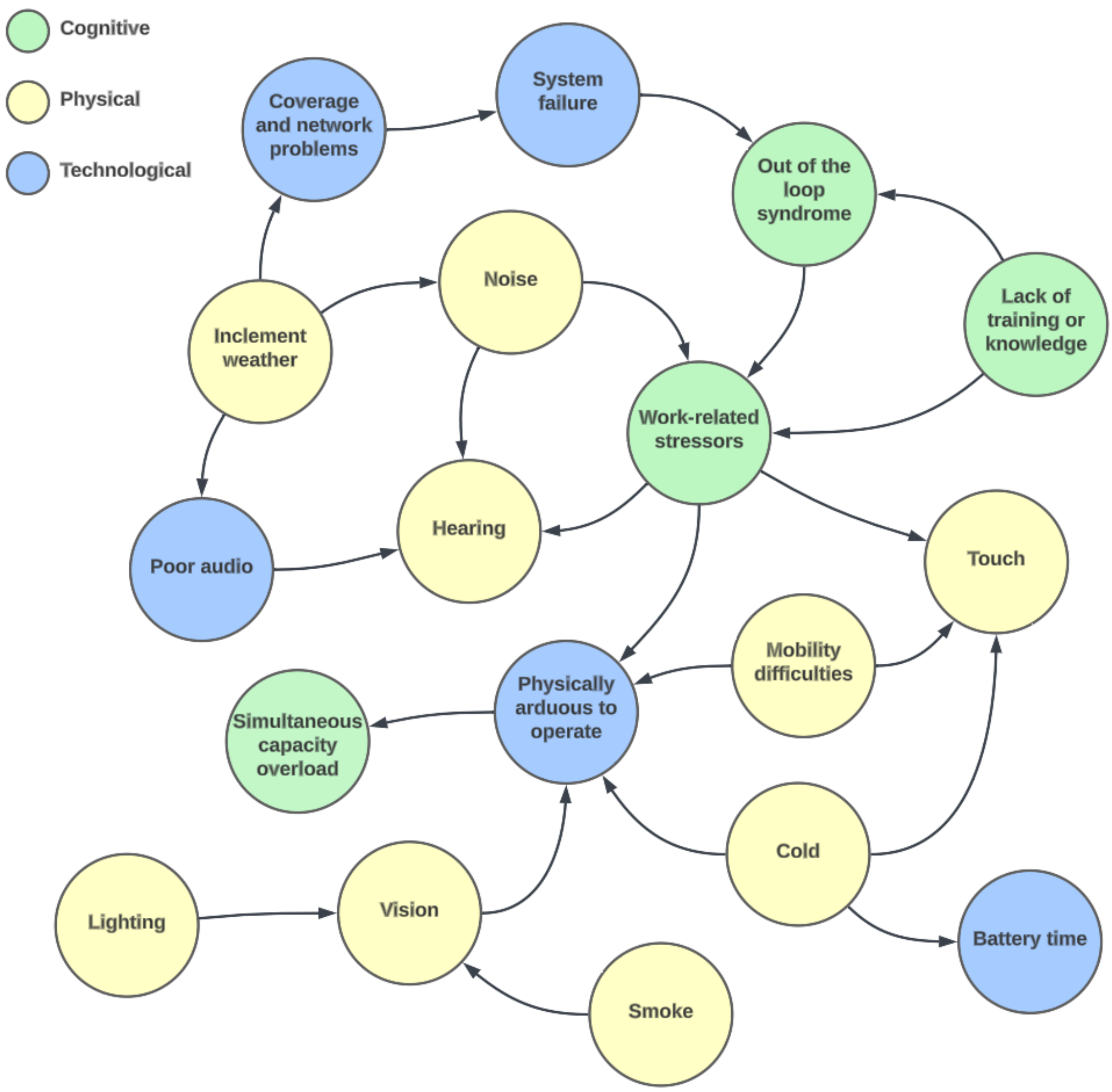

Figure 16 Network of barrier relations

The barrier relations in Figure 16 are derived from the data collected on crisis responder's experiences. Our data supports more relations of barriers than what is included in the figure, but the purpose is merely to illustrate the network of barrier relations. The figure does not illustrate all barriers experienced simultaneously, but rather barriers that could arise and subside based on the factors that determine which barriers are experienced during a crisis, as explained earlier. Furthermore, the arrows in the figure do not always mean pure causation but could mean an amplification of the barriers they point to. For example, technology may be *Physically arduous to operate* before it is affected by other barriers such as *Vision, Cold, Mobility difficulties* and *Work-related stressors*. However, these barriers could amplify the existing problem due to the inadaptability of the technology. When the physical design of the device is not adapted to mitigate the antecedent barriers, attainment of SA could be undermined further.

A concrete example of how *Mobility difficulties* affects *Physically arduous to operate* is that gloves (which impedes mobility) make it harder or impossible to use technology. This was mentioned by P1, P2, P5 and P7. If the technology is not adapted for use with gloves, it becomes *Physically arduous to operate*. Similarly, if the technology is not adapted for use with impaired *Vision*, for example due to *Smoke* or *Lighting*, the user may find it *Physically arduous to operate*. This was mentioned by P13 and P6. *Work-related stressors* and *Cold* could amplify the adverse impact of technology that is *Physically arduous to operate* because stress and cold makes it harder to type on a small screen on a mobile phone, as mentioned by P13. P12 mentioned that *Cold* made buttons on the radio hard and difficult to press, and this is another example of how technology becomes *Physically arduous to operate,* since the radio is not adapted for use in a *Cold* environment.

5.2.3 Some barriers impede SA indirectly

Some barriers do not undermine SA directly but are dependent on affecting other barriers to undermine SA. For example, *Lighting* would not be a barrier if it did not cause problems with *Vision*. *Lack of salience* would not be a barrier if it did not cause problems with *Data overload*. *Cold* would not be a barrier if it did not cause problems with *Touch, Battery time* and *Physically arduous to operate*. An awareness of this relation between barriers is significant because a barrier solely operating as an antecedent could be one of the underlying causes to the real problem. Without addressing the underlying causes, the problem may continue to persist. For example, if the goal is to alleviate the issue of *Data overload* without knowing the underlying causes, erroneous methods for alleviation may be applied. Understanding that *Lack of salience* is an underlying cause for *Data overload* makes it possible to solve this aspect of the problem by implementing salience in the information systems. Figure 17 illustrates how some barriers from the interview data are dependent on affecting other barriers to undermine SA. It also illustrates that some barriers can undermine SA directly and still cause or amplify the effect of other barriers.

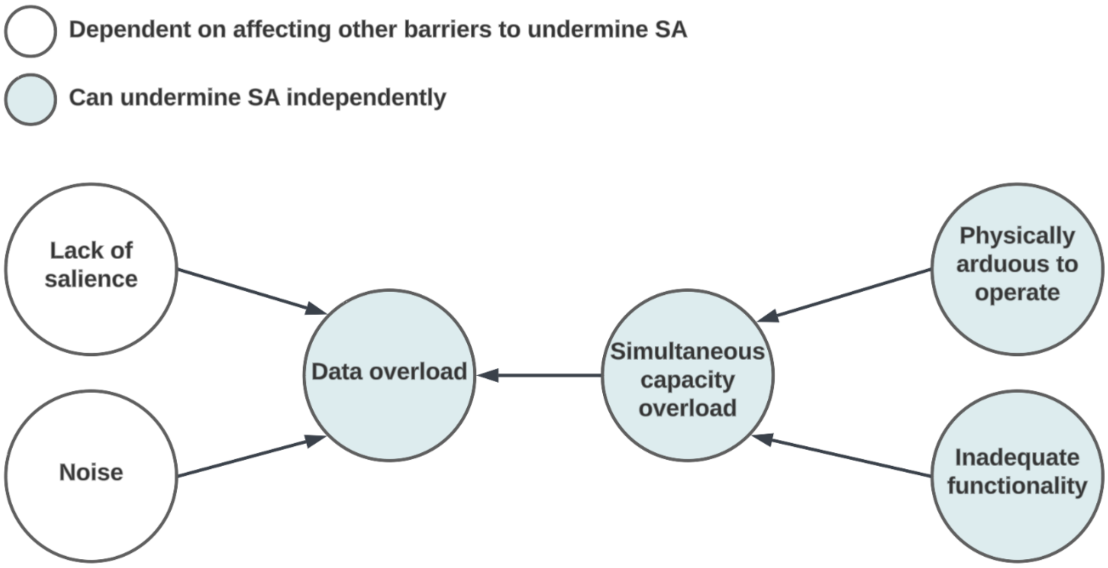

Figure 17 How barriers undermine SA directly and indirectly.

5.3 Operational vs. tactical

As presented in the findings, our data indicates barriers that are specific to certain operative levels. Even among the specific agencies within the operative levels there are exclusive barriers. For example, based on the data from the interviews, fire officers at the tactical level are exclusively experiencing the barriers *Heat*, *Smoke*, and *Fragile hardware*. In addition to those, the barriers that were exclusively mentioned in the context of tactical crisis responders are *Mobility difficulties, Cold, Dirt, Lighting, Smell, Touch, Vision, System access issues* and *Surroundings require attention*. The only barrier exclusively mentioned for the operative level was *Poor air quality*, and this barrier was only mentioned once. However, some barriers have been mentioned significantly more often on the operational level, such as *Simultaneous capacity overload*, *Language or terms*, *Requisite memory trap*, and *System failure*.

Most barriers experienced exclusively by crisis responders at the tactical level are *Physical* barriers. This is probably because they experience different environments and surroundings that affect their senses. In comparison, crisis responders at the operative level are generally situated in an office, which is a relatively static and calm environment. Despite the benefit of their surroundings, most of the barriers experienced more often by crisis responders at the operational level are *Cognitive* barriers. This is probably because their work requires high cognitive capabilities and takes its toll on the mental workload.

Despite the apparent differences in barriers experienced in the various roles and operative levels, the number of participants is too low to determine whether these results are generalizable. A broader subject selection could reveal deeper insight into what kind of barriers are experienced in different contexts. Thus, quantitative research is necessary to accurately determine the roles and operative levels that experience specific barriers.

5.4 Contributions and implications

This thesis contributes to both theory and practice and has several implications for further research, both based on findings and the limitations of this thesis.

5.4.1 Contribution to theory

The theoretical perspective for this thesis is primarily based on these three ideas derived from Endsley's work:

- SA is the main precursor to decision-making (Endsley, 2000).
- Information systems made for dynamic operational constraints should be designed so that one can achieve the greatest degree of SA (Endsley, 2000).
- There are several factors that are shown to influence SA in the dynamic decision-making cycle (Endsley, 1995).

These statements formed the foundation of this thesis and served as a basis to create the research question. One motivation for identifying barriers is to unravel how crisis information systems can be improved by implementing counter measures to the barriers impeding attainment of SA, which consequently could enhance decision-making and ultimately lead to better outcomes in crisis situations. The systematic literature review revealed three main themes of barriers: *Cognitive*, *Physical* and *Technological*. These findings were validated and expanded through qualitative interviews with 14 crisis responders. The initial theoretical perspective described in Section 2.2 has also been validated and expanded with empirical data and is illustrated in Figure 18 below.

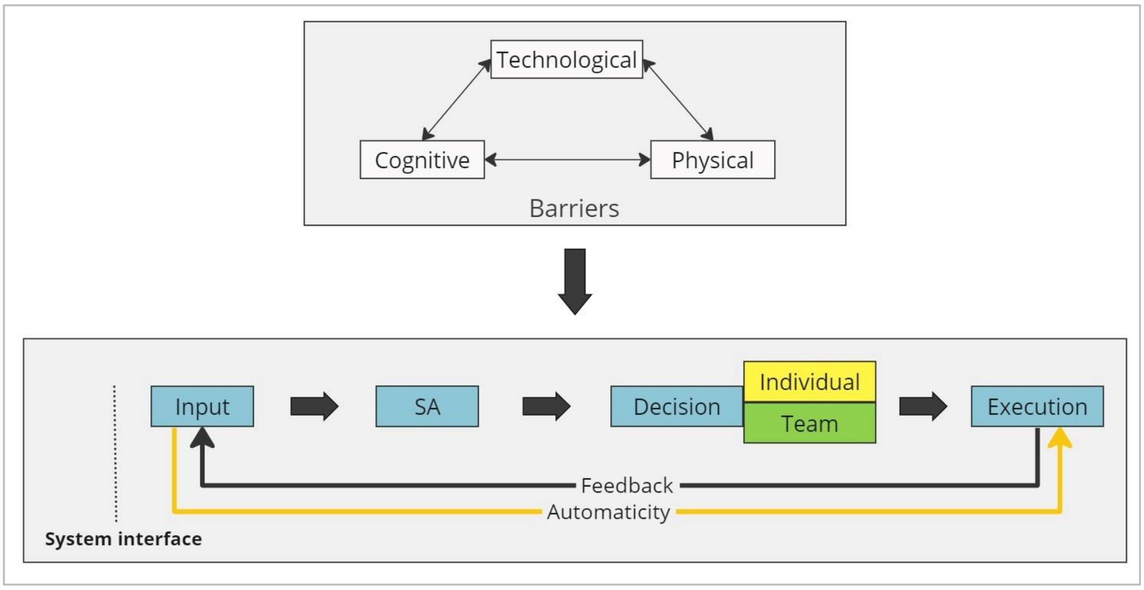

Figure 18 Barriers disrupting the decision cycle.

As explained in Section 2.2, the model is used by the Norwegian police and explains key elements in a decision-making cycle to operative police officers. Information from the crisis is filtered through a system interface, resulting in the input that is used to attain SA from technology. SA is the main precursor for decision-making both on individual and team level. The decision then affects the execution and performance in a situation. The result of the execution becomes new input, which affects the SA. Input can also trigger an automatic response, which leads directly to execution (Johnsen, n.d.). This thesis contributes to theory by incorporating *Cognitive*, *Physical* and *Technological* barriers into the existing model presented by Johnsen (n.d.), illustrating how barriers impede the use of technology and impair the quality of SA attained.

Even though the goal of this thesis is to discover barriers related to the impediment of SA, Figure 18 illustrates that barriers can impede the entire decision cycle, not just SA. This is because SA is affected by input, decisions, and execution. For example, if a barrier impedes a crisis responder from using technology to execute a decision, it breaks the iterative cycle, and SA is impeded as well. A concrete example from our interview data is when P13 was unable to convey a critical message on the radio, which was to turn on the water pump to activate the water hose. Conveying this message is the execution of a decision that would have generated new input to the crisis responder who was standing ready by the water pump. P13 experienced the barrier *Inadequate functionality* since the radio did not adequately fulfill the requirements of the crisis responder, for example with extended radio functionality that allows someone with critical information to override the person talking on the radio. As a result, the person standing by the water pump did not get the input and did not attain the SA required to form a basis for favorable decision-making, which is to execute the task of turning on the water pump. Under time-critical circumstances like this, where a fire was spreading to adjacent cabins, the time lost due to barriers can be detrimental to the outcome of the crisis.

This is one of many examples from our interviews that illustrate how barriers can impede attainment of SA by disrupting another element of the decision cycle. Additionally, it illustrates the adverse impact barriers can have on SA and the other elements of the decision cycle. Thus, we propose that the model displayed in Figure 18 should be used as a theoretical framework for further research on crisis information systems and that it lays the foundation for mitigating barriers in future development of crisis information systems. Further research could contribute with extensions and improvements of the model, which consequently benefits crisis management with contributions to practice by supplying more context and understanding of the factors that impede attainment of SA through information systems.

5.4.2 *Contribution to practice*

When it comes to contributions to practice, the barriers experienced in crisis situations are a crucial point of consideration for system developers when creating crisis information systems. To mitigate the barriers impeding crisis responders from attaining SA through information systems, the first step is to identify which barriers they experience. Thus, the identification of barriers in this study is a step towards ensuring that crisis information systems can be developed in a manner that emphasizes the mitigation of these barriers. As mentioned in the motivation for this thesis, previous research argues that universal design and accessibility principles can be a cure for barriers (Gjøsæter et al., 2019). Some of the barriers identified in this thesis can in fact be alleviated by using recognized design principles for user interface and user experience, or by having more focus on universal design. One example is universal design principle 3: *simple and intuitive use*, which consists of several guidelines (The Centre for Excellence in Universal Design, n.d.). One of the guidelines is to eliminate unnecessary complexity, which directly addresses the barrier *Complexity creep*. Another guideline is to accommodate a wide range of literacy and language skills, which directly addresses the barrier *Language or terms*. However, some of the identified barriers may be more demanding to alleviate than others and require more user involvement and user testing. Crisis information systems must therefore be developed in a human- and context-centered way. Crisis responders can benefit from the identified barriers if system developers concentrate on alleviating them when developing crisis information systems.

Furthermore, crisis responders may benefit from being aware of barriers that can be experienced during crisis situations. Even though the barriers uncovered in this thesis have been derived from interviews with crisis responders, some of the barriers may be ingrained in their mind and their habits, resulting in no conscious effort to alleviate them. By reading about the barriers and the ways they may affect attainment of SA, a fresh perspective may contribute to new ideas on how the barriers can be alleviated. Additionally, for people with little experience on using information systems in crisis situations, learning about potential barriers that could impede attainment of SA could be a first step towards reducing their impact. In addition to an increased awareness of barriers, understanding the mental impact of barriers like *Work-related stressors* could be beneficial. During the interview, P10 emphasized that an awareness of how the body reacts to stress would be helpful in counteracting its detrimental effects. The participant argues that one must have a plan or system to handle stress reactions. Crisis responders should therefore focus on learning about stress management to enhance their capabilities of dealing with stress in crisis situations.

Another contribution to practice is the emphasis on training, both in small incidents and in major crisis situations. This is because *Lack of training or knowledge* is a major barrier for attaining SA, according to the interview data. Training on technology usage could reduce errors and increase efficiency, and training on crisis management in general could make routine tasks ingrained and relieve the strain on the mental capacity. An increased level of competence on how to use technology and the surplus of mental capacity could benefit crisis responders by providing possibilities for attaining a higher level of SA through technology, potentially resulting in better decision-making and better outcomes of crisis situations. Furthermore, one of the detrimental consequences of *Lack of training or knowledge* is the adverse impact it has on other barriers, such as *Work-related stressors* and *Out of the loop syndrome*, as illustrated in Figure 16. It also affects *Simultaneous capacity overload* and other barriers. Training on stress management has already been suggested. Thus, we additionally suggest training on using the backup systems to reduce *Out of the loop syndrome,* and training on increasing simultaneous capacity. This is because mitigating barriers that are amplified by *Lack of training or knowledge* could reduce their impact.

Finally, the barriers identified can also benefit decision-making in crisis management at a strategic level. Procurement of technology should be influenced by the technology's capability to alleviate barriers experienced in crisis situations. As a result, the most suitable technology can be used by crisis responders, barriers can be avoided or minimized, and the outcome of a crisis could be improved.

5.4.3 Implications for further research

The scope of barriers encompassed in this thesis is anything that can impede the use of information systems to attain SA during crisis situations. This scope is extensive, and we argue that a major contribution of this thesis is the implications for further research that can be derived from our findings. We did not identify any previous research in the literature review that had the purpose of mapping out all barriers in this regard, which indicates an unexplored gap in research that needs to be filled. In this subsection we will suggest areas for further research based on our findings and analysis.

More research should be done on the overarching barrier themes and their specific barriers in general. There are many ways of naming and structuring barriers, and more research on the identified barriers could provide even more accurate and detailed explanations of barriers. Particularly research that is done in-depth for specific stakeholders, by researching the tactical and operational levels individually since our findings indicate some significant differences in what barriers they experience. More in-depth research by investigating the different agencies individually, and the different roles and positions could provide valuable insights into the specific barriers experienced across all levels of crisis response. Systems should be developed to fit the needs of the user, and by identifying the barriers associated with specific roles and positions, and by making systems adaptable for use in specific situations, the barriers can be alleviated for everyone.

Additionally, research on barriers experienced by other stakeholders than crisis responders should be executed to encompass barriers applicable for crisis help volunteers, specific professions, civilians affected by crisis, and other relevant crisis stakeholders that use information systems to attain SA. The barriers experienced could also vary based on the country the crisis occurs in due to differences in climate, culture, economy, crisis response structure and processes, technology used, and other factors, which is why it is relevant to research barriers in other countries than Norway. Furthermore, research on barriers experienced in specific types of crisis and disasters could be beneficial if there are any extraordinary barriers that occur under specific circumstances.

Section 5.2 describes how barriers are related and can be viewed as a network of cause and effect. More research should be done on these relations to map out how barriers affect each other. This could provide results that highlight the gravity of underlying problems. For example, if there are barriers in the network that cause or amplify several other barriers, mitigating these underlying barriers (if possible) could potentially terminate or debilitate a chain reaction, which leads to exponential benefits. Furthermore, by researching the severity of barriers, i.e., which barriers have the most significant impact on SA, it is possible to create a prioritization of which barriers should be alleviated. This should be done in consideration with how complicated it is to alleviate the barrier. For example, *Poor air quality* may not be as impactful as *Work-related stressors*, but installing air ventilation in the emergency call centers is probably easier than significantly decreasing stress levels in humans.

Finally, further research should be done on the higher-level barriers explained in Section 4.5. This includes interoperability between systems used across and within agencies, law complexities regarding privacy and confidentiality when sharing information in crisis situations, barriers for technology procurement due to economic constraints, and barriers related to the adoption of new technologies in agencies due to old organizational structures and processes. These barriers are outside the scope of this thesis because they are not barriers experienced *during* crisis situations, but rather complex, preceding factors that influence attainment of SA through information systems when a crisis occurs. Researching the higher-level barriers is important because it could lead to contributions on how to solve the underlying problems that impede attainment of SA, improving the current situation. It could also help in further understanding and alleviating the barriers identified in this thesis. For example, could *Missing functionality* be a result of economic constraints?

5.5 Limitations

Before using our findings to embark on further research, it is important to be aware of the limitations this research has encountered. The first limitation that needs to be addressed concerns the representativeness of the findings. Some interview participants are constrained by confidentiality when explaining the barriers they have experienced. For example, the duty of confidentiality from P12 hindered the collection of data about the system used and its corresponding barriers. This has also been a factor preventing some participants mentioning specific technology used when experiencing barriers, e.g., only saying “the system” instead of explaining what specific system is used. However, most participants were able to talk about the systems, and the ones who were not still provided insightful information about external factors influencing the use of the systems.

Trust and dignity are factors that influence how participants talk about barriers. The desire to come across as professional and not reveal barriers that could weaken their professionalism was evident in a few participants. When explaining limitations related to physical and cognitive capabilities, participants are required to reveal personal vulnerabilities and shortcomings, which is challenging for some people. Memory is also a factor determining whether all barriers experienced were mentioned. Many of the participants pointed out that it was difficult to remember barriers in the aftermath of a crisis, and that in a crisis you have most likely experienced barriers that you do not recognize afterwards.

The last limitation that may have prevented the truest representation of barriers is translation from Norwegian to English. Because our findings may be of interest to others outside of Norway, it was decided that the thesis should be written in English. The interviews, on the other hand, were held in Norwegian, and there is therefore a risk that some nuances of expressions may be lost in the translation. To counteract this limitation, we have discussed possible translations with our supervisors when expressions have been difficult to translate, hence ensuring that quotes have been translated with emphasis on maintaining the truest and closest representations of the participant’s original statements.

6 CONCLUSION

The goal of this study was to discover barriers for using information systems to attain SA during crisis situations. Previous research indicated that these barriers exist, such as the demons of SA and situational disabilities. However, there was a gap of research on systematically mapping out these barriers, particularly with a scope that encompass barriers holistically, without constraints on the type of barriers experienced during crisis situations. This discovery shaped the research question:

> *What are the barriers that can impede the use of information systems to attain situational awareness during crisis situations?*

The research question was answered by conducting a systematic literature review where a basis of barriers was discovered, in addition to conducting qualitative research, where 14 crisis responders from health, fire and police services from the tactical and operational levels were interviewed. The data collection and analysis resulted in a total of 43 barriers and themes, and all barriers were categorized under one of the three main themes: *Cognitive, Physical* and *Technological*. Most barriers identified in the interviews were either undiscovered in the literature review or renamed and subdivided into new barriers for improved accuracy and descriptions. Our findings indicate that the barriers experienced during crisis situations are multifarious and attempts to mitigate them should be undertaken to increase SA attained from information systems used in crisis response.

The analysis of the collected data revealed an important aspect of barriers: there is a relation between them. That means some barriers are antecedents that cause new barriers, and some barriers are a consequence of other barriers. How barriers occur and affect each other can be viewed as a network of cause and effect, where barriers arise and subside with fluctuating intensity. Additionally, some barriers are purely antecedent, which means they only exist as a barrier because they cause or amplify other barriers.

This thesis contributes to theory and practice by exposing barriers experienced when using information systems to attain SA during crisis situations. However, there are several aspects of our findings that would benefit from more research. For example, by researching barriers in specific crisis contexts, and by researching the impact of barriers and possibilities for mitigating them. Additionally, more research on barrier relations could reveal ways to reduce the cause-and-effect problem. The implications for practice and further research support the creation and use of reliable information systems that live up to the standards required to mitigate barriers for attaining SA in crisis situations. As a result, crisis stakeholders can achieve a greater basis for decision-making, which is a precursor to favorable outcomes of crisis situations where the safety of individuals is sustained.

7 REFERENCES

Al-Dahash, H., Thayaparan, M., & Kulatunga, U. (2016). Understanding the Terminologies: Disaster, Crisis and Emergency. *32nd Annual ARCOM Conference*, *2*, 1191-1200.

Alexander, D. (2005). Towards the Development of a Standard in Emergency Planning. *Disaster Prevention and Management*, *14*, 158-175. https://doi.org/10.1108/09653560510595164

Aune, L. (2019). *Politiet i nasjonal krisehåndtering* Universitetet i Stavanger. https://uis.brage.unit.no/uis-xmlui/handle/11250/2619518?show=full

Bernard, H. R. (2011). *Research Methods in Anthropology* (5 ed.). AltaMira Press.

Berner, M., Augustine, J., & Maedche, A. (2016). The Impact of Process Visibility on Process Performance. *Business & Information Systems Engineering*, *58*. https://doi.org/10.1007/s12599-015-0414-0

Bhandari, P. (2020). *What Is Qualitative Research? Methods & Examples*. Scribber. https://www.scribbr.com/methodology/qualitative-research/

Brann & Redning. (2006). *IR-kamera*. Brann & Redning. https://brannredning.no/fagstoff/ir-kamera/

Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology. *Qualitative Research In Psychology*, *3*(2), 77-101. https://doi.org/10.1191/1478088706qp063oa

Casula, M., Rangarajan, N., & Shields, P. (2021). The potential of working hypotheses for deductive exploratory research. *Quality & Quantity*, *55*(5), 1703-1725. https://doi.org/10.1007/s11135-020-01072-9

Computer Hope. (2021). *System failure*. Computer Hope. https://www.computerhope.com/jargon/s/systemfa.htm

Crosland, M., Wang, W., Ray, J., Michelson, S., & Hutto, C. J. (2017). Cognitive Ergonomics Applied to the eQRH: Developing an Electronic Quick Reaction Handbook for Use During Aviation Emergencies. In *Advances in Neuroergonomics and Cognitive Engineering* (pp. 27-38). https://doi.org/10.1007/978-3-319-41691-5_3

Danielsen, F., Flak, L. S., & Sæbø, Ø. (2022). Understanding Digital Transformation in Government. In *Public Administration and Information Technology* (pp. 151-187). Springer. https://doi.org/10.1007/978-3-030-92945-9

Doeweling, S., Tahiri, T., Sowinski, P., Schmidt, B., & Khalilbeigi, M. (2013). Support for collaborative situation analysis and planning in crisis management teams using interactive tabletops. *Proceedings of the 2013 ACM international conference on Interactive tabletops and surfaces*, 273-282. https://doi.org/10.1145/2512349.2512823

Eide, A. W., Haugstveit, I. M., Halvorsrud, R., Skjetne, J. H., & Stiso, M. (2014). Key challenges in multi-agency collaboration during large-scale emergency management. *CEUR Workshop Proceedings*, *953*.

Endsley, M. (1995). Toward a Theory of Situation Awareness in Dynamic Systems. *Human Factors: The Journal of the Human Factors and Ergonomics Society*, *37*, 32-64. https://doi.org/10.1518/001872095779049543

Endsley, M. (2000). Situation awareness analysis and measurement, chapter theoretical underpinnings of situation awareness. In (pp. 3-33). Mahwah, NJ: Lawrence Erlbaum Associates. https://www.researchgate.net/publication/292771806_Situation_awareness_analysis_and_measurement_chapter_theoretical_underpinnings_of_situation_awareness

Endsley, M., Bolté, B., & Jones, D. (2003). Designing for Situation Awareness. In (1 ed.). Taylor & Francis Inc.

Endsley, M., & Rodgers, M. (1996). Attention Distribution and Situation Awareness in Air Traffic Control. *Proceedings of the Human Factors and Ergonomics Society Annual Meeting*, *40*. https://doi.org/10.1177/154193129604000216

Endsley, M. R. (1988a). Design and Evaluation for Situation Awareness Enhancement. *Proceedings of the Human Factors and Ergonomics Society Annual Meeting*, *32*(2). https://doi.org/10.1177/154193128803200221

Endsley, M. R. (1988b). Situation awareness global assessment technique (SAGAT). *Proceedings of the IEEE 1988 National Aerospace and Electronics Conference*, 789-795 vol.783. https://doi.org/10.1109/NAECON.1988.195097

Endsley, M. R. (2021). *Situation Awareness Measurement: How to Measure Situation Awareness in Individuals and Teams* (Vol. 5). Human Factors and Ergonomics Society.

Endsley, M. R., & Garland, D. J. (2000). *Situation Awareness Analysis and Measurement*. Lawrence Erlbaum Associates, Inc.

Endsley, M. R., & Jones, D. G. (2012). *Designing for Situational Awareness* (2 ed.). CRC Press Taylor & Francis Group.

Engen, O. A. H., Pettersen, K. A., Kruke, B. I., Lindøe, P. H., Olsen, K. H., & Olsen, O. E. (2016). *Perspektiver på samfunnssikkerhet.* Oslo: Cappelen Damm AS.

Giannoumis, A. G., Gjøsæter, T., & Paupini, C. (2020). Towards an Indoor Navigation Application for Emergency Evacuations and Persons with Visual Impairments – Experiences from First Responders and End Users. In *Information Technology in Disaster Risk Reduction* (pp. 159-167). https://doi.org/10.1007/978-3-030-48939-7_14

Giannoumis, A. G., Gjøsæter, T., Radianti, J., & Paupini, C. (2019). Universally Designed Beacon-Assisted Indoor Navigation for Emergency Evacuations. In *Information Technology in Disaster Risk Reduction* (pp. 120-129). https://doi.org/10.1007/978-3-030-32169-7_9

Gilson, R. D. (1995). SITUATION AWARENESS – SPECIAL ISSUE PREFACE. *Human Factors*, *37*(1), 3-4. https://doi.org/https://doi.org/10.1518/001872095779049426

Gjøsæter, T., & Radianti, J. (2019). Evaluating Accessibility and Usability of an Experimental Situational Awareness Room. In *Advances in Design for Inclusion* (pp. 216-228). https://doi.org/10.1007/978-3-319-94622-1_21

Gjøsæter, T., Radianti, J., & Chen, W. (2019). Understanding situational disabilities and situational awareness in disasters. *Proceedings of the International ISCRAM Conference*, 940-949. https://www.scopus.com/inward/record.uri?eid=2-s2.0-85077759426&partnerID=40&md5=558d07008caa6753729decc9969678c9

Gjøsæter, T., Radianti, J., & Chen, W. (2020). Towards situational disability-aware universally designed information support systems for enhanced situational awareness. *Proceedings of the International ISCRAM Conference*, 1038-1047. https://www.scopus.com/inward/record.uri?eid=2-s2.0-85095608164&partnerID=40&md5=5d1a3fc133c7954615127fb89d56711c

Grinko, M., Kaufhold, M.-A., & Reuter, C. (2019). Adoption, Use and Diffusion of Crisis Apps in Germany. *Proceedings of Mensch und Computer 2019*, 263-274. https://doi.org/10.1145/3340764.3340782

Hiltz, S. R., Hughes, A. L., Imran, M., Plotnick, L., Power, R., & Turoff, M. (2020). Exploring the usefulness and feasibility of software requirements for social media use in emergency management. *International Journal of Disaster Risk Reduction*, *42*. https://doi.org/10.1016/j.ijdrr.2019.101367

Huggins, T. J., & Prasanna, R. (2020). Information Technologies Supporting Emergency Management Controllers in New Zealand. *Sustainability*, *12*(9). https://doi.org/10.3390/su12093716

Israel, M., & Hay, I. (2006). *Research Ethics For Social Scientists* (1st ed.). SAGE Publications Ltd.

Jacobsen, D. I. (2018). *Hvordan gjennomføre undersøkelser?* (3rd ed.). CAPPELEN DAMM AS.

Jacobsen, L. G., Lerseth, S. K., Eik, M., Nyberg, L., & Hansen, Ø. (2021). *Evaluering av Øvre Romerike brann og redning IKS (ØRB) sin krisehåndtering av leirskredet i Ask*. Rogaland Brann og Redning IKS. https://www.rogbr.no/ASK-rapporten_280621.pdf

John, D. (2022). *Inductive Approach (Inductive Reasoning)*. Business Research Methodology. https://research-methodology.net/research-methodology/research-approach/inductive-approach-2/#_ftn2

Johnsen, B. H. (n.d.). *Beslutningstaking i operative situasjoner*. Politiet. https://www.politiet.no/globalassets/04-aktuelt-tall-og-fakta/22-juli/beslutningstakning.pdf

Johnson, R. B. (1997). Examining the validity structure of qualitative research. *Education*, *118*(2), 282. https://www.researchgate.net/publication/246126534_Examining_the_Validity_Structure_of_Qualitative_Research

Kaber, D. B., & Endsley, M. R. (1997). Out-of-the-loop performance problems and the use of intermediate levels of automation for improved control system functioning and safety. *Process Safety Progress*, *16*(3). https://www.academia.edu/19830590/Out_of_the_loop_performance_problems_and_the_use_of_intermediate_levels_of_automation_for_improved_control_system_functioning_and_safety

Kuligowski, E. D., Gwynne, S. M., Kinsey, M. J., & Hulse, L. (2017). Guidance for the Model User on Representing Human Behavior in Egress Models. *Fire technology*, *53*(2), 649-672. https://doi.org/10.1007/s10694-016-0586-2

Kyne, D., & Pathranarakul, P. (2006). An Integrated Approach to Natural Disaster Management: Public Project Management and Its Critical Success Factors. *Disaster Prevention and Management*, *15*, 396-413. https://doi.org/10.1108/09653560610669882

Lund, M. S. (n.d.). Kommunikasjonssystemer for beredskap og krisehåndtering – teknologi og utfordringer. In *Beredskap og krisehåndtering. Utfordringer på sentralt, regionalt og lokalt nivå* (Vol. 1). Cappelen Damm Akademisk. https://fhs.brage.unit.no/fhs-xmlui/bitstream/handle/11250/2880971/Kommunikasjonssystemer.pdf?sequence=1&isAllowed=y

Luokkala, P., & Virrantaus, K. (2014). Developing information systems to support situational awareness and interaction in time-pressuring crisis situations. *Safety Science*, *63*, 191-203. https://doi.org/10.1016/j.ssci.2013.11.014

McNab, A. L., Hess, T., & Valacich, J. S. (2009). Designing Interfaces for Faster Information Processing - Examination of the Effectiveness of Using Multiple Information Cues. *AMCIS 2009 Proceedings*, *699*. http://aisel.aisnet.org/amcis2009/699

Myers, M. D., & Newman, M. (2007). The qualitative interview in IS research: Examining the craft. *Information and Organization*, *17*(1), 2-26. https://doi.org/10.1016/j.infoandorg.2006.11.001

Nasjonalt Kommunesamarbeid For 110-Sentralene. (2022). *Bliksund valgt som leverandør av videoløsning til alle 110 sentralene i Norge*. NKS110. https://nks110.no/1470/

Nini, M. (2020). *Situational awareness: What it is and why it matters as a management tool*. CQ Net. https://www.ckju.net/en/dossier/situational-awareness-what-it-and-why-it-matters-management-tool

Norwegian Directorate for Civil Protection (DSB). (2019). *Analyser av krisescenarioer 2019*. Statsforvalteren. https://www.statsforvalteren.no/siteassets/fm-troms-og-finnmark/samfunnssikkerhet-og-beredskap/analyser-av-krisescenarioer-2019.pdf

Norwegian Directorate for Civil Protection (DSB). (2023). *Antall reelle oppdrag hvert år*. Brannstatistikk. https://www.brannstatistikk.no/brus-ui/search?searchId=2C38B785-9FDD-48B1-8400-0B9708F367CB&type=SEARCH_DEFINITION

Norwegian Police. (2022). *Annual Police Report 2021*. Regjeringen. https://www.regjeringen.no/contentassets/80197702ddb144e8a016a040e656751f/politiets-arsrapport-2021.pdf

Nunavath, V., & Prinz, A. (2017). LifeRescue Software Prototype for Supporting Emergency Responders During Fire Emergency Response: A Usability and User Requirements Evaluation. In *Human-Computer Interaction. Interaction Contexts* (pp. 480-498). https://doi.org/10.1007/978-3-319-58077-7_39

Oates, B. J. (2006). *Researching Information Systems and Computing*. SAGE Publications Ltd.

Official Norwegian Report. (2000). *Et sårbart samfunn - Utfordringer for sikkerhets- og beredskapsarbeidet i samfunnet*. Regjeringen. https://www.regjeringen.no/contentassets/1c557161b3884335b4f9b89bbd32b27e/no/pdfa/nou200020000024000dddpdfa.pdf

Ogbonna, U. K., Paupini, C., & Gjøsæter, T. (2022). Situational Disabilities in Information Systems for Situational Awareness in Flood Situations in Nigeria. *Information Technology in Disaster Risk Reduction 2022*, *672*. https://doi.org/doi.org/10.1007/978-3-031-34207-3_4

Okoli, C. (2015). A Guide to Conducting a Standalone Systematic Literature Review. *Communications of the Association for Information Systems*, *37*. https://doi.org/10.17705/1CAIS.03743

Onorati, T., Malizia, A., Diaz, P., & Aedo, I. (2014). Modeling an ontology on accessible evacuation routes for emergencies. *Expert Systems with Applications*, *41*(16), 7124-7134. https://doi.org/10.1016/j.eswa.2014.05.039

Posey, B., & Wigmore, I. (2020). *What is crisis management?* Techtarget. https://www.techtarget.com/whatis/definition/crisis-management

Prasanna, R., Yang, L., & King, M. (2009). On-Site Information Systems Design for Emergency First Responders. *Journal of Information Technology Theory and Application*, *10*(3), 5-27. https://aisel.aisnet.org/jitta/vol10/iss1/2/

Prasanna, R., Yang, L., & King, M. (2013). Guidance for developing human–computer interfaces for supporting fire emergency response. *Risk Management*, *15*(3), 155-179. https://doi.org/10.1057/rm.2013.3

Recker, J. (2021). *Scientific Research in Information Systems*. Springer.

Salmon, M. P., Stanton, A. N., Walker, H. G., & Jenkins, P. D. (2017). *Distributed situation awareness*. Taylor and Francis Group.

Schroeder, J. M., Manz, D. O., Amaya, J. P., McMakin, A. H., & Bays, R. M. (2018). Understanding past, current and future communication and situational awareness technologies for first responders. *Proceedings of the Fifth Cybersecurity Symposium*, 1-14. https://doi.org/10.1145/3212687.3212861

Schwab, P.-N. (2022). *Snowball effect: advantages, disadvantages, implementation*. Into The Minds. https://www.intotheminds.com/blog/en/snowball-effect/

SMstudy. (2016). *Exploratory Research Design*. SMstudy. https://www-smstudy-com.translate.goog/article/exploratory-research-design?_x_tr_sl=en&_x_tr_tl=no&_x_tr_hl=no&_x_tr_pto=sc

Solberg, S., Halvorsen, J., Urdal, A., Sørsdal, L., Aasgaard, M., Parnemann, O. P., Skogstad, W., & Eggertsson, Y. (2018). *Håndbok for redningstjenesten*. Hovedredningssentralen.

Stanton, N. A., Chambers, p. R. G., & Piggott, J. (2001). Situational Awareness and Safety. *Safety Science*, *39*, 189-204. https://bura.brunel.ac.uk/bitstream/2438/1804/1/Situation_awareness_and_safety_Stanton_et_al.pdf

Steen-Tveit, K., & Radianti, J. (2019). Analysis of Common Operational Picture and Situational Awareness during Multiple Emergency Response Scenarios. *Proceedings of the International ISCRAM Conference*, *52*(49). https://iscram2019.webs.upv.es/wp-content/uploads/2019/09/ISCRAM2019_Proceedings.pdf

Steen-Tveit, K., Radianti, J., Gjøsæter, T., & Chen, W. (2020). SMS-based real-time data collection for evaluation of situational awareness and common operational picture: Lessons learned from a field exercise. *Proceedings of the 17th International Conference on Information Systems for Crisis Response and Management*, 276-284. https://idl.iscram.org/files/kristinesteen-tveit/2020/

The Centre for Excellence in Universal Design. (n.d.). *The 7 Principles*. Universaldesign. https://universaldesign.ie/what-is-universal-design/the-7-principles/

Tianfield, H. (2016). Cyber Security Situational Awareness. *2016 IEEE International Conference on Internet of Things (iThings)*, 782-787. https://doi.org/10.1109/iThings-GreenCom-CPSCom-SmartData.2016.165

Tunold, S., Radianti, J., Gjøsæter, T., & Chen, W. (2019). Perceivability of Map Information for Disaster Situations for People with Low Vision. In *Universal Access in Human-Computer Interaction. Theory, Methods and Tools* (pp. 342-352). https://doi.org/10.1007/978-3-030-23560-4_25

Vold, B. (2022). *Flere ambulanseoppdrag i 2021*. Statistics Norway. https://www.ssb.no/helse/helsetjenester/statistikk/spesialisthelsetjenesten/artikler/flere-ambulanseoppdrag-i-2021

Webster, J., & Watson, R. (2002). Analyzing the Past to Prepare for the Future: Writing a Literature Review. *MIS Quarterly*, *26*. https://doi.org/10.2307/4132319

8 APPENDIX

APPENDIX A - Interview guide (In Norwegian)

Spørsmål
Før vi starter: • Muntlig samtykke med navn (har lest samtykkedokument?)
• Vi skriver masteroppgave om barrierer ved bruk av teknologi i krisesituasjoner eller nødsituasjoner. • Hensikten er at det vi finner ut kan brukes til å lage bedre systemer som legger til rette for disse barrierene, spesielt i de situasjonene og kontekstene de brukes. Det er viktig at systemene som lages blir laget for de som skal bruke systemene, og at de er tilpasset bruken på best mulig måte. • Med barrierer så mener vi det som kan gjøre det vanskelig å få en forståelse av situasjonen gjennom å bruke teknologien. Det kan være fysiske, kognitive eller tekniske årsaker som kan stå bak. For eksempel hvis det er mye røyk så det blir vanskelig å se, hvis man er stresset eller hvis systemet er dårlig designet så det er vanskelig å bruke og å få tilgang på informasjon. Vi kommer til å snakke litt mer om hva vi mener senere. • Første del av intervjuet vil handle om bakgrunnsinformasjon. Den andre del av intervjuet handler om bruk av teknologi for å få situasjonsforståelse. Den tredje delen er hoveddelen som handler om opplevelse av barrierer i krisesituasjoner for å få situasjonsforståelse. Og til slutt vil vi ha en refleksjonsdel. **Spørsmål?**

Bakgrunnsinformasjon
1. Kan du fortelle litt om jobben din?
    a. Hvilket yrke jobber du i?
        i. Hvilken stilling har du, og hvilke arbeidsoppgaver medbringer dette?
    b. Hvor (geografisk) har du jobbet?
2. Hvor mye erfaring har du?
3. Er du glad i teknologi og synes du det er enkelt å bruke?
    a. Både i jobb og privat.

- Nå vil vi snakke litt om bruk av teknologi for å få situasjonsforståelse før vi begynner å snakke om barrierer.
- Med situasjonsforståelse så mener vi til den graden man klarer å plukke opp informasjonen om det som skjer i situasjonen, forstå hva det er som skjer, og basert på det man forstår, forutse det som kommer til å skje videre. Og hvis man har en god situasjonsforståelse så kan man ta bedre beslutninger for situasjonen. Er du/dere enig i denne beskrivelsen?
- Vi vil stille noen spørsmål om teknologien du/dere bruker til å få situasjonsforståelse, og hvor viktig den er.

Bruk av teknologi og situasjonsforståelse

1. Hva slags teknologi bruker du i nødstilfeller eller kriser? (Gå gjennom hver teknologi hvis det er relevant)
   a. Hva slags teknologi brukes mest og hva er grunnen til det?
2. Hvor viktig synes du de systemene/teknologiene du nevnte er for å få situasjonsforståelse og hvor stor innvirkning har disse på de beslutningene du tar?
   a. I hvilke situasjoner er det viktigst å bruke teknologi? (F. eks i store eller små kriser?)
   b. Synes du teknologien er viktigst for å få en individuell situasjonsforståelse eller en felles situasjonsforståelse i teamet?

- Nå skal vi snakke litt om selve barrierene ved bruk av teknologi.
- Vi lurer på alt som kan skje i en nødsituasjon som kan skape barrierer for bruk av teknologien for å få en god situasjonsforståelse.
- Vi er i utgangspunktet interessert i tre kategorier barrierer: Fysiske barrierer (Med fysiske barrierer mener vi for eksempel det som er i miljøet rundt deg som vær og objekter som fysisk hindrer bruk av teknologien, eller dine egne fysiske begrensninger i forhold til sanser og bevegelse), Kognitive barrierer (Altså mangel på mental kapasitet til å få situasjonsforståelse gjennom bruk av teknologi), og Teknologiske barrierer (Altså begrensninger ved selve teknologien som gjør det vanskeligere å bruke den til å få situasjonsforståelse). Målet er å avdekke så mange barrierer som mulig.
- Vi lurer på erfaringer som dere har hatt på øvelser og i virkeligheten, og det er ikke veldig viktig at situasjonen er en faktisk krise så lenge det er en situasjon hvor de samme barrierene kan oppleves i en krise.

Opplevelse av barrierer

1. Har du et eksempel på en større krisesituasjon du har opplevd? (Enten øvelse eller ekte)
2. Hva er det du tenker på når du hører barrierer for å bruke teknologi i et nødstilfelle eller krise?
    a. Har du et eksempel på en situasjon hvor barrierer gjorde det vanskelig å ta gode beslutninger?
3. Har du eksempler på noen flere kognitive barrierer du har opplevd i en krise? Altså mangel på mental kapasitet til å forstå situasjonen.
4. Hva med fysiske barrierer? Med fysiske barrierer mener vi for eksempel det som er i miljøet rundt deg som vær og objekter, eller dine egne fysiske begrensninger i forhold til sanser og bevegelse.
5. Hva med teknologiske barrierer? Altså begrensninger ved selve teknologien som gjorde den vanskelig å bruke? Dette kan for eksempel være barrierer med selve enheten eller barrierer med applikasjonen til enheten som for eksempel lite intuitivt design.
6. Hva er konsekvensene av disse barrierene? Hender det at teknologien blir ubrukelig?
7. Merker du at du opplever forskjellige barrierer i forskjellige situasjoner, eller er det ofte de samme barrierene? (F. eks stor eller liten situasjon)

Åpen refleksjon

1. Er det noe du ville endret med teknologien som brukes nå, eller noe du synes mangler?
2. Har du noe mer du ønsker å legge til?

Annet

- Hva synes du om temaet og intervjuet?
- Hvis du kommer på noen barrierer senere som du ikke kom på i intervjuet, ta gjerne kontakt med oss og si ifra.
- Kjenner dere noen flere som kunne vært med på intervju?
- Hvis vi lurer på noe i ettertid kan vi sende mail?

APPENDIX B - Barrier definitions

Cognitive barrier	Definition
Lack of training or knowledge	Lack of training, experience, or knowledge on how to use the crisis information systems, and on how to handle crisis situations altogether.
Work-related stressors	Stress is a state of mental or emotional strain or tension resulting from adverse or demanding circumstances. Some stress factors include time pressure, mental workload, and uncertainty (Endsley et al., 2003).
Data overload	Inability for a human to process the amount of information taken in, leading to lapses in SA (Endsley et al., 2003).
Simultaneous capacity overload	Occurs when a human is supposed to use multiple information systems simultaneously to attain SA but fails to do so due to cognitive overload.
Surroundings require attention	Occurs when a situation requires a human to shift their attention away from the crisis information system to deal with the surroundings, causing loss of SA that could have been attained from the technology. This does not include shifting attention towards surroundings that provide better SA than the technology.
Errant mental models	Bad interpretations and projections of the situation from information received through technology. Can lead to cues being misinterpreted (Endsley et al., 2003).
Out of the loop syndrome	When automation does not behave as expected, understanding the system, or taking back manual control may be difficult (Endsley et al., 2003).
Language or terms	Inability to understand the language spoken or written, or inability to understand terms used.
Requisite memory trap	Inability to keep information in the short-term memory (Endsley et al., 2003).
Attention tunneling	Locking in on certain aspects or features of the environment but neglecting other aspects that could be important to attain SA (Endsley et al., 2003).

Physical barrier		Definition
Environment: Attributes related to the surroundings that undermine attainment of SA through technology	Cold	Low temperatures in the environment impeding the use of technology.
	Inclement weather	Harsh weather conditions like storms, heavy rain, and/or heavy snowfall that impedes the use of technology.
	Heat	High temperatures in the environment caused by fire, impeding the use of technology.
	Dirt	Any type of dirt, grime, soot, dust, or spillage that could contaminate the technological equipment, impeding its use.
	Lighting	The absence or presence of light impedes the use of technology.
	Noise	Disturbances such as loud or unpleasant sounds that impedes the use of technology.
	Poor air quality	Lack of fresh air, causing loss of concentration when operating technology.
	Smoke	Particles in the air caused by fire impedes the use of technology.
Senses: Barriers related to perception through hearing, vision, touch, and smell.	Hearing	Unambiguous
	Smell	Unambiguous
	Touch	Unambiguous
	Vision	Unambiguous
Mobility difficulties		Inability to move freely and use hands to operate technology.

Technological barrier		Definition
Poor software design: The software is designed in a manner that impedes its usefulness for attaining SA. This includes a low degree of usability and poor functionality.	Inefficient user interface	The user interface is designed unfavorably for acquiring or providing information quickly and efficiently, or for completing other tasks related to attainment of SA.
	Complexity creep	Systems with too many features make it difficult for a person to develop an accurate mental model of how the system works (Endsley et al., 2003).
	Inadequate functionality	Functionality that currently exists in the system is flawed and impedes the attainment of SA.
	System access issues	Problems that arise when accessing the systems, increasing the time it takes to start using the system.
	Lack of salience	Important information does not get highlighted.
Physically arduous to operate		The technological device has a poor physical device design that does not accommodate and adapt to user needs, resulting in difficulties in operating the technology to attain SA.
Coverage and network problems		Technology loses coverage or network connection, causing disruptions or discontinuation of communication.
Missing functionality		Technology lacks functionality that would have been helpful for attaining SA.
System failure		A system failure can occur because of a hardware failure or a severe software issue, causing the system to freeze, reboot, or stop functioning altogether (Computer Hope, 2021).
Excessive technology		Unnecessary technology that does not increase SA, but on the contrary becomes a liability for attaining SA.
Hardware Limitations: Barriers related to the tangible components of technology that could compromise or terminate its usage.	Poor audio	Poor sound quality caused by audio components in the technology.
	Fragile hardware	Technology is not adapted to endure harsh conditions and becomes damaged or unusable.
	Battery time	Technology runs out of power because of too low battery capacity.

APPENDIX C – Participant consent form (In Norwegian)

Vil du delta i forskningsprosjektet
Barrierer ved bruk av teknologi i krisesituasjoner?

Dette er et spørsmål til deg om å delta i et forskningsprosjekt hvor formålet er å finne hvilke barrierer som kan oppleves i krisesituasjoner, som gjør det vanskelig å få god situasjonsforståelse gjennom bruken av teknologi. I dette skrivet gir vi deg informasjon om målene for prosjektet og hva deltakelse vil innebære for deg.

Formål
Vi skriver masteroppgave om barrierer ved bruk av teknologi i krisesituasjoner eller nødsituasjoner. Hensikten er at det vi finner ut kan brukes til å lage bedre systemer som legger til rette for disse barrierene, spesielt i de situasjonene og kontekstene de brukes. Med barrierer så mener vi det som kan gjøre det vanskelig å få en forståelse av situasjonen gjennom å bruke teknologien. Det kan være fysiske, kognitive eller tekniske årsaker som kan stå bak. For eksempel hvis det er mye røyk så det blir vanskelig å se, hvis man er stresset, eller hvis det ikke er dekning. I intervjuet vil visnakke om bakgrunnsinformasjon, bruk av teknologi for å få situasjonsforståelse, opplevelse av barrierer, og til slutt litt refleksjon rundt det vi har snakket om.

Prosjektet gjennomføres i sammenheng med masteroppgaven vår.

Hvem er ansvarlig for forskningsprosjektet?
Universitetet i Agder, Fakultet for samfunnsvitenskap / Institutt for informasjonssystemerer ansvarlig for prosjektet.

Hvorfor får du spørsmål om å delta?
Vi ønsker at du vil delta fordi du har erfaring med bruk av teknologi i krisesituasjoner, nødssituasjoner eller lignende situasjoner som er relevant for det vi ønsker å finne ut av. Rekruttering skjer gjennom eget personlig nettverk, CIEM (Center for Integrated Emergency Management) sitt nettverk og snøballmetoden (spør de som intervjuer om de kjenner noen flere vi kan intervjue).

Hva innebærer det for deg å delta?
Beskriv metode (spørreskjema, intervju, observasjon etc.), omfanget, hvilke opplysninger som samles inn og hvordan opplysningene registreres (elektronisk, notater, lyd-/videoopptak), f.eks.:

- «Hvis du velger å delta i prosjektet, innebærer det at du blir med på et intervju hvor vi spiller inn lyd og video. I intervjuet vil vi snakke om bakgrunnsinformasjon, bruk av teknologi for å få situasjonsforståelse, opplevelse av barrierer, og til slutt litt refleksjon rundt det vi har snakket om. Det er antatt at intervjuet vil vare i 30 –45 minutter.»

Det er frivillig å delta

Det er frivillig å delta i prosjektet. Hvis du velger å delta, kan du når som helst trekke samtykket tilbake uten å oppgi noen grunn. Alle dine personopplysninger vil da bli slettet. Det vil ikke ha noen negative konsekvenser for deg hvis du ikke vil delta eller senere velger å trekke deg.

Ditt personvern –hvordan vi oppbevarer og bruker dine opplysninger

Vi vil bare bruke opplysningene om deg til formålene vi har fortalt om i dette skrivet. Vi behandleropplysningene konfidensielt og i samsvar med personvernregelverket.

- Vi som skriver masteroppgaven (*Sindre Broby Foss* og *Kirsti Nesse*) og veilederne våre (*Terje Gjøsæter* og *Jaziar Radianti*) er de eneste som vil ha tilgang til dataen vi samler inn.
- For å sørge for at ingen uvedkommende får tilgang til personopplysningene dine, vil vi slette lyd- og videoopptak med en gang det har blitt transkribert. Det transkriberte dokumentet vil bli lagret i OneDrive som forvaltes av Universitetet i Agder.

Hvis du deltar i intervjuet vil du ikke kunne identifiseres gjennom de opplysningene du gir ved publikasjon.

Hva skjer med personopplysningene dine når forskningsprosjektet avsluttes?

Prosjektet vil etter planen avsluttes når prosjektet er godkjent. Dette vil være rundt juni 2023. Etter prosjektslutt vil datamaterialet med dine personopplysninger anonymiseres. Datamaterialet som samles inn vil bli anonymisert ved at det slettes når prosjektet er ferdig. Lyd og video slettes allerede når alt er transkribert.

Hva gir oss rett til å behandle personopplysninger om deg?

Vi behandler opplysninger om deg basert på ditt samtykke.

På oppdrag fra Universitetet i Agder, Fakultet for samfunnsvitenskap / Institutt for informasjonssystemer har Personverntjenester vurdert at behandlingen av personopplysninger i detteprosjektet er i samsvar med personvernregelverket.

Dine rettigheter

Så lenge du kan identifiseres i datamaterialet, har du rett til:

- innsyn i hvilke opplysninger vi behandler om deg, og å få utlevert en kopi av opplysningene
- å få rettet opplysninger om deg som er feil eller misvisende

- å få slettet personopplysninger om deg
- å sende klage til Datatilsynet om behandlingen av dine personopplysninger

Hvis du har spørsmål til studien, eller ønsker å vite mer om eller benytte deg av dine rettigheter, ta kontakt med:

- Universitetet i Agder, Fakultet for samfunnsvitenskap / Institutt for informasjons-systemer med:
  - Veileder: Terje Gjøsæter, terje.gjosater@uia.no
  - Student: Sindre Broby Foss, FossSindre@gmail.com.

Vårt personvernombud: Trond Hauso, Personvernombud@uia.no

Hvis du har spørsmål knyttet til Personverntjenester sin vurdering av prosjektet, kan du ta kontakt med:
Personverntjenester på epost (personverntjenester@sikt.no) eller på telefon: 53211500.

Med vennlig hilsen

Terje Gjøsæter (Forsker/veileder) **Sindre Broby Foss**

Terje Gjøsæter Sindre Broby Foss

Samtykkeerklæring

Jeg har mottatt og forstått informasjon om prosjektet *Barrierer ved bruk av teknologi i krisesituasjoner* og har fått anledning til å stille spørsmål. Jeg samtykker til:

□ å delta i intervju

Jeg samtykker til at mine opplysninger behandles frem til prosjektet er avsluttet

----

(Signert av prosjektdeltaker, dato)