Situation Awareness in Disaster Management:

A Study of a Norwegian Collaboration Exercise

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May 2014

Acknowledgments

We would like to thank our supervisor Thomas Hoff for his feedback and guidance throughout this year, from the idea to the resulting product. A special thanks goes to Kjell Ivar Øvergård for inviting us to his kitchen and providing valuable insights to the data analysis.

Thanks to BRIDGE and the SINTEF team for the opportunity to participate in the project and to do research on a Norwegian collaboration exercise. We would especially like to thank Ida Maria Haugstveit, Jan Håvard Skjetne and Aslak Eide for their contributions.

Much appreciation goes to the tactical and incident commanders who found the time in their busy schedules for the interviews, as well as to the emergency personnel who responded to the questionnaire.

We are grateful to Pål Lystad, who prior to the exercise, gave us the opportunity to experience emergency response in Oslo, and to prepare us for the large-scale exercise to come.

Thanks to our fellow students for academic and social support during this year. Especially thanks to Sasan Zarghooni for sharing his expertise in human factors, and to Katrine Håkensen for help with back-translating the questionnaire.

Last, but not least, we are eternally grateful to our families and closest friends for keeping up with us during this year. In addition, we would like to thank each other for the excellent collaboration, academic discussions and for pushing each other's boundaries during the past year.

Oslo, May 2014

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Abstract

Managing disasters is a complex and dynamic task. Collaboration between emergency agencies is commonly reported to be the weakness in disaster mitigation. The purpose of this article is to explore situation awareness (SA) in relation to ICT-use, expertise, and workload, factors that are previously found to influence SA. The online questionnaire used to gather data in a Norwegian collaboration exercise setting consisted of SART, NASA-TLX, and demographical questions. The data analysis revealed that task/system factors, such as the use of multiple ICT-devices and in particular the use of mobile phone, were associated with higher SA in the present exercise. Expertise, which is an individual factor, did not reveal any connection to SA. Further, the role of respondents was found to be a moderating factor in the relationship between SA and workload. The results of this study provide an insight in the field of disaster management and contribute to an increased understanding of the interaction between SA, ICT-use, expertise and workload in this domain.

Situation Awareness in Disaster Management: A Study of a Norwegian Collaboration Exercise

Disaster mitigation has been a persevering topic for a long time (std.meld. nr. 29 (2012-2013), 2014). The local terrorist attack at Oslo and Utøya (2011) and other international catastrophes (e.g. the Indian Ocean earthquake and tsunami in 2004 and the Deepwater Horizon explosion in 2010) render research in this area highly relevant. There is no universally accepted definition of term disaster, and terms like *disaster*, *crisis* and *emergency* are often used interchangeably (Shaluf & Said, 2003). According to Boin and Hart (2010), all these terms refer to a large-scale, threatening, urgent and uncertainty-filled disruption of the status quo in a community or organisation. The United Nations Global Assessment Report on Disaster Risk Reduction from 2013 states that economic losses from disasters during the last three years have soared past $100 billion (UNISDR, 2013). Ultimately, disaster management is not only about reducing the cost of disasters; it is about saving lives and contributing to a safe society. As stated by Waugh and Streib (2006): "modern disaster management presents a paradox: on one hand, emergency response requires meticulous organisation and planning, but on the other hand, it is spontaneous" (p.132). Research on disaster management is essential in order to find solutions for disaster mitigation that take into account this paradox, as well as accumulate knowledge and lessons learned from previous disruptions.

Disaster management is often characterized by a shared authority, dispersed responsibility, and resources that are scattered across large geographical areas. Achieving situation awareness has repeatedly proved to be a critical commodity in collaborative environments (Bolstad & Endsley, 2003, Shu and Furuta 2005, Stanton, Salmon, Walker, & Jenkins, 2009). *Situation awareness* (SA) is a term given to the level of awareness that an individual has of a situation, or merely the understanding of "what's going on" (Endsley, 1995b). Maintaining SA is often a key to success, especially in dynamic situations that require rapid decision-making. Failure to achieve SA can lead to catastrophic events such as the USS Vincennes accident (Endsley, 1995b), where an Iranian civilian passenger aircraft was shot down by an American missile cruiser. The decision maker in this accident made a correct decision (if hostile, warn off and then shoot down if warning is ignored), yet his SA was poor, which contributed to an incorrect perception of the incoming aircraft as hostile.

Efficient disaster mitigation is dependent on collaboration between people from the emergency rescue services, voluntary organisations, actors from the industry, municipality, and external expert organisations. Collaboration includes working to achieve common goals, and all types of collaboration include information sharing between the involved parties (Robinson & Gaddis, 2012). Reports from recent disasters suggest poor collaboration between emergency rescue agencies (NOU: 2012: 14). As identified in previous research, multi-agency collaboration can be improved by focusing on three aspects: establishing and maintaining shared SA, efficient communication across emergency agencies, and achieving adequate organizational understanding (Eide, Haugstveit & Halvorsrud, 2012).

The term *situation awareness* is seemingly easy to comprehend; it refers to the degree of a person's awareness or understanding of the situation. Research on the topic identifies many mechanisms in apprehending a given situation that are not easily accounted for (Garbis & Artman, 2004). Different external and internal factors influence the achieving and maintaining SA (Endsley, 1995b). Vaitkunas-Kalita, Landry and Yoo (2011) have discovered large differences in the use of the term *situation awareness* by scientific users and non-professionals. Consequently, many attempts to define, explain and measure SA have taken place, and no unified and consensual theory has been established.

The aim of the current paper is to explore SA in disaster management through factors that influence SA, based on a Norwegian collaboration exercise. A summary of the SA research field will be followed by the presentation of the factors that influence SA, which will be summarized and then tested empirically.

Theoretical Approaches to SA

SA has become a popular term within academic circles since the 1990s. Significant research contributions on SA have been made to the following domains: safety (Jackson, Chapman, & Crundall, 2009; Stanton, Walker, Young, Kazi, & Salmon, 2007), automation (Merat, Jamson, Lai, & Carsten, 2012; Parasuraman, Sheridan, & Wickens, 2008; Stanton & Young, 2005), aviation (Lancaster & Casali, 2008), air traffic control (Remington, Johnston, Ruthruff, Gold, & Romera, 2000; Sethumadhavan & Durso, 2009), military (Bryant & Smith, 2013); and healthcare (Luz et al., 2013; Wauben et al., 2011). SA originated in the military research during World War I (Stanton, Chambers, & Piggott, 2001), and has become one of the key factors in contemporary disaster management (Hagen, Poudyal Chhetri, & Steiner, 2013).

According to Stanton, Salmon, Walker, and Jenkins (2010), SA can be assessed through the lens of three different schools of thought. A psychological approach refers to SA as something residing "in-mind" of an individual. An engineering approach refers to the phenomenon as situated 'in-world' (e.g. in displays and measurement tools). At last, an "in-

interaction" approach combines the fields of human factors and ergonomics, and claims that SA is the result of an interaction between an individual and its environment. Each of these disciplines places a different emphasis on the concept of what SA is and how it manifests itself. Furthermore, SA can be assessed on a different levels of analysis; an individual- or a group-level of analysis.

Individual SA. Endsley (1988) advocates the "in-mind" approach and defines SA as "the perception of the elements in the environment within a volume of time and space, the comprehension of their meaning and the projection of their status in the near future" (p. 97). SA is understood as a product of a situation assessment, which is a three level process incorporated in the cognitive processing of an individual (see figure 1). Endsley's three-level model consists of perception (e.g. perceive smoke), comprehension (understand its meaning) and projection (predict future outcomes of the action) (Endsley, 1995b). The model has its theoretical foundation in information processing theory and the recognition-primed decision (RPD) model (Klein, Calderwood, & Macgregor, 1989). The basic mechanisms that constitute SA are short-term sensory memory, perception, working memory, and long-term memory. The organisation of long-term memory is based on mental models, which are defined as "the mechanisms whereby humans are able to generate descriptions of system purpose and form, explanations of system functioning and observed system states, and predictions of future system states" (Rouse & Morris, 1986, p.7-8). It is evident that the definition of SA is highly based on the definition of mental models.

SA is affected by a person's goals and expectations, which influence the direction of attention, the information perception and interpretation (Endsley, 1995b). The model shows that external and internal factors influence situation assessment, decision-making, and performance of action. SA is influenced by external factors, such as workload and system design, and internal factors, like goals, preconceptions and experience. The combination of these factors influences the consequent decision-making and the resulting action.

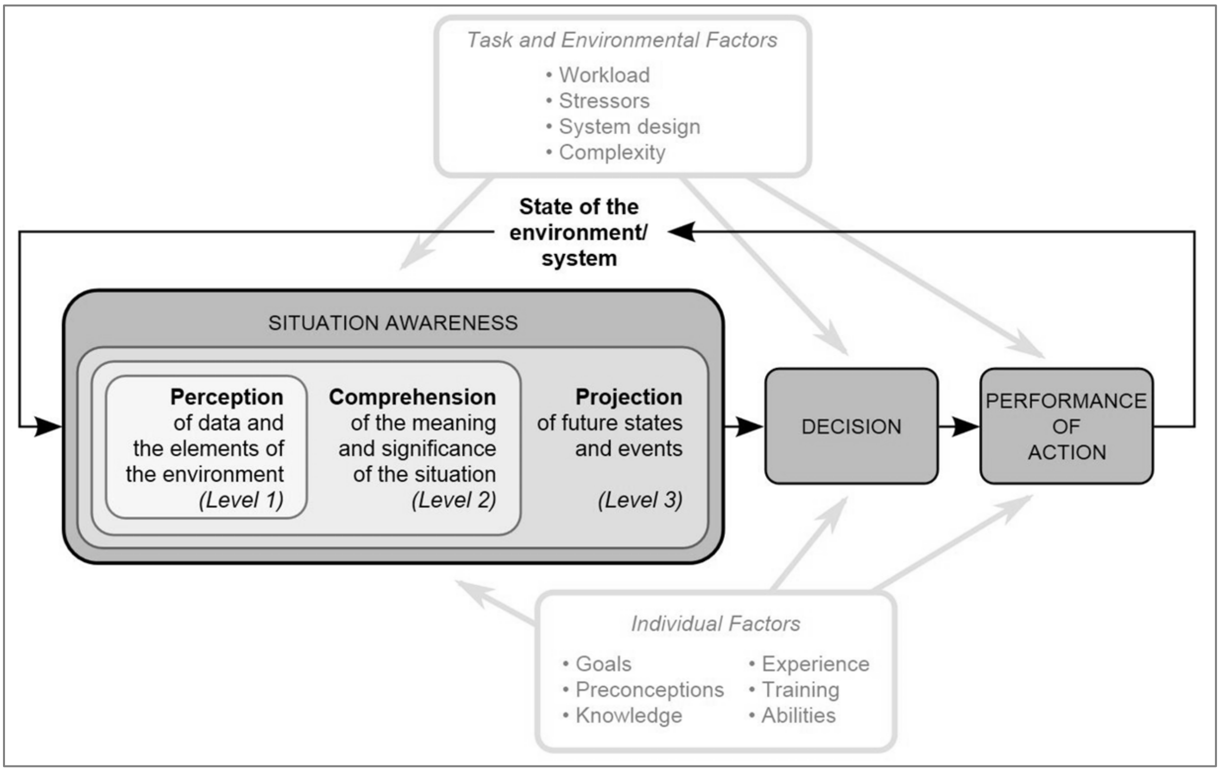

Figure 1. Model of SA in dynamic decision-making (adaptation from Endsley, 1995b).

The presented model has its shortcomings. It defines SA as a *product*, separate from the process of achieving SA, nonetheless the three stages that are described in the model, e.g. perception, understanding and projection, are *processes* involved in development of SA. Thus, the distinction between SA as a product or a process can be vague. Further, the model is based on mental models, which similarly to SA is an abstract construct, making it difficult to operationalise and measure SA. According to Parasuraman et al. (2008), mental models support SA, but are a distinct construct from SA. Next, Salmon, Stanton, Walker, Jenkins, and Rafferty (2010) suggest that the level three – projection, can be reached without going through the preceding levels. The RPD model (Klein et al., 1989) can explain this objection where the decision-maker projects the future events based on his or her previous experience, even if the decision-maker cannot account for this process. Despite this critique, the three-level model provides a comprehensible framework for measuring and accounting for the basis of decision-making.

Bedny and Meister's (1999) activity theory model represents another model of SA. This model combines consciousness and diverse "in-world" activities, and takes the process approach to SA. They propose that the extent to which information-processing methods are involved in achieving SA is dependent on the nature of the task and the goals of the individual. Furthermore, Smith and Hancock's (1995) perceptual cycle model advocates the combination of process and product approach and views SA as an "in-interaction" between the human and the world. Hence, this approach focuses on the dynamic nature of SA and merges continuous sampling of the world (process) with the updating of the world model at any given point in time (product).

Although all three models appear to have some element of truth, none of them gives a complete explanation of SA (Sorensen, Stanton, & Banks, 2011). Endsley's three-level model is so far the most developed approach, both in terms of measurement and application, despite some controversy about the underpinnings of the model (Stanton et al., 2001). A general assumption within this approach is that achieving a higher SA is the ultimate goal in all situations (Endsley, 1995b).

The most frequently used measurement tools for the individual level of SA analysis comprise of freeze-probe techniques where the task is briefly interrupted in order to administrate SA related queries, and subjective rating techniques where either the task performer or a subject matter expert is asked to rate their own SA (see method section). Performance measures are also frequently used, but a number of problems concerning the relationship between SA and performance affect these measures. As stated by Endsley (1995b) "although good SA will increase the probability of good performance but cannot guarantee it" (p.40).

Group-level SA. The formerly presented models represent primarily an individual level of analysis, with the three-level model as the most recognized so far. In group-SA research, no consensus exists on whether group SA is best understood as the sum of the individual SAs, or if a system approach is better suited where team interaction becomes prevalent as well. Several attempts have been made to explain group SA, but still, extensive debates exist around the concept, and none of the approaches includes a solid tool for measuring group SA (Gorman, Cooke, & Winner, 2006; Patrick & Morgan, 2010; Salmon, Stanton, Walker, & Green, 2006). The major approaches to group-oriented SA are team SA, shared SA, distributed SA, and compatible SA. The distributed SA approach has received most acknowledgements so far, despite its lack of proper measurement tools (Salmon et al., 2008).

Team and shared SA. Team SA is a multi-dimensional construct consisting of individual SA-contributions, whereas shared SA is the part of SA, which is overlapping between team members. Although it is tempting to aggregate the individual team-members' SA together to provide a representation of team SA, as proposed by Kaber and Endsley (1998), it has been argued widely that team SA is more than the sum of its parts (Salas, Prince, Baker, & Shrestha, 1995; Salmon, Young, & Cornelissen, 2013). In order to organise this construct, Salas, Cooke, and Rosen (2008) suggest that team SA comprises of individual SA and team processes. Shared SA implies that every group member understands a given situation in the same manner. This approach is based on the notion that the group members possess “a shared mental model” which helps them to form accurate explanations and expectations, coordinate their actions and adapt their behaviour (Jonker, van Riemsdijk & Vermeulen, 2011).

Distributed and compatible SA. Distributed SA (DSA) involves different agents, including non-human agents, with different views of the situation on the same scene. Together, it is expected that the group’s DSA is more than what individual analyses can account for (Stanton et al., 2006). DSA is different to team SA, and is assessed in a system perspective. DSA is defined as “activated knowledge for a specific task, at a specific time within a system” (Stanton et al., 2009, p.51). As an extension of Endsley’s three-level model, distributed SA sees a group as “one individual”. In this case the perception phase within one individual (perceive smoke) triggers the comprehension phase in a different person (call for emergency), which again triggers the projection phase in the last person (incident commander arrives and sees possible outcomes of the situation). According to Stanton et al. (2006), each agent within a system holds their own SA, which may be very different from, although compatible with, that of other agents.

The key difference between existing team SA models (e.g. Salas et al., 1995; Endsley & Robertson, 2000) and the approach described by Stanton et al. (2006) relates to the issue of shared vs. compatible SA and the treatment of SA as a system level phenomenon. The DSA is considered to be something more than the sum of each individual`s SA.

The individual measurement techniques described earlier cannot assess group level SA, as these focus solely on the awareness ‘in-the-head’ of an individual. The measurement tool that is proposed to measure DSA is *propositional networks* (Stanton, Salmon, Walker, Baber & Jenkins, 2005). This technique represents a network of information nodes and their interconnections based on observational or verbal transcript data of a team in action. This measurement method is criticised for lack of validation, lack of adequate assessment of individual SA processes, and restriction to only post-task measurement possibilities (Salmon et al., 2008). Moreover, specific software is required in order to analyse propositional networks.

All of the presented models cover important aspects of SA. The two most renowned models are based on Endsley’s (1995b) theory of SA in dynamic systems and the distributed

SA-theory of Stanton et al. (2006). The former is easy to operationalise because of its discrete levels of SA (Kaber, Perry, Segall, McClernon, & Prinzel III, 2006), whereas the latter is dependent on the knowledge activated by various cognitive, behavioural and system components, and because of that it is difficult to operationalise and measure (Sorensen et al., 2011).

Next, we will turn to the review of the factors that the prevailing research claims to be influencing SA.

Factors Influencing SA in Disaster Management

Disaster management is recurrently associated with varying complex tasks (Durso, Rawson, & Girotto, 2007) and collaboration between different agencies (Manoj & Baker, 2007; Smith & Dowell, 2000), both influencing individual and group SA. Poor resource management can be a liability in disasters where time and resources are scarce. Knowledge about factors that influence SA is valuable in disaster management. Following is a review of how ICT-use, expertise, and workload influence SA. These factors are believed to influence SA as either a task- and environmental factor or an internal factor, according to the three-level model (Endsley, 1995b).

ICT-use. Many different parties are required to collaborate in large-scale operations, such as disaster management. In emergency collaboration, most of the communication is bound to take place via information communication technology (ICT) as the involved agencies are often located over a large geographical area. ICT, such as radio or mobile phones, supply users with less information than face-to-face communication because the implicit information like body language and environmental cues are left out (Sonnenwald, Mclaughlin, & Whitton, 2004). Thus, SA may be positively affected by including a more realistic view of the situation (Endsley, 1995b). By incorporating SA in the design of ICT that is used in disaster management, collaboration can be more effective and efficient (Nickerson, 2011).

The way information is presented has a direct link to SA (Sauer et al., 2002; Thomas & Wickens, 2006). A pilot study found that audio transmitted information was preferred over graphical visualised information, as it would require too much attention to keep track of the monitor, but this relationship was true only in novel situations (Lancaster & Casali, 2008). Additionally, the design of the displays influences the achieving of SA (Sauer et al., 2002; Thomas & Wickens, 2006). The choice of either presenting the information visually or auditory is an important decision in the design of ICT.

Bolstad and Endsley (2003) advocate that the use of domain specific communication tools is the best alternative in order to support collaborative processes such as planning, tracking information, brainstorming, data gathering/distribution and shared SA. Domain specific tools are tools that are highly customized according to the specific tasks of the team and their information needs. Incident commanders who are not trained in using the appropriate ICT-devices can fall back to known behavioural patterns, resulting in utilizing less efficient, but familiar devices (Gilovich, Griffin & Kahneman, 2002). This phenomenon, where individual cognitive processes (either conscious or unconscious) ignore part of the information is referred to as heuristic decision-making (Gigerenzer & Gaissmaier, 2011).This may be detrimental to team member`s SA as essential information is left out from “rational” decision-making.

An important aspect is *if* and *how* the ICT-devices are used. According to Endsley (1995b), the ICT should promote shared understanding of the situation, e.g. team members who share displays with same information. On the other hand, Stanton et al. (2009) advocate that every person sees the situation differently; ergo ICT should reflect the individual variability, yet it is not clear how individual requirements can be supported by the design of ICT.

The last section has presented the state of current research on SA and ICT-use. The emphasised aspects in relation to SA are the choice of auditory or visual stimuli use in ICT-design, the use of domain specific tools vs. general-purpose tools, and familiarity of the accessible ICT-devices.

Expertise. Subject Matter Experts (SMEs) show consistently higher SA scores than laypersons (Chauvin, Clostermann, & Hoc, 2009; Fowlkes, Salas, Baker, Cannon-Bowers, & Stout, 2000; Stanton et al., 2006; Stanton et al., 2009). Experimental evidence suggests that anticipating the consequences of actions, consistent with Endsley’s third level of SA, is central to pilot expertise as well as to other task domains (Doane, Sohn, & Jodlowski, 2004). Next, it is argued that SA is determined by a generic declarative knowledge built from experience (Rousseau, Tremblay, Banbury, Breton, & Guitouni, 2010). Patrick, James, Ahmed, and Halliday (2006) argue that poor SA scores can be interpreted as a person’s failure to perform the task of achieving SA satisfactorily, or a person’s lack of the necessary awareness or knowledge on that matter. In short, expertise of SMEs is often presented as a function of their knowledge and experience in their respective fields.

Personnel working in disaster mitigation represent many types of SMEs in an emergency domain. A criterion for becoming an incident commander is having extensive emergency response-experience (PBS 1, 2011). Both leaders and operative personnel are trained to acquire necessary knowledge and expertise through education and hands-on experience to be able to perform their job. Previous research (Eid et al., 2004) indicates that not only the expertise of leaders has an effect on operative personnel's SA, but also their ability to lead and convey their knowledge to others, and their ability to adapt to new situations.

To summarise, expertise influences the way SA is achieved. As mentioned previously, the individual SA construct is based on mental models, which develop over time, as the operator becomes more experienced in his or her domain. Consequently, emergency personnel with more working experience should be able to achieve a higher SA than personnel with less experience, with less mental workload imposed by this process.

Workload. One of the factors often investigated in conjunction with SA is workload, which is defined as "the cost of accomplishing task requirements for the human element of a human-machine system that may result in subjective discomfort and reductions in performance or physiological reactions" (Hart & Wickens, 1990). A number of researchers have found that the relationship between workload and SA is not straightforward (Vidulich & Tsang, 2012; Wickens, 2002; Wickens, 2008). Some researchers argue that a higher level of workload is associated with decreased SA (Alexander & Nygren, 2000; Won, Condon, Landon, Wang, & Hannon, 2011). On the other hand, Endsley (1993) suggests that specific situations can consist of high workload and high SA, as well any other combination. As indicated by Perry, Sheik-Nainar, Segall, Ma, and Kaber (2008) there is a workload threshold below which SA can be achieved effectively and consistently, and above which SA begins to degrade. The study advocates that some level of workload may be tolerable or even beneficial with respect to achieving and maintaining SA in planning tasks.

Workload is affected by ICT-use. A performance study of aircraft pilots indicated an increased workload and almost perfect SA when using textual data on displays compared to speech alone (Lancaster & Casali, 2008). Another study found that its participants won fewer games with eight aiding-robots compared to only four; indicating SA loss due to increased workload, caused by the cognitive effort of controlling more robots and task switching (Squire & Parasuraman, 2010). Subsequent research has also found similar results (Chen & Barnes, 2012). These results indicate that more resources do not necessarily lead to less workload and higher SA, and that other factors are contributing to this relationship.

Several studies have shown that there are confounding variables regarding the relationship between SA and workload, e.g. performance (Sebok, 2000) and level of automation (Wickens, 2008). In addition, Won et al. (2011) argues that this relationship could be influenced by the role possessed by an individual in team-based operations.

The Present Study

The purpose of this study is to empirically test if ICT-use, expertise and workload influence SA in disaster management process, as proposed by the theoretical review of these variables. The present study is based on an emergency collaboration exercise, which took place in September 2013 on the South-West coast of Norway. The presentation of hypotheses regarding SA and the three presented factors, ICT-use (H1), expertise (H2) and workload (H3) will follow.

As stated earlier, research shows that auditory ICT-devices are preferred to visual devices under unfamiliar or stressful situations, such as disaster management. Also, it is argued that a combination of both auditory and visual ICT-devices would benefit SA. According to these notions, the following hypothesis is formulated:

H1A: Respondents who use both auditory and visual ICT-devices will have higher SA than respondents using only one type of device.

Stanton et al. (2006) argues that SA is distributed across both human and non-human agents. More information nodes, in form of ICT, provide more information, which relieves human operators from remembering this information at all times. The following hypothesis will explore the use of multiple ICT-devices and SA:

H1B: Use of multiple ICT-devices will be associated with higher SA than use of none or only one ICT-device.

As previously discussed, Bolstad and Endsley (2003) argue that specific types of collaborative tools are better suited for supporting collaborative processes than others. Based on this, the following hypothesis is formulated:

H1C: Domain specific tool-use during the exercise will be associated with higher SA than use of any other device.

Previous research shows consistently that experts tend to have higher SA due to their extensive knowledge and experience in their domain. Emergency response workers are required to have adequate education and training in order to perform their job. The number of years of work experience emergency personnel have in the emergency domain is assumed to differentiate between their expertise. Hence, the following hypothesis is formulated:

H2: Respondents who have longer work experience in emergency response will be associated with higher SA.

There is no consensus on the relationship between SA and workload, but most researchers seem to agree that high workload conditions would lead to degraded SA. As the acute phase of disaster management is often associated with high workload, the following hypothesis is stated:

H3A: Respondents who report high workload will be associated with low SA.

At last, as previously assumed by Won et al. (2011), the role of team members may moderate the relationship between SA and workload. According to the emergency response structure (see method), the participants of the exercise can be divided into operative personnel and leaders, representing both tactical and operational levels. The following hypothesis will explore this notion:

H3B: The relationship between SA and workload will be moderated by the role of the participants.

Method

Data for this project was collected by two master-degree students from the Department of Psychology at the University of Oslo, participating in the BRIDGE-project as a part of the SINTEF Human-Computer Interaction team. The data was collected during observation of a collaboration exercise, along with after-the-fact group interviews and an online questionnaire. The subsequent data analysis was based on the data from the online questionnaire.

The Collaboration Exercise

A large collaboration exercise was arranged as a part of the BRIDGE (Bridging resources and agencies in large-scale emergency) project during the fall of 2013. This project works towards improving disaster and emergency management through developing technological and organisational solutions. The ultimate goal of BRIDGE is to improve the safety of the population by developing technical and organizational solutions that significantly improve disaster and emergency management in the EU Member States (http://www.bridgeproject.eu). The exercise was a full-scale operation where police-, fire-, and emergency rescue departments along with other rescue agencies and voluntary organisations from the Norwegian South-West coast collaborated in order to prevail fictitious terrorist- and explosive threats. Approximately a hundred casualties had to be attended to at three different locations during the exercise.

Throughout the exercise, an advanced communication technology (ACT) designed by a Norwegian research organisation was applied. ACT focuses on improved information visualisation and interaction among central actors in the emergency response, in order to support their common operational picture. This is achieved by presenting three types of information: information about the incident, about the response, and information from external services. The information is then distributed across tablets, PC's and a touch sensitive table situated at the incident command outpost. According to this description, ACT is a domain specific tool in the present emergency response.

Emergency Response in Norway

Emergency response agencies in Norway are organised in three levels of command: the strategic level, the operational level, and the tactical level. The strategic level is represented by administrative executives who carry political responsibility. They make long-term decisions, and provide guidance to the public and the participants of the response teams. The operational level consists of emergency centrals, which are in charge of allocating resources in their designated geographical area. The first responders on-site constitute the tactical level of command. They use their professional expertise to address the threat, minimise the consequences and provide immediate relief. The first responders report to their respective tactical leaders, which represent a connection between operational and strategic levels, and have a decision authority on-site. During disaster management, all three levels have to communicate in order to achieve common SA and effective collaboration.

Emergency management is set to revolve around the incident command outpost (see figure 2). Operative personnel from each emergency department have to report to their respective tactical leader, who then communicates the information across the emergency departments. The tactical leaders are a part of the incident command outpost, and work together with the incident commander, who has close communication with the operational commander (112 – central). The appointed incident commander is usually an experienced police officer who has the tactical responsibility of the emergency response team on-site.

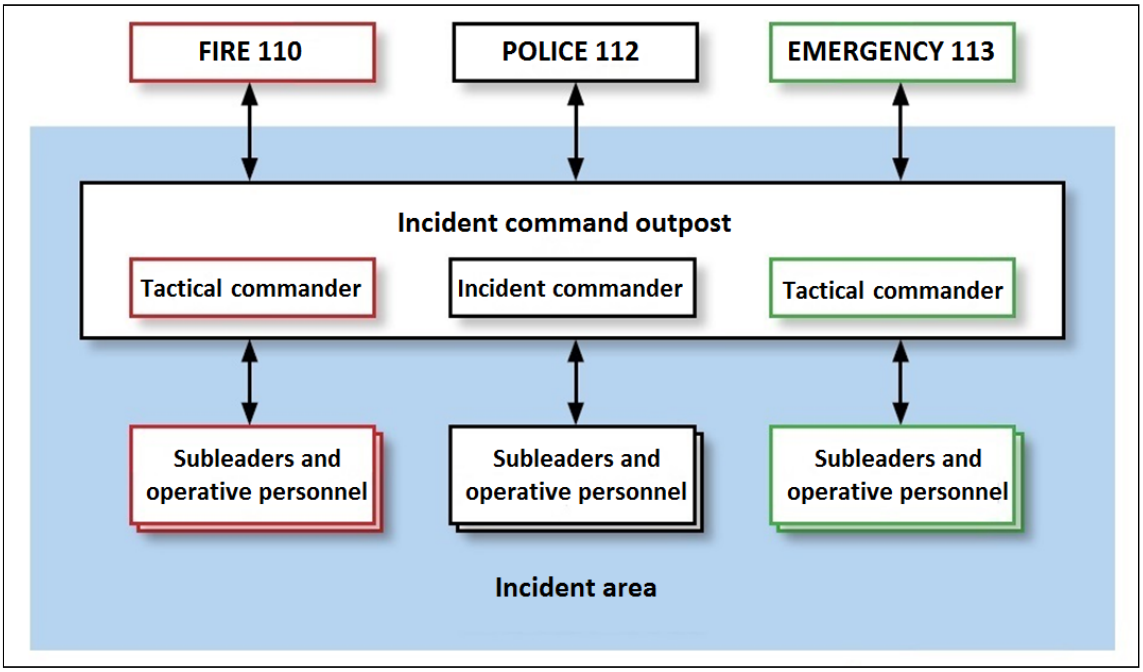

Figure 2. Depiction of emergency response management on-site (PBS 1, 2011).

Preparing Data Collection

The aim of the data collection was to achieve sufficient information regarding individual SA, workload, participant's role, experience, and ICT-use during the exercise. This was accomplished by using the Situation Awareness Rating Technique (SART) (Taylor, 1990), NASA Task Load Index (NASA-TLX) (Hart & Staveland, 1988) and supplemental questions regarding the respondents' ICT-use, years of working experience and role during the exercise.

SART is a ten-item multidimensional measurement tool that is one of two validated SA measurement techniques (Salmon et al., 2006). It is a subjective self-reporting postoperative measure. The second technique is SAGAT (Endsley, 1995a), which uses a freeze-probe technique to measure SA during simulation exercises. SART was the preferred tool for measuring SA, because it has proven to be a better choice in dynamic situations (Salmon et al., 2009). In addition, SAGAT requires interruptions of the exercise, which was undesired in the present case.

SART is based on a SA model that consists of three dimensions: demand (D), supply (S) and understanding (U) (Taylor, 1990), and is calculated by the equation SA = U – (D – S). Taylor (1990) states that SA depends on the respondent's understanding (U) (e.g., quality and quantity of the information she receives) of the situation, and the difference between the demand (D) (e.g., complexity of operation) and the available supply (S) (e.g., ability to concentrate). When demand exceeds supply, there is a negative effect on understanding and an overall reduction of SA.

SART consists of ten questions that are answered on a semantic differential scale, ranging from 1 to 7. An example question used in the questionnaire is: "*how much mental capacity do you have to spare in the situation? Do you have sufficient to attend to many variables (7) or nothing to spare at all (1)?*".

In order to assess workload, NASA-TLX (Hart & Staveland, 1988) was chosen as it is the most commonly used and the most widely validated of the various tools available for measuring workload (Salmon et al., 2006). NASA-TLX consists of six items measuring different aspects of workload on a 100-points scale ranging between high and low. The second part of TLX intends to create individual weightings of the six subscales, which is performed by asking the respondents to make 15 paired comparisons between the subscales, based on their importance. An example of a question from NASA-TLX is: "*How much time pressure did you feel due to the rate or pace at which the tasks or task elements occurred? Was the pace slow and leisurely or rapid and frantic?"* NASA-TLX is, like SART, also a subjective self-reporting postoperative measure.

Adaptation of the Questionnaire

Some alterations to the mentioned instruments were necessary in order to measure SA and workload efficiently at the exercise. First, SART was translated to Norwegian while a translated version of NASA-TLX was already available. Biographical data such as age, education, role, and department were included for controlling purposes during the subsequent analysis. The questionnaire was distributed via the web-based service EasyQuest. Due to formatting restrictions in EasyQuest, both SART and NASA-TLX were presented on a semantic differential scale, ranging from 1 to 7. Time is a limited resource for emergency response personnel, therefore weighting of NASA-TLX was omitted in order to minimise the time it took to complete the questionnaire. This choice was based on the notion of Moroney, Biers, Eggemeier, and Mitchell (1992) who advocate that the use of unweighted NASA-TLX scores is adequate when time is scarce. Please see appendix E for the full-scale version of the online questionnaire used in this study.

The questions in SART refer to a specific critical situation. Due to this, a common critical situation during the exercise for all three emergency response departments had to be defined before distributing the questionnaires. This was achieved by group-interviewing incident- and tactical commanders from the different departments the day after the exercise.

The steps from a Critical Incident Technique (CIT) (Flanagan, 1954, see table 1) were executed during the interviews. Specific probes were generated beforehand, based on the observation of the exercise (see appendix C). The aim of the group interviews was to achieve consensus between the participants about what the most critical situation actually was.

Table 1
Critical Incident Technique (Flanagan, 1954)

	Steps of Critical Incident Technique
1.	Select the incident to be analysed.
2.	Gather a description of the incident in question, from beginning to end.
3.	Construct a timeline of the incident.
4.	Select the most critical situation during the incident.
5.	Probe the selected situation with specific probes generated beforehand.

The CIT technique can be used both on the individual and team level. Group interviews were selected in order to ensure that one specific department would not focus on the situations relevant for their own department, reducing subjective selection of the most critical situation.

Validity and Reliability

The SART and NASA-TLX questionnaires are acknowledged as sufficient methods for measuring SA and workload in previous research (Won et al., 2011). A Norwegian version of NASA-TLX has been previously tested in a Norwegian context (Stafseth, Karlsen, Langerud, & Bjørkli, manuscript in preparation). In order to improve the content validity of the present adaptation of the SART questionnaire, a back-translation test, according to Brislin’s (1970) classic back-translation model, and a pilot study were conducted. The authors conducted the translation from English to Norwegian and a peer student in organisational psychology conducted the back-translation. The results of the back-translation test indicated good conceptual similarity. The pilot study was completed in order to assess comprehensiveness of the questionnaire in Norwegian context. Some necessary linguistic adjustments were performed, as well as thorough instructions regarding the questionnaire were added before the final distribution.

The reliability of the questionnaire was assessed using Cronbach’s alpha coefficient. Both SART and NASA-TLX alpha scores were calculated, including three subscales of SART, see table 2 for alpha values. Results reveal from poor but acceptable (SART), to good (NASA-TLX) reliability scores (George & Mallery, 2003).

Table 2

Reliability scores for SART and NASA-TLX.

Questionnaire	Cronbach's alpha
SART	
Situation awareness	0.521
Demand	0.740
Supply	0.608
Understanding	0.531
NASA-TLX	
Workload	0.790

Procedure

The questionnaire was distributed using EasyQuest, an online tool for collecting data. A snowball-method was used to distribute the questionnaire where incident- and tactical command leaders from the police-, fire- and health departments distributed the questionnaire to their peers, personnel and superiors. This method was chosen due to e-mail address confidentiality restrictions in some of the responding departments. The respondents were provided with instructions regarding the questionnaire. The critical incident was defined as the first half hour after the police-, fire- and health emergency personnel arrived at the incident area. The questionnaire consisted of three mandatory parts: SART, NASA-TLX, and supplementary questions regarding the exercise. As a result, the questionnaire contained no missing values. Responses were collected online during a four weeks period after the exercise. Three e-mail and two telephone reminders were administered during this period.

Statistical Considerations

SART and NASA-TLX measure variables on the ordinal level. This may not comply with the assumptions for some of the parametric analyses performed in this study (Kuzon, Urbanchek, & McCabe, 1996). Nonetheless, it is commonly accepted that ordinal scales may be used in parametric testing, and studies have found that parametric statistics are still robust with respect to violations of these assumptions (Norman, 2010). The demographical questions were regarded as categorical for ICT-use, and as ordinal level of measurement for work experience.

Three different statistical methods were used to analyse the data. The differences in SA with regard to the independent variables were analysed using a one-way analysis of variance. The relationships between SA and the predicting variables were assessed using regression and correlation analyses. To investigate a possible interaction, an analysis of covariance was conducted using the univariate general model in SPSS. The alpha threshold of α =.05 was used for all analyses.

Ethical Considerations

Any potential negative effects of the interviews or questionnaires on the life and health of the respondents were considered non-existent. It was ensured that the informants were treated with respect, and that their integrity was preserved, in accordance with the Norwegian Work Environment Act.

The participants of the focus-group interviews were informed prior to the interviews, both orally and in writing that participation was voluntary and that they could withdraw from the study for any reason and at any point in the study (see Appendix B). The interviewees were assured that the information they provided during the interview would be used only to assess the most critical situation during the exercise. The questionnaire respondents were informed about the voluntary consent, anonymity and the questionnaires accordance to the ethical guidelines in the invitation e-mail (see Appendix D) and again prior to the beginning of the questionnaire.

This study was permitted to gather and store data connected to the BRIDGE-project (project number 28066), granted by the Norwegian Social Science Data Services (NSD) to SINTEF. Some information about collaboration exercise is publicly available through national media sources.

Participants

There were 55 respondents that replied to the online questionnaire. This indicates a response rate of approximately 51 %, based on the information provided by incident- and tactical commanders of each respective emergency department. The exact response rate could not be assessed, as there were no participant statistics available from the exercise. The sample consisted of 49 male and 6 female respondents from three departments: police (n = 21), fire, (n = 16) and emergency health department (n = 18) (see work experience distribution per department presented in table 3). A total of 18 respondents had a leader position during the exercise. Only two of these were women. The respondents' age varied from 25 to 59 years, with the majority of respondents between 32 to 38 years.

Table 3
Participants work experience distribution across departments.

	Work experience in emergency agency					
	0 - 3 years	4 - 7 years	8 - 11 years	12 - 15 years	> 15 years	**Total per department**
Police department	1	6	7	2	5	**21**
Fire department	2	3	1	1	9	**16**
Emergency health department	0	1	6	6	5	**37**
Total per category	**3**	**10**	**14**	**9**	**19**	**55**

Results

The results of the analysis on the influence of ICT-use, expertise, and workload on SA in the collaboration exercise will be presented next. The descriptive statistics of SA indicated a normal distribution, $M = 18.31$, $SD = 6.53$, and range $R = 2\text{-}32$.

Testing of Hypotheses

First, the distribution of ICT-use was explored. 47 % of the respondents used only one ICT-device, whereas 45 % were using either two or maximum three ICT-devices during the exercise. The majority (69 %) of the respondents were using radio for communication purposes; and 51 % of the respondents were using mobile phone. Please see total and overlapping use of technology in figure 3. There were 38 respondents who used only auditory ICT-devices, 3 respondents who used only visual devices, and 9 respondents who used both auditory and visual ICT-devices. There were 5 respondents who did not use any ICT-devices during the exercise.

Hypothesis 1A predicted that respondents who used both auditory and visual ICT-devices would have higher SA than respondents who used none or only one type of ICT-devices. A one-way ANOVA analysis revealed no significant differences between respondents who used different types of ICT-devices (F (3, 51) = 1.853, $p = .149$). Which means that hypothesis 1A is rejected.

Hypothesis 1B stated that the use of multiple ICT-devices would be associated with higher SA than the use of none or only one ICT-device. The next analysis compiled the number of ICT-devices used, exploring whether the number of devices used could explain the variance in SA. The regression analysis revealed that some of the variance in SA could be explained by using multiple devices ($r = .274$, $p = .043$, $\beta = .274$) during the exercise. The results from exploring the ICT-usage during the exercise indicate that 7.5 % of the variance in SA can be explained by the number of ICT-devices used (r^2 = .075). The hypothesis 1B is accepted.

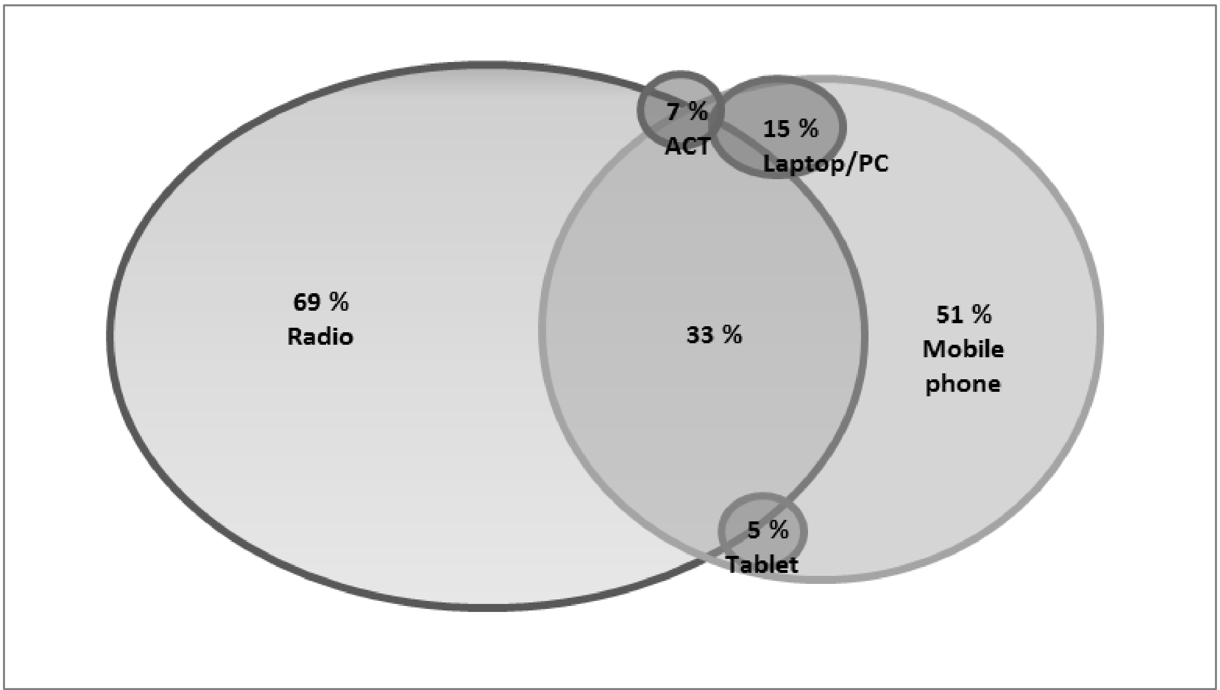

Figure 3. Venn-diagram for technology use during the exercise. Each circle represents a different ICT-device that was used by the respondents. Overlapping areas indicate the percentage of respondents that used multiple devices.

Hypothesis 1C predicted that the use of domain specific tools would yield a higher SA than the use of any other device during the exercise. In the present exercise advanced communication technology (ACT) was defined as domain specific tool. The regression analysis of the different ICT-devices used during the exercise and SA revealed that mobile phone was the only device that explained some variance in SA (r = .30, r^2 = .09, p = .026) (see table 4 for a correlation matrix of all measured devices). The hypothesis 1C is rejected.

Table 4
Correlations between SA and ICT-devices that were used during the exercise.

Situation Awareness	Radio	Mobile phone	Tablet	Laptop/PC	ACT
Pearson Correlation	.129	.300*	.063	.004	-.067
Sig. (2-tailed)	.347	.026	.649	.976	.624

* Correlation is significant at the 0.05 level (2-tailed).

Hypothesis H2 predicted that respondents who have longer work experience in emergency response would have higher SA. The number of years of working experience in the emergency response department was used as a measure of expertise. A one-way ANOVA analysis revealed no significant differences (F (4, 50) = .518, p = .723) between the categories of years of working experience in emergency agencies with respect to SA. The hypothesis H2 is rejected.

Hypothesis 3A stated that in disaster management SA would be associated negatively with workload. The present study did not yield a significant correlation between workload and SA (r = -.058, p = .677). As the correlation is near zero, this result is neither consistent with the advocates of the negative relationship between SA and workload, nor Endsley's (1995b) statement of different possible relationships between these variables. The hypothesis 3A is rejected.

Finally, *hypothesis 3B* predicted that role would be a moderating factor in the relationship between SA and workload, according to suggestion of Won et al. (2011). A visual inspection of the data concerning this relationship revealed an interaction between the variables (figure 4). Following the descriptive analysis of the data, role was included in the univariate general linear model in SPSS as an independent variable. SA was included as a dependent variable and workload as a covariate. The result of this analysis indicates that the main effect of workload on SA was not significant (F (1, 51) = 1.156, p = .29); the main effect of role on SA was significant in that the leaders had marginally higher SA than the operative personnel (F (1, 51) = 5.066, p = .03). Furthermore, there was a significant interaction between workload and role, (F (1, 51) = 5.500, p = .02), meaning that for leaders SA seems to correlate positively with workload (r = .452), while the opposite relationship seems to be present for operative personnel (r = -.230). The results yield added support for hypothesis 3B.

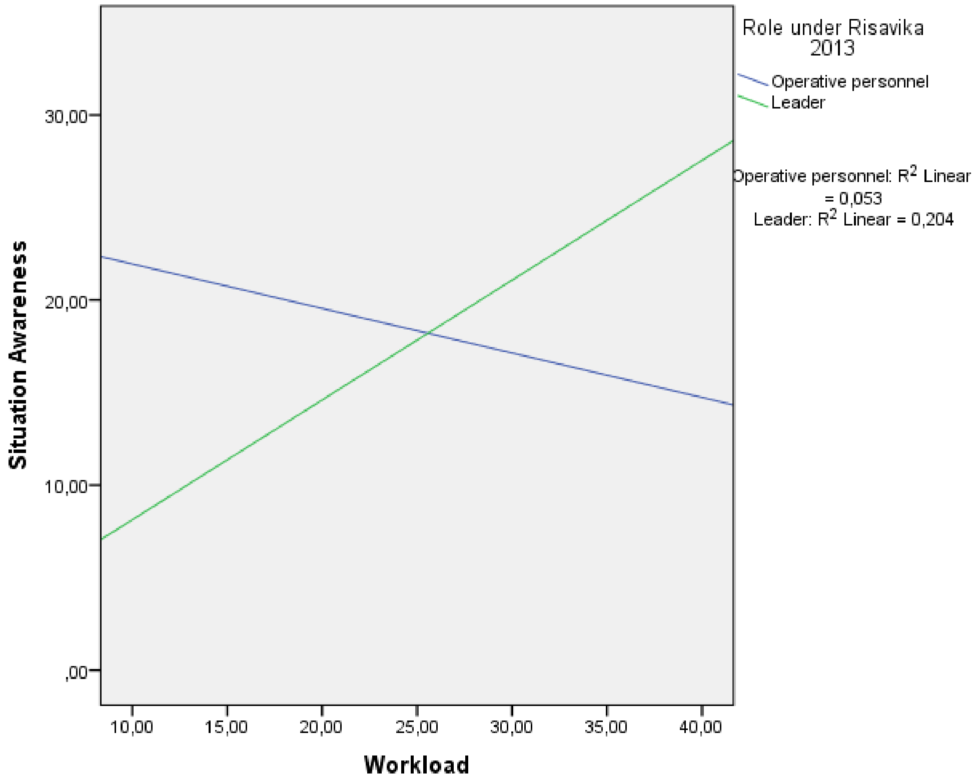

Figure 4. Visual presentation of the interaction effect between workload and role on SA. Operative personnel have negative relationship between SA and workload, whereas leaders have a positive relationship between the same variables.

Discussion

Summary and Discussion of the Results

The purpose of the present article is to examine if ICT-use, expertise, and workload influence SA in disaster management. These factors represent important aspects of the three-level model presented by Endsley (1995b) and are predicted to influence SA. Expertise is an individual factor while ICT-use and workload are the environmental factors that influence SA. Data on SA, ICT-use, expertise, and workload were gathered after a large-scale collaboration exercise using an online questionnaire. The measurement tools chosen to assess SA and workload were SART and NASA-TLX respectively. Data regarding expertise and ICT-use were gathered through various demographical questions.

Hypotheses 1A-1C concern the connection between ICT-use and SA. Hypothesis 1A predicted that respondents who used the combination of auditory and visual ICT-devices would be associated with higher SA than respondents who used only one type of device. Hypothesis 1A did not reveal any significant results, meaning that the use of both auditory and visual ICT-devices was not associated with higher SA than use of either auditory or visual ICT-devices alone. This result may have been affected by unequal distribution of the use of auditory versus visual devices during the exercise. The fact that only three respondents used visual ICT-devices may be attributed to the time pressure and high mobility in emergency management, thus making it unlikely that emergency services personnel would use visual ICT-devices under high stress conditions.

The research on secondary task performance in driving indicates that tasks, which require visual attention, lead to more degraded performance on the primary task than auditory tasks (Schömig, & Metz, 2013). Following this logic, it can be assumed that the use of visual ICT-devices in disaster management could interfere with performance, and for this reason emergency personnel avoided the use of these devices. The results of Young, Salmon and Cornelissen (2013) indicate that visual distractions do not degrade a driver’s SA, but change the content of SA. The respondents from this study did not perceive less information, when distracted by visual stimuli, but their attention was focused on different aspects of the task. We argue that even if the use of both auditory and visual ICT-devices in disaster management is impractical due to limited spare capacity, the visual ICT-devices have the potential to direct emergency personnel’s attention to the relevant elements of the situation, which is beneficial for SA.

The hypotheses 1B and 1C concern the environmental factors of Endsley’s (1995b) model and their results indicate that use of multiple ICT-devices and a mobile phone in particular were associated with highest SA scores. The current results support the notion proposed by Endsley (1995b) that task or system factors influence SA.

Hypothesis 1B stated that respondents who used different number of ICT-devices during the exercise would have different levels of SA. The regression analysis showed that use of multiple ICT-devices during the exercise was significantly correlated with respondents’ SA. As the maximum number of ICT-devices used during the current exercise was three, this result indicates that the use of three ICT-devices was associated with higher SA than the use of only one ICT-device. We can assume that the relationship between number of ICT-devices used and SA is not linear, e.g. the use of ten ICT-devices would not yield the same result. It is evident that the use of multiple ICT-devices will benefit SA only up to some extent. Thereafter, it may be expected that the workload of managing multiple devices would outperform the utility of these devices. We can expect a U-formed relationship between number of ICT-devices and SA. Endsley (1995b) states that less communication between the team members is needed in order to achieve higher SA, if the members have a shared mental model. This means that such teams would be able to obtain higher SA without the use of ICT-devices. As emergency responders are often spread across large geographical areas, the use of ICT is an inevitable prerequisite of communication in disaster management. Following this notion, we argue that this finding indicates that information needs of the responders in order to achieve sufficient SA were not covered by the functions of one specific ICT-device. This lead responders to use multiple ICT-devices. This view is consistent with the conclusion of the evaluation committee of the exercise, which points out that the ICT used during the exercise lacks sufficient functionality and capacity (Breivoll, 2014, p.3).

Hypothesis 1C predicted that use of domain specific tools during the exercise would be associated with higher SA than use of any other ICT-device. As proposed by Bolstad and Ensdsley (2003), the domain specific tools are tailored to the specific information needs of the people who use them. The present study defined ACT as the domain specific tool, as it was designed to support SA of the emergency services' personnel and facilitate decision making of incident and tactical commanders. Additionally, radio could also be defined as a domain specific tool because it is the preferred ICT-tool in emergency response, defined by the National Police Directorate (2013). Neither use of ACT or radio during the exercise was associated with higher SA. This result may indicate that the use of domain specific tools has no connection to SA in disaster management. Other possible explanations will be discussed below.

There were only four incident and tactical commanders that used ACT during the exercise, which could explain why the use of ACT did not influence SA. On the contrary, 69 % of the respondents used the radio. The use of radio provides auditory information gathering and distribution, which is transcribed by the operators at the operational centrals. Visual display of this information is available for every responder who has the access to the operational log of the event. According to the previously mentioned notion from the National Police Directorate (2013), radio should be the preferred choice for efficient information distribution. This may not be the case with information inquiries. Respondents indicated that certain inquiries on the radio had to be repeated several times before they got an answer, besides several respondents referred to a radio breakdown during the exercise. As long as technological breakdowns occur, there is a need for backup solutions, e.g. use of multiple ICT-tools.

Further, as indicated by the current results, the use of mobile phone was the only ICT-device that yielded a positive correlation with SA. It is likely that information inquiries were done by use of mobile phones, as this device allows a fast, direct one-to-one communication.

In addition, the mobile phone is a familiar device to most people, which may explain why it was used in the stressful environment of disaster management. This is consistent with the earlier discussion on heuristic decision-making. Additionally, this finding may indicate that the emergency responders perceive mobile phone as a more reliable communication tool than any other ICT. The radio breakdown may also have contributed to the fact that those respondents who did use the mobile phone perceived their SA to be higher than those respondents who did not have the opportunity to replace radio with other ICT-devices. The use of the mobile phone as a communication tool in a disaster management has limitations. It is basically a one-to-one communication tool, which requires the knowledge of whom to call. Communication in disaster management based on personal connections is incapable to utilize all available resources. Not engaging spare resources in disaster management has repeatedly been pointed out as a weakness in previous post-disaster reports (St.meld. nr. 21. 2012-2013).

The previous passages discussed the results of hypotheses 1A to 1C. These results indicate that use of multiple ICT-devices is beneficial for SA; either it is based on the need for multiple functions, or the necessity for backup solutions in case of ICT breakdown. Further, customized communication tools, such as ACT, may have the potential to benefit SA of emergency personnel by combining auditory and visual stimuli, if these tools are familiar and used for both small accidents and full-scale emergencies.

Hypothesis 2 concerns an individual factor of Endsley`s (1995b) three-level model - expertise. Expertise was operationalised as years of working experience in the emergency department. This hypothesis predicted that respondents with longer work experience in emergency response would have higher SA scores, but was rejected. This is in contrast to the three-level model, among other studies on SMEs and SA (Chauvin et al., 2009; Fowlkes et al., 2000; Stanton et al., 2006). Three possible explanations to this will be provided.

First, the expertise variable was based on how many working years in an emergency department each respondent reported, and then testing for the difference in level of SA between the categories of working years. The majority of the respondents reported to have more than three years of work experience. This indicates that the population in the present sample was homogeneous, which may explain why no differences were found. Second, it may be speculated that the measured variables were not sensitive enough in order to capture differences in respondents' expertise. However, the study of Selcon, Taylor and Koritsas (1991) indicate that SART shows an added utility to detect effects when respondents' experience is an independent variable, like in the this study.

Third, it may be that other individual variables than years of working experience are responsible for the variance in SA during disaster management. These may include, e.g. specific personality traits of the respondents, which are not accounted for in the three-level model. Previous research on hazard detection (Underwood, Ngai & Underwood, 2013) discovered that there were no differences in SA due to experience, if the hazard was abrupt. In case of gradual-onset hazards, more experienced respondents had higher SA than the novices. As the acute phase in disaster management is often an abrupt disruption, this could explain why no difference in SA was found due to experience. In sum, this finding may be an indication that the task or system factors were more important than the individual factors for achieving SA during the present exercise. Based on the magnitude of expertise's prominence in previous research (see theory); we argue that expertise still is a crucial factor for higher SA levels.

Hypothesis 3A predicted that there would be a negative correlation between SA and workload during the acute phase of the exercise. An ongoing debate revolves around the relationship between these variables. The results of this study did not reveal a negative correlation between SA and workload, which is commonly found in previous research (Mouloua, Gilson, Kring & Hancock. 2001). Moreover, several studies indicate that SART and NASA-TLX may measure the same overlapping constructs (Hendy, 1995, Selcon, Taylor & Koritsas, 1991). Advocates of this perspective claim that SART subscales *supply* and *demand* measure the workload imposed by the situation. On the other hand, Parasuraman, Sheridan and Wickens (2008) resolve this debate by concluding that both SA and workload are distinct and viable constructs that are valuable in understanding and predicting human-system performance in complex systems. This is in accordance with Endsley's (1993) conclusion that SA and workload may interact under certain conditions, but behave independently in others. The latter study suggests searching for confounding variables, which may explain why favourable (high SA and low workload) or unfavourable (high SA and high workload) combinations of these variables arise. Since the correlation was not significant, the results may support the notion that SA and workload are two separate constructs with varying inter-relations. It is acknowledged that the sample size and a potential overlapping of the measurement tools may have contributed to camouflaging this relationship. Nonetheless, it is emphasized that the present results do not yield added support to the existence of the negative correlation between SA and workload.

Hypothesis 3B predicted that respondents' role during the exercise would influence the relationship between SA and workload. It was found that role significantly moderates this relationship. A leader's role was associated with a positive correlation between SA and workload. On the other hand, the role of operative personnel was associated with a negative correlation between the same variables. This is consistent with the suggestions that Won et al. (2011) made based on their research on SA and workload. There are three proposed explanations to the present interaction effect.

First, it may be argued that leaders function as information hubs. Leaders tended to use multiple types of ICT-devices and as a result had access to more information that was communicated than the operative personnel did during the exercise. This may have given leaders the opportunity to understand more of what was going on. As stated earlier, handling multiple ICT-devices can lead to information and workload overload (Squire & Parasuraman, 2010), but in the present study leaders seemed to be unaffected by this during the exercise, and managed to maintain a high SA despite an increase in workload. On the other hand, it may seem that the operative personnel had access to less information than leaders and therefore could not maintain high SA. As noted by Gorman, Cooke and Winner (2006), not everyone in the team has to be aware of the same information. Rather, it is more important to ensure that the right information reaches the right person at the right time, in this way creating a compatible system that supports DSA.

Second, this finding may indicate that leaders have more experience and better developed mental models of the situation, due to their specific experience in the leader role and not their working experience in general. This may indicate that leader experience is qualitatively different from the general emergency experience. This suggestion is consistent with the RPD model (Klein et al., 1989), which suggests that experts develop intuition that is difficult for them to verbalize, however it plays a crucial role in achieving higher levels of SA. This qualitative difference in general and leader experience was not captured by the present questionnaire. Moreover there could be other individual variables than expertise that influence this relationship, e.g. personality of leaders, or the recruitment process of emergency leaders that accounts for many of these individual factors.

Finally, the present result may indicate that leaders are more biased in judging their own performance, hence reporting a higher SA under high workload conditions. As observed during the exercise and preparatory emergency sit-ins, incident- and tactical commanders have lots of authority and are concerned about having and projecting that they have full control of the situation regardless the circumstances. On that account, they may be less prone to admit lower SA during the most acute phases of disaster management.

In conclusion, the results of the hypothesis 3B provide an important contribution to workload-SA debate, suggesting that role moderates this relationship in emergency management. This finding may be applicable to other domains as well, as the role of confounding variables was suggested by research in other domains than disaster management. Future research should investigate this effect further. Possible practical implications affect the use of ICT and other support tools for decision-making.

General Discussion

Disaster management is a highly complex task with many varying factors, and an understanding of what's going on is a crucial component that influences the decision making of the emergency personnel. As previously outlined, although SA is not essential for performance, it does increase the probability for successful disaster mitigation. This study has investigated if ICT-use, expertise and workload influenced SA in a Norwegian collaboration exercise. Next, the general discussion regarding the findings of this study will follow.

As stated previously in the theory section, SA can be regarded as either an individual phenomenon, according to Endsley (1995b), or as a group-level phenomenon as proposed by Stanton et al. (2009). In the present study, the measurement tools assessed SA on an individual level. However, SA may also be accounted as something that is distributed across team members. The next two implications of the findings will be discussed in the light of both the individual and distributed level of SA analysis.

The first implication concerns the use of ICT-devices in disaster management. This study suggests that focus on ICT-device use and design may be beneficial for SA. Thus, adapting technology to the information needs of emergency personnel and adequate training in their use is beneficial in disaster mitigation. On the other hand, a group-level approach proposed by Stanton et al. (2009) suggests that SA should be viewed as a systems phenomenon. According to this approach, shared SA is not possible to achieve because every person would experience the same situation differently; disaster mitigation would benefit from focus on distributed and compatible SA, e.g. adapting ICT to individual information requirements that are compatible with those of the other team members.

According to the individual level of analysis, the focus should be on creating shared SA amongst emergency personnel, e.g. via ICT. Distribution of information should take all the individuals working in disaster management into account, providing them with rich and relevant information about the incident. From the group-perspective, it may be speculated that ICT used in the current exercise have fulfilled its purpose sufficiently. The emergency personnel used appropriate ICT-devices according to their task requirements, but did not achieve high SA regarding the acute phase of the exercise as a total. Regardless if SA is assessed according to Endsley or Stanton, the conclusion is that ICT is an important factor in disaster management. Whether the redesign of currently available ICT is needed, is dependent on the level of analysis of SA.

The second implication concerns workload and SA. It was found that leaders and operative personnel respond differently to high workload conditions concerning SA. These results imply that leaders may be capable of maintaining high SA during high workload conditions, and can therefore handle more information via multiple ICT-devices than the operative personnel are able to. The evaluation report of the exercise (Breivoll, 2014) stated that there were major challenges in establishing and distributing shared SA (p.3). This statement can be attributed to the use of ICT discussed previously, or to the lack of coordination on the higher decision level, e.g. incident- and tactical commanders (Breivoll, 2014, p.11). The report states that operative personnel is required to report relevant information about the incident to their respective commanders, and the personnel of the incident command outpost is responsible for distributing information in order to support shared SA of all involved parties. Considering the information flow scheme, the current results indicate that information failure occurred at leaders' level. Leaders in the present exercise, which succeeded in achieving high SA, failed to support shared SA in operative personnel. On the individual level of SA, the results suggest that extra resources are needed in order to achieve a higher SA for operative personnel. If the results are considered on the group-level of analysis, it may indicate that SA is indeed distributed across different team members, but it is the leaders who need to support their SA, and techniques for distributing their insights of what's going on to the operative personnel.

Limitations

This study has certain limitations when it comes to the SA concept, the measurement, the interview and the chosen critical situation, and the respondents of the questionnaire. Next, how these limitations may have affected the results will be discussed.

The concept. The first limitation concerns the concept of SA. As stated earlier, SA is an abstract construct, which is defined differently according to the theoretical foundation of the concept and according to the level of analysis (individual or group). This makes it difficult to conclude if the respondents in the present study had an overall good or poor SA, or to establish an "optimal" SA that should be strived to attain.

Measurement. SART and NASA-TLX are post-operative subjective measures of SA and workload respectively. The questionnaires, which are executed after-the-fact, are vulnerable to respondents' decay in memory. The participants were prompted to complete the questionnaire as soon as possible after the exercise, in order to minimise this effect. The data may also have been biased due to social desirability of its respondents, or the mere fact that introspecting oneself regarding SA is a difficult task, which is not accurately reflected in the questionnaire. These limitations need to be taken into account when assessing the results of the current study.

Despite the consensus in the academic circles, that DSA is a better alternative for assessing SA in teams (Stanton et al., 2009) due to sounder theoretical base than the three-level model (Endsley, 1995b), the propositional networks measurement tool does not enable contrasting SA of different teams. This tool provides a qualitative assessment of team's SA and describes the framework for analysing collaborative activities in the specific case. On the contrary, the three-level model defines a specific system and individual factors that can be assessed and improved in order to increase individual SA.

The interview and the critical situation. Two limitations exist regarding the focus group interview and the critical situation established during the interview. First, the interviewees' lack of emergency response experience may have influenced the probe questions that were asked during the interview. A sit-in at the emergency response unit in Oslo prior to the focus group interview was conducted in order to achieve sufficient understanding regarding the topic.

The second limitation concerns the specific situation that was required for both SART and NASA-TLX (see method). The investigated exercise lasted several hours, and consisted of many different situations. The respondents were asked to focus on the first half hour after the incident occurred, as this was defined as the most critical phase during the exercise by the focus group interviews. This may have biased the data, as several of the respondents were located in different geographical areas and situations during this time. As stated by Endsley (1995b), SA is temporal in nature such that SA is built up over time. Although it is difficult to define the specific details that the operator needs to perceive and understand, there are relevant elements that are common for multiple persons in the explored situation. Thus focusing on the timeframe instead of the geographical location gave the respondents possibility to focus on the shared elements of the situation.

Respondents. The sampling for the current study was not done randomly. For practical reasons, contact persons in each emergency department did the selection of the participants. A list of all participants in the collaboration exercise and their contact information was not available. There is a reason to believe that an invitation to the questionnaire was distributed only to certain emergency responders through the snowball method, suggesting a possibly biased sample.

In conclusion, even if this study had various limitations, measures have been taken in order to minimize the negative consequences.

Conclusion

SA is an important aspect in disaster management. The results from this study provide support that individual oriented SA is influenced by ICT and workload during a crisis scenario. Consequently, the results yield an added support to the notion that environmental factors influence SA, according to the three-level model of SA (Endsley, 1995b). In order to improve SA in disaster management, it is important to focus on the use of the right ICT according to the role’s information requirements. ICT should be a familiar and reliable source of communication. Additionally, leaders seem to be able to maintain high SA under high workload conditions, unlike the operative personnel. Thus, the role of the emergency personnel during disaster management imposes different requirements to information distribution and use of ICT.

The present research points out practical and theoretical implications for how ICT should be used during large-scale disasters, and to the understanding of the relationship between SA and workload, differentiated by role. Further research on the topic should combine individual and group-level approach to SA in order to gain better understanding of the concept in a dynamic environment.

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Appendix A: Information Sheet

SINTEF

SINTEF IKT
Postadresse:
Postboks 124 Blindern
0314 Oslo

Besøksadresse:
Forskningsveien 1
0373 Oslo

Sentralbord: 22067300
www.sintef.no

Deres ref.:	**Vår ref.:**	**Prosjekt / Sak:**	**Dato**
	Jan Håvard Skjetne	BRIDGE	2013-09-03

Informasjonsskriv til intervjudeltagere

BRIDGE er et EU-finansiert forskningsprosjekt som hadde oppstart våren 2011. Formålet med prosjektet er å øke sikkerheten i samfunnet gjennom utvikling av tekniske og organisatoriske løsninger for forbedret krisehåndtering og beredskap. Hovedfokus i prosjektet er utviklingen av løsninger som understøtter og frembringer samarbeid mellom aktører på det tekniske og organisatoriske nivå. Et viktig ledd i BRIDGE er derfor å forstå hva slags informasjon som blir produsert i krisesituasjoner, hvordan folk genererer, deler og lager mening ut av denne informasjonen, og hvordan disse prosessene kan bli bedre understøttet i fremtiden. For mer informasjon om BRIDGE-prosjektet, se http://www.bridgeproject.eu/.

I forbindelse med BRIDGE-prosjektet ønsker SINTEF, samt to masterstudenter tilknyttet prosjektet, å intervjue deltagere fra øvelsen. Studentene, Jørgen Ernstsen og Daniela Villanger som studerer arbeids- og organisasjonspsykologi ved Universitetet i Oslo, skal skrive sine oppgaver om situasjonsbevissthet i krisesituasjoner og har fått tillatelse til å observere Øvelse [redacted] i [redacted], med oppstart [redacted] september 2013. Det ønskes å observere ved å ta notater og stille spørsmål under øvelsen (så langt det ikke forstyrrer arbeidet til involverte parter under øvelsen), for så å gjennomføre intervjuer i ettertid av øvelsen. Deretter vil det sendes ut spørreskjemaer til operativt personell i løpet av påfølgende måned. Innsamlet datamateriale vil analyseres for å kartlegge deltagernes situasjonsbevissthet under øvelsen. SINTEF ønsker videre å bruke datamaterialet studentene får tilgang til i forbindelse med BRIDGE-prosjektet.

Vi gjør oppmerksom på at deltakelse er frivillig, og at alle operatører og andre som er til stede har rett til å ikke delta eller trekke seg når som helst, uten å måtte oppgi noen grunn for dette. Alle involverte har også rett til å be om at lydopptaker blir stoppet/startet, samt om å slette deler av lydopptaket hvis dette er ønskelig.

Alt datamaterialet vil bli behandlet konfidensielt i overensstemmelse med det Europeiske databeskyttelsesdirektivet (95/46/EF 1998). Prosjektet har blitt meldt inn til den Norske Samfunnsvitenskapelige Datatjeneste (NSD), personvernombudet for forskning i Norge og er godkjent med referanse 28066. Merk at personopplysninger vil bli behandlet strengt fortrolig og kun vil bli delt mellom BRIDGE-medlemmer tilknyttet SINTEF. Datamaterialet vil bli anonymisert før bruk i analyser. Innsamlet data vil bli oppbevart på-, og delt gjennom sikre serverløsninger, og tilgang til anonymisert data vil kun bli gitt til medlemmer av BRIDGE prosjektet. Under ingen omstendigheter vil tilgang til den innsamlete data gis til utenforstående som ikke er involvert i prosjektet. Data vil bli anonymisert før bruk i analyser, rapporter, publikasjoner, presentasjoner, samt i de to masteroppgavene, slik at det ikke inneholder noen opplysninger som kan identifisere enkeltpersoner. I noen tilfeller kan publikasjoner og presentasjoner gjøre bruk av anonymiserte sitater. Ved prosjektslutt i 2015 vil personidentifiserbar data bli slettet. Anonymisert data kan beholdes på ubestemt tid.

Hvis dere har spørsmål, vennligst kontakt prosjektleder Jan Håvard Skjetne per e-post (jan.h.skjetne@sintef.no) eller telefon (22067871 / 93409191).

Med vennlig hilsen

Ida Maria Haugstveit
SINTEF ICT

Appendix B: Consent Form

BRIDGE
EU FP7 Project No. 261817

European Commission
Seventh Framework Programme (FP7-SEC-2010-1)
SEC-2010.4.2-1: Interoperability of data, systems, tools and equipment

www.sec-bridge.eu
www.bridgeproject.eu

Bridging Resources and Agencies in Large-Scale Emergency Management

Samtykkeskjema for deltagelse i EU prosjektet BRIDGE

Ved å signere dette skjemaet bekrefter du at du har mottatt informasjon om prosedyrene og detaljer rundt prosjektet, at du har fått tilstrekkelig mulighet til å vurdere denne informasjonen, og at du frivillig vil delta i prosjektet. Du vil motta en kopi av dette samtykkeskjema.

☐ Jeg bekrefter at jeg har lest og forstått informasjonen i skrivet "Informasjonsskriv til intervjudeltagere", datert 3.september 2013.

☐ Jeg har hatt muligheten til å vurdere denne informasjonen, og fått tilfredsstillende svar på spørsmål vedrørende forskningen.

☐ Jeg sier meg villig til å delta i forskningsprosjektet og forstår at min deltakelse er frivillig.

☐ Jeg forstår at jeg når som helst kan trekke meg som deltaker, uten å matte oppgi noen grunn for dette.

☐ Jeg tillater at mine svar blir tatt opp på lydbånd.

☐ Jeg er innforstått med at informasjonen jeg gir kan bli delt med medlemmer av prosjektet, og brukt i rapporter, presentasjoner, og andre publikasjoner.

☐ Jeg er innforstått med at informasjonen jeg gir vil bli behandlet konfidensielt av alle forskerne.

☐ Jeg forstår at all data som samles inn vil bli behandlet anonymt.

Vennligst signer på baksiden av arket

NAVN (vennligst bruk blokkbokstaver):

____

ADRESSE:

____

____

SIGNATUR til deltaker: _________________________

DATO OG STED: ____

Appendix C: Critical Incident Technique Procedure

Steg 1: Velg kritisk hendelse, som i vår tilfelle blir samarbeidsøvelsen.

Steg 2: Samle inn informasjon om samarbeidsøvelsen.

- Ber deltagere i fokusgruppen å beskrive øvelsen [redacted]. Beskrivelsen bør inneholde informasjon om hva som førte til situasjonen, detaljert beskrivelse av episode under øvelsen og beskrivelse av utfallet for hver nevnte episode.

Suksesskriterier: Noterer alle nevnte situasjoner, rik beskrivelse for hele øvelsen, ingen av deltagere har noe å tilføye mer.

Steg 3: Lage tidslinje sammen med fokus-gruppen

- Gå gjennom beskrivelse i steg 2 for å supplere hver episode med tidsaspekt og varighet, evt. andre tilhørende episoder. Fokus på både fysiske hendelser, mentale prosesser og persepsjon av hver episode.

Suksesskriterier: Gå gjennom hver notert situasjon og supplere med tid og varighet. Spørre om fysiske, mentale prosesser under hver situasjon. Få deltagere til å reflektere over hva som egentlig skjedde. Noter hva de legger vekt på.

Steg 4: Velge ut spesifikke episoder som kan granskes videre

- Sammen med fokus-gruppen velge episoden som oppfattes som mest kritisk/avgjørende under hele øvelsen. En slik episode bør omfatte alle involverte enheter på alle nivåer. Etablere felles tidsramme som alle enheter kan assosiere episoden med.

Suksesskriterier: Få deltagere til å bli enige om en situasjon som var mest kritisk for alle involverte. Notere kriterier de bruker for å velge den mest kritiske hendelsen. Er kriteriene like for alle?

Steg 5: Stille spesifikke spørsmål i forhold til den valgte situasjonen

- Hva slags teknologiske hjelpemidler brukte du under denne situasjonen?
- Kan du fortelle litt om de tilgjengelige teknologiske hjelpemidlene? (fordeler + ulemper)
- Hvilke andre enheter/hvem samarbeidet du med?
- Kan du beskrive hva som førte til denne situasjonen?
- Har du vært i en lignende hendelse før?
- Hva var din viktigste informasjonskilde?
- Hvordan vurderer du mengde og kvalitet på tilgjengelig informasjon?
- Hva var det du eller andre gjorde som var særlig effektivt/ineffektivt under situasjonen?
- Hva var utfallet av dine handlinger?
- Hvorfor det du gjorde var effektivt?
- Hva annet kunne blitt forventet i en slik situasjon?
- Hvordan har denne øvelsen vært i forhold til reelle krisesituasjoner?

- Ulike kategorier av jobbnivå, f.eks. ledere og operativ personell; finnes det flere?
- Utdanningskategorier på tvers av etater: høyskole/universitet, fagskole/fagbrev, kurs, andre?

Appendix D: E-mail with the Link to Questionnaire

ØVELSE [redacted] - SPØRREUNDERSØKELSE

I forbindelse med øvelsen [redacted] gjennomføres det en spørreundersøkelse om deltagernes forståelse og tolkning av ulike situasjoner under øvelsen (deltagernes situasjonsbevissthet). Dette er en del av EU-prosjektet BRIDGE som handler om samarbeidet på tvers av etater og landegrenser ved større ulykker. Undersøkelsen er anonym og underlagt internasjonale etiske retningslinjer.

Spørreundersøkelsen tar omtrent 5 minutter å svare på. Vennligst følg linken under for å starte spørreskjema:

https://www.easyquest.no/p/Collect/3291c983-00eb-42e1-966e-a242011bdb9d

Ditt bidrag er viktig for videreutvikling av samhandling og kommunikasjon mellom nødetatene.
Vi takker for at du tar deg tid til å gjennomføre spørreundersøkelsen.

Vennlig hilsen,

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Universitetet i Oslo og SINTEF

Appendix E: EasyQuest Questionnaire

Denne undersøkelsen består av to deler.

DEL 1

I undersøkelsen blir det gjennomgående referert til en spesifikk situasjon under øvelsen. Situasjonen det refereres til er den første halvtimen etter at brann- politi- og helsepersonell ankom skadestedet for sikring av området, skadde og eventuelle terrorister. Ta utgangspunkt i hvor du befant deg eller hva du gjorde i dette aktuelle tidsrommet.

Det er viktig at du fokuserer kun på denne definerte situasjonen, og i den grad det er mulig ikke lar andre situasjoner før- eller etter denne situasjonen påvirke svaralternativene. Prøv å svare så godt du kan.

	1	2	3	4	5	6	7
Stabilitet under situasjonen: Var situasjonen stabil og grei eller var den ustabil med raske endringer? 1 = stabil og 7 = ustabil	○	○	○	○	○	○	○
Kompleksitet i situasjonen: Var situasjonen enkel og "rett frem" eller hadde den mange ulike komponenter? 1 = enkel og 7 = komplisert	○	○	○	○	○	○	○
Variasjon i situasjonen: Var det få faktorer som endret seg under situasjonen eller var det mange faktorer som var i endring? 1 = få endringer og 7 = mange endringer	○	○	○	○	○	○	○
Emosjonell aktivering: Hadde du lav grad av årvåkenhet eller var du våken og klar for handling? 1 = lite aktivert og 7 = veldig aktivert	○	○	○	○	○	○	○
Konsentrasjon: Konsentrerte du deg om kun ett moment ved situasjonen eller konsentrerte du deg om flere momenter? 1 = fullt konsentrert om ett moment og 7 = konsentrert om mange momenter	○	○	○	○	○	○	○

Delt oppmerksomhet: Var du fullt oppmerksom på ett aspekt ved situasjonen eller var du oppmerksom på flere aspekter? 1 = oppmerksom på ett aspekt og 7 = oppmerksom på flere aspekter	○	○	○	○	○	○	○
Ledig mental kapasitet: Hadde du ingen ledig mental kapasitet til overs eller hadde du ledig kapasitet til å ivareta mange momenter ved situasjonen? 1 = ingen ledig mental kapasitet og 7 = ledig mental kapasitet	○	○	○	○	○	○	○
Informasjonsmengde: Mottok du lite informasjon eller mye informasjon om situasjonen? 1 = lite informasjon og 7 = mye informasjon	○	○	○	○	○	○	○
Informasjonskvalitet: Var mottatt informasjon uoversiktlig og mangelfull eller var den utfyllende og detaljert? 1 = uoversiktlig/mangelfull og 7 = utfyllende/detaljert	○	○	○	○	○	○	○
Kjennskap til situasjonen: Var situasjonen helt ny eller har du mye relevant erfaring med lignende situasjoner? 1 = ny situasjon og 7 = mye relevant erfaring	○	○	○	○	○	○	○
Hvor mentalt og perseptuelt krevende var situasjonen? 1 = meget lav og 7 = meget høy	○	○	○	○	○	○	○
Hvor fysisk krevende var situasjonen? 1 = ikke belastende og 7 = meget belastende	○	○	○	○	○	○	○
Hvor stort tidspress opplevde du under situasjonen? 1 = god tid og 7 = lite tid	○	○	○	○	○	○	○
Hvor hardt anstrengte du deg under situasjonen? 1 = lite og 7 = mye	○	○	○	○	○	○	○
Hvor høyt var ditt frustrasjonsnivå under situasjonen? 1 = meget lavt og 7 = meget høyt	○	○	○	○	○	○	○
Hvor bra mener du at du klarte oppgaven i henhold til instruksene? 1 = dårlig prestasjon og 7 = god prestasjon	○	○	○	○	○	○	○

DEL 2

Generell informasjon og biografiske data

Hvor kritisk vurderer du den nevnte situasjonen?

- Ikke kritisk
- Lite kritisk
- Ganske kritisk
- Vedig kritisk

Er det en annen situasjon du vurderer som mer kritisk?

- Nei, undersøkelsens situasjonen var den mest kritiske
- Ja, det er en annen situasjon som var mer kritisk. Hvilken?

Hvis ja, hvor kritisk var denne situasjonen?

- Jeg svarte nei, undersøkelsens nevnte situasjonen var den mest kritiske
- Ikke kritisk
- Lite kritisk
- Ganske kritisk
- Veldig kritisk

Hvor gammel er du?

- 18 - 24 år
- 25 - 31 år
- 32 - 38 år
- 39 - 45 år
- 46 - 52 år
- 53 - 59 år
- 60 - 66 år
- Mer enn 67 år

Hva er ditt kjønn?

Høyeste fullførte utdanning

Hvilken etat jobber du i?

- ☐ Politi
- ☐ Brann
- ☐ Helse
- ☐ Annet, spesifiser her:

Hvor mange år har du jobbet i denne etaten?

- ○ 0 - 3 år
- ○ 4 - 7 år
- ○ 8 - 11 år
- ○ 12 - 15 år
- ○ Mer enn 15 års erfaring

Under øvelsen [redacted], i hvilken rolle deltok du i øvelsen?

- ☐ Lederrolle (innsatsleder, fagleder, teamleder eller lignende)
- ☐ Operativt personell (politibetjent, beredskapstroppen, sykepleier, brannmann eller lignende)
- ☐ Sykehuspersonell
- ☐ Nødsentral (112, 113, 110, LRS, HRS)
- ☐ Annet, spesifiser her:

Hvor mange års erfaring har du med lederansvar?

- ○ Har ikke hatt lederansvar
- ○ 0 - 3 år
- ○ 4 - 7 år
- ○ 8 - 11 år
- ○ Mer enn 12 år med lederansvar

Under øvelsen, hvilke andre etater hadde du direkte samarbeid med?

- ☐ Helse (inkl. AMK-sentralen)
- ☐ Brann (inkl. 110-sentralen)
- ☐ Politi (inkl. Operasjonsentralen)
- ☐ Annet, spesifiser her: ______

Hvilke teknologiske hjelpemidler benyttet du for kommunikasjon?

- ☐ Nødradio/samband
- ☐ Mobiltelefon
- ☐ Tablet/nettbrett
- ☐ Laptop/PC
- ☐ MASTER-table eller andre MASTER-applikasjoner
- ☐ Annet, spesifiser her: ______

Har du deltatt på en samhandlingsøvelse før?

- ○ Ja
- ○ Nei

Hvor fornøyd er du med læringsutbytte av øvelsen?

- Veldig misfornøyd
- Litt misfornøyd
- Fornøyd
- Ganske fornøyd
- Veldig fornøyd

Hvordan opplevde du øvelsen [redacted] i forhold til reelle hendelser?

- Ikke realistisk
- Lite realistisk
- Ganske realistisk
- Veldig realistisk

Hvor mye visste du om øvelsen på forhånd?

- Nesten alt
- Jeg visste min rolle og arbeidsoppgaver i øvelsen
- Jeg visste om øvelsen, men ikke om jeg kom til å være med
- Jeg visste ikke om øvelsen
- Annet, spesifiser her:

Har du noen kommentarer om øvelsen [redacted]? Dine kommentarer er viktige for evalueringen av denne øvelsen og planlegging av videre samhandlingsøvelser.