Situation Awareness Under Task Complexity:
The Role of Information

Johannes Schmied, Nord University, Bodo, Norway

🆔 https://orcid.org/0000-0002-0553-0794

Abbas Strømmen-Bakhtiar, Nord Universitetet Handelshøgskolen, Bodo, Norway

🆔 https://orcid.org/0000-0002-4700-723X

ABSTRACT

Performing tasks under task complexity (TC), for example, during the management of a crisis, can be challenging. One relevant research stream has so far dealt with modelling task complexity while another research stream has established the importance of situation awareness (SA) during crisis management. This study takes into consideration these two research streams and builds a model on how SA is achieved under task complexity. The research shows that information of high information quality (IQ) reduces the level of task complexity, and influences—as well as is influenced by— situation awareness. The practice of collecting and disseminating relevant and timely information as a critical resource in improving SA should be carried out continuously. This continuous process can be improved by using information technologies as automating tools. Moreover, the study shows how shared mental models can improve SA under task complexity. A case study approach, based on qualitative data focusing on theory building, is applied. Unit of analysis is a Norwegian hospital.

KEYWORDS

Complexity, Crisis Management, Emergency Management, Information, Information Quality (IQ), Situation Awareness (SA), Task Complexity (TC)

INTRODUCTION

We adopt the definition of "task as behaviour requirements" by Wood (1986, p. 62), stating that tasks are a behavorial responses of an individual. The aim of these responses is to reach a "specific level of performance" (Wood, 1986, p. 62). In our interpretation, the definition can include more than one person, as several individuals within and across organizations can be joining to perform the responses.

We use the definition of task complexity (TC) by Hærem, Pentland, and Miller (2015), who in turn draw upon Oeser and O'Brien (1967). Both sets of scholars establish TC similar to a decision tree. According to Hærem et al. (2015), tasks are paths and potential routes to reach particular goals in the network. This creates nodes and ties which may in addition change over time, which gives a

dynamic element to complexity (Wood, 1986). In contrast to simple tasks, the more choices that are possible in order to reach goals (Wood 1986), and the more unexplainable interrelations of components in the network of actors (Flood 1987), the more complex is a task. As our systems and organizations evolve into more complex systems, dealing with TC has become more urgent (Campbell, 1988; Hærem et al., 2015).

Although in literature on complex systems there is a focus on situation awareness (SA) as part of the decision process, TC is less of an issue (Endsley, 2001; Wright, Taekman, & Endsley, 2004). However, coming back to Hærem et al. (2015) and Campbell (1984), complex systems and complex tasks are so interwoven that we believe SA is central within TC as well. We use the SA definition by Endsley (2001), which is also supported by Wright et al. (2004, p. 4). Endsley (2001, p. 4) defines SA as a 3-level model consisting of "Perception of the elements in the environment", "Comprehension of the current situation" and "Projection of future status". High stress and high workload may additionally hinder SA (Wright et al., 2004).

When comparing the studies by Hærem et al. (2015) and Campbell (1984) with the studies by Endsley (2001) and Wright et al. (2004), there is one more aspect which becomes clear: Information and the quality of information appear to be important for both assessing tasks and gauging their complexity when it comes to *SA* (Endsley, 2001; Wright et al., 2004). In our view, both Hærem et al. (2015) and Campbell (1984) give this aspect too marginal consideration. We define information as "know who, what, where, when and how many" (Ackoff, 1989). In contrast to Ackoff, we also include how-to (Ackoff, 1989). We start with the *information quality* (IQ) definition by Nelson, Todd, and Wixom (2005), stating that quality of information is created by the level of completeness, accuracy, format and currency of the information. However, throughout the analysis, we find out that the given model requires a different look at the information-related parameters.

This study investigates the role of *SA* under task complexity. In addition, it poses a fundamental question connected to *SA* under *TC* – whether information may play a more significant role than previous research suggests.

The study provides a literature survey and establishes the analytical model of *SA* under *TC* and the role of information. An empirical case study investigates the ambulant professional organisation of Nordland hospital. Interviews, discussion of existing procedures as well as observation of the largest University-organized emergency management exercise ("exercise Nord 2019") are the main means of data collection.

LITERATURE SURVEY

Situation Awareness in the Light of Task Complexity

According to Crichton, Lauche, and Flin (2005), *SA* is one of the five incident command skills besides decision-making, teamwork, leadership and communication. *SA* may suffer from *"information gaps, the lack of fluent communication, and the fact that there is no common operational picture"* (Seppänen, Mäkelä, Luokkala, & Virrantaus, 2013, p. 1). Information is constantly mentioned as an attribute to support a common operational picture (ibid.).

Improvement in situation awareness, including tasks such as the assessment of urgency, is connected to increasing decision-making capability (Chung, 2005; Endsley, 2017; Gerdtz & Bucknall, 2001). *SA* literature particularly states the importance of being up to date with overall capabilities in a dynamic environment (Endsley, 2017).

Some studies have looked at the individual challenges of a decision process connected to *SA* if something is urgent (Gerdtz & Bucknall, 2001). Klein (2000) places *SA* in a model linked to the performance of the actor (e.g. in such a task as an assessment). Other studies have focused on the fact that *SA* also requires actors to be up to date with the capabilities of other actors, groups and organisations (Coffey, 2012; Rimstad et al., 2014). Shared sense-making and joint mental models

may become important here (Grimes, 2010; Pearson & Clair, 1998). Particularly shared mental models have been connected to increased team *SA* (Bolstad, Cuevas, Gonzalez, & Schneider, 2005). Also, according to Bolstad et al. (2005), shared mental models play a direct role in forming (shared) situation awareness. Shared mental models have in addition been connected with "a set of concepts and language" to simplify the transmission of information (Denzau & North, 1994, p. 10).

In this light, increased *SA* is linked to the available information in the shared mental model. However, if the information is not available, information search may take time, which in turn may potentially deteriorate the situation that needs to be solved (Gerdtz & Bucknall, 2001). Janis and Mann (1977) argue that time pressure leads to a less thorough information search, which limits going into the depths of alternatives to gain *SA* (Edland & Svenson, 1993). Also, Chung (2005) sees time constraints as well as communication difficulties as the main criteria why decisions have to be made based on incomplete information, and - as a consequence - potentially incomplete situation awareness.

According to Gerdtz and Bucknall (2001), primary reasons that influence assessment time to increase *SA* are:

1. There was preparation time (decrease of assessment time);
2. The process is interrupted (increase);
3. If information donor and recipient use different languages (increase);
4. The background of the actor (depending).

To understand the role and the sequence of situation awareness, it helps to look again at the "model of SA in dynamic decision making" by Endsley (2017, p. 35) in the introduction. The *SA* model consists of three levels and precedes the act of decision making (see also Wright et al. (2004)).

These levels do constitute some overlap to what Gaba, Howard, and Small (1995) present as constituents of *SA* – namely being aware of subtle cues, noticing evolving situations as well as being aware of particular knowledge elements. All these constituents by Gaba et al. (1995) are dynamic. They imply that once a task is being performed, a change of the *SA* may appear that may require an adjustment to the action (Gaba et al., 1995).

Wright et al. (2004) argue that individuals with lower *SA* are more prone to decision errors. Interestingly, Endsley (2017) mentions *TC* as a challenge to gaining situation awareness. Even though we see that the *SA* literature does draw upon *TC* of situation awareness, it does not seem to be central. Besides, there is little reference to the objectives of those tasks.

Understanding Leading Task Complexity Theory

There have been attempts at quantifying the complexity of tasks (Campbell, 1988; Hærem et al., 2015). Hærem et al. (2015) draw upon Oeser and O'Brien (1967) and design TC as a formula: "Task complexity $= \sum_g \sum_p$ ties$_{g,p}$ where paths (p) are routes to particular goals (g) representing the attainment of an outcome". In addition, Campbell (1984) mentions that contradiction and interrelation when facing a task may be described by task complexity.

The complexity of tasks, according to the framework by Campbell (1988), is characterised by changes (Campbell refers to an increase) in the information load, the diversity of information or the rate of an information change. It will be interesting to discuss information further at a later stage, as first impressions suggest that it is not always clear whether information increases or decreases task complexity.

Additionally, Campbell's concept enables to distinguish four task characteristics which contribute to complexity. These are "(a) the presence of multiple potential ways (i.e., paths) to arrive at a desired end-state, (b) the presence of multiple desired outcomes (i.e., end-states) to be attained, (c) the presence of conflicting interdependence among paths to multiple outcomes, and (d) the presence of uncertain or probabilistic links among paths and outcomes" (Campbell, 1988, p. 43). The higher the value of each of the above characteristics, the more complex the task to work on a major goal.

Interestingly enough, Wright et al. (2004) analyse tasks and conclude that "major" goals will be reached by fulfilling a set of sub-goals. Wright et al. (2004). They also claim that *SA* (levels 1-3) is required for each of the sub-goals. This means, consequently, that task fulfilment of the major goal would be dependent on a collection of task complexities, unless exact sub-goals are designated as main goals. But what if the goal is not clear, or partly unknown, or changes over time?

Information and Task Complexity

In line with Wright, Schoonhoven, Scott, Flood, and Forrest Jr (1980, p. 894) suggest that "An interest in "technology" - as this focus (somewhat misleadingly) has been labelled - is justified by the sensible assumption that one cannot intelligently design appropriate organisational arrangements unless one first knows what type of work is to be performed". Yet, when information is lacking, objectives become fuzzy (Bellman & Zadeh, 1970) and strategies to cope with the situation become less clear.

Weick and Sutcliffe (2015, p. 66) argue that the organisation for complex tasks should not be overly simplified, as this may discourage the potential for "process variety,[…] argumentation, and more capability and willingness to act to understand". This suggests therefore that a simplification of, or a decrease in value of the variables within the presented formula by Hærem et al. (2015) may not be the single solution to cope with task complexity. Another solution may present itself by exploring further the aforementioned information.

Hærem et al. (2015) are aware of the importance of information (see *"information cues"*) to complexity. Based on Wood (1986) and Campbell (1988), they argue that information needs to be processed, otherwise it increases task complexity. On the other hand, there are studies which consider complexity to increase through lack of information (Xia & Lee, 2005), which may often lead to problems of coordination (Robson, Katsikeas, & Bello, 2008). Obviously, there needs to be some difference between the two concepts of information presented; the discussion on *IQ* may be able to provide some help to clarify the discrepancy. *IQ* ascribes specific attributes to information, so it can be used to its fullest potential (Nelson et al., 2005). Related to situation awareness, the literature on shared mental models does also mention that added information of quality may improve awareness (Denzau & North, 1994). Although in their meta-study Lee, Strong, Kahn, and Wang (2002) construct a method for assessing and benchmarking information quality, they do not mention whether it may be of relevance for *TC* and situation awareness.

Information quality-related discussion in literature is wide-reaching. For example, Gorman et al. (2000) ask if information may be used in small units, or whether it is more problem-oriented to use bundles of information. Bundles are said to be better to "support diverse, complex, and often simultaneous tasks" (Gorman et al., 2000, p. 287), while previous sources talk about increased complexity through information overflow. Gorman et al. (2000) also discuss the role of other physical support for technology related to information management (Kardex notes, ICU flow sheets, Resident's worksheets…), with a generally positive emphasis on the performance. Technology to make information mobile (Hajiheydari & Hanafizadeh, 2013), as well as relying on other organizations to provide information management and technology has also been subject of performance related research (Talpeanu & Rusu, 2017). Also studies within business research, assign platforms and tools to manage information an important role (Lavassani & Movahedi, 2017). Can technology add to information quality when presented with task complexity?

ANALYTICAL MODEL AND RESEARCH QUESTIONS
BASED ON THE THEORY PERSPECTIVE

Similarly to Hærem et al. (2015), and drawing upon Oeser and O'Brien (1967), Schoonhoven et al. (1980) explain *TC* and uncertainty via 1) *"the set of activities performed"* when performing a task (eg triage) and 2) the set of choices which the actor has to choose from. At the same time, we take into account literature such as Wright et al. (2004) and Endsley (2017), where *SA* always precedes the

decision task. Hence, it is *SA* rather than decision making or task fulfilment, which is most closely connected to the *TC* variable. A preliminary model, therefore, should contain the variables: situation awareness, *TC* and information.

Based on the review of the extant literature, we pose two research questions:

RQ1: What is the role of information in reducing task complexity?
RQ2: What is the role of *SA* for mediating information and task complexity?

STUDY FIELD AND RESEARCH OBJECT

Choosing the right study context may be relevant. Gorman et al. (2000) state that context characteristics may be important for a model including task complexity. Characteristics include the user (or research subject), the task they have to perform and the information space they are operating in (ibid.). Previous studies are located among others in the area of *SA* in clinical settings (Gorman et al., 2000) and children's hospital intensive care units (Brady et al., 2013).

Our research rests in a medical setting. It focuses on so called ambulant staff (actors) connected to a Northern Norwegian hospital. We have determined that a study of these actors, who require *SA* to deal with task complexity, helps to elaborate on our research questions. The relevant sub-organizations for data-generation stem from the "Norsk Indeks for Medisink Nødhjelp"/[Norwegian Index for Medical Emergency Aid] (NAKOS, 2018). The ambulant staff is connected to the following sub-organizations:

- **"*Akuttmedisinsk kommunikasjonssentralen*" [Ambulance communication center] (AMK):** Actors at AMK coordinate the ambulance resources to and from an incident-site. They need to be in constant contact with the incident commander health (who is part of ambulance on an incident site) as well as the ambulance-centers. AMK is connected to the joint planning headquarters by ambulance, police, fire brigade, the (so called SAMLOK) located in Bodø/Northern Norway;
- **Ambulance:** These actors can be sent via air or ambulance-car and are often the first professionals on site. They receive information from AMK and take the relevant decisions on site. This unit also includes the position of ***incident leader health* (ILH)**, which is a main role during coordination of larger incidents and is located at the ***incident leader commando area* (ILKO)** on site;
- **330 Squadron:** In Bodø, the area of this study, this military-affiliated helicopter unit supports airborne activity. They carry on board a doctor from the hospital and rescue personnel with ambulance education. They are often faster than ambulance cars and have an important role in difficult terrain (sea, mountains,…);
- **"*Akuttmottak*"/*Emergency room* (ER):** Actors in the ER will be the ones to receive the patients at the hospital. They need to assess what to do with the patients and what resources to mobilize and use.

The *Norwegian Index for Medical Emergency Aid* (NAKOS) stated a main challenge connected to *SA* in ambulant work: *"Systemene for lokal, regional og nasjonal registrering og rapportering holder ikke det kvalitetsnivået som er ønskelig"* [The systems for local, regional and national registering and reporting do not meet the desired quality level] (Nilsen et al., 2014, p. 18). Hence, it is important to understand which challenge within the Norwegian system these actors will face to create *SA* and to manage to handle *TC* beyond their own position. Two types of *SA* are important in the ambulant field:

- **Situation awareness concerning patient:** When it comes to *SA* within the health sector, studies such as Braddock, Fihn, Levinson, Jonsen, and Pearlman (1997, p. 340) provide a good insight on the implications of performing a task: Namely, *"committing to a particular course of action"*.

Nonetheless, these studies focus mostly on the tasks directly related to the patients and they observe both cues for *SA* and decision made (Ofstad et al., 2014);

- **Situation Awareness Concerning Logistic:** When faced with task complexity, (e.g. a mass-rescue incident; special incidents such as *chemical, biological, radiological and nuclear defense* (CBRNE) or incidents with *ongoing life-threatening violence* (pågående livstruende vold (PLIVO)), the operational aspect related to the logistics of a rescue operation becomes more and more important, as well as a main concern of situation awareness.

These two types of situation awareness, "patient" and "logistics", are interwoven and find consideration in every role. Nonetheless, this study mostly concentrates on the second one - logistics.

When it comes to information management within the Norwegian ambulance system, a set of standards provide clear framework for decision tasks. One of the most important standards is the previously mentioned Norwegian Index for Medical Emergency Aid (NAKOS, 2018). Within the standard, a group of mass-rescue incidents *("masseskadehendelse")* are mentioned as particularly critical due to time-resources-challenges. Time-critical information related to availability and mobilization of resources to the incident site is therefore regarded as crucial for studying situation awareness:

Kjørevei, Møteplass, Innsatsområde, Skadeomfang, Melder, vitner, mv; farlig område, Situasjonsrapport fra første enhet på stedet, Viktig informasjon for den videre planlegging av ressurser, I form av materiell, personell, beredskap osv. [Infrastructure, meeting places, areas of operation, extent of injury, person reporting from the incident site, dangerous areas, situation report by the first professional at the site, important information for further planning of material-, personnel- and emergency resources] (NAKOS, 2018, p. 21) are all part of the important information.

As an example, when it comes to mass-rescue incidents, the "Nasjonal veileder for masseskadetriage"/[national guidelines for mass-rescue triage] come into play, particularly as long as there is an imbalance between the quantity of injured people and the available resources (Helsedirektoratet, 2013). This shall support *SA* towards the right issues. According to the document, "common" principles of documentation will come back into play as soon as enough resources are restored.

METHOD

To acquire knowledge on the variable (situation awareness),– a look at the explanation of previous studies helps to gain an understanding of how to measure it. Brady et al. (2013) define key indicator events which demonstrate a lack of *SA* in case they appear. Gaba et al. (1995) refer to Tenney et al. (1992) and Sarter and Woods (1991), who introduce hypothetical scenarios and simulations to gain an insight into the *SA* (in this case, most likely a perceived situation awareness).

Wright et al. (2004), on the other hand, highlight several means of measuring including measurement of direct performance (time on task, rate of error, deviations from the objective), mental measures of side tasks - which indicate that the actor is not too invested with the core-task - and physical analysis of the task-performers' body (e.g. Eye tracking, time used…). When it comes to tasks with potentially unclear objectives, these studies are aware that objective measures (such as *Goal Directed Task Analysis* (GDTA) [compare Gaba et al. (1995)]) may be challenging, hence a subjective assessment is needed. The present study is therefore framed on a data generation based on hypothetical case discussion with actors connected to the study object. Observation of the incident leader health (ILH) at exercise NORD 2019, a full case mass rescue exercise, provides in-depth data.

The first methodological step was to cooperate with the potential sub-organizations throughout informal interviews. This created an understanding of the relevant types of tasks to be assessed. These tasks were related to the decision makers' *SA* under task complexity.

In a second step, semi-structured interviews were conducted to gain further insights into the relations between situation awareness, *TC* and information. In contrast to Schoonhoven et al., who followed a quantitative approach (Schoonhoven et al., 1980), this study has built up theory by a qualitative case study approach.

Questions were related to background of participant, information and professionalization-related topics and situation awareness, as well as further considerations, context and on-task complexity. The following table describes the interview participants.

RESULTS

This research is aimed at finding out what the role of information is in the light of *SA* capability under task complexity. The results show that information has a substantial effect on task complexity, as well as that it interacts with the dependent variable situation awareness.

Situation Awareness Under Task Complexity

The criticality of a mission, or at least how critical it is assessed to be, plays a large role on how complex the following tasks will be and how urgent the actors judge the situation. On both the operational and the tactical level, the actors in the study acted on the basis of two main premises concerning *SA* and relevant information.

Situation Awareness on Risk, Safety, Criticality and Urgency

The first premise for on-site actors is personal safety and assessment of risks connected to any activity at the incident site. Aspects such as perception of elements in the environment like weather conditions (e.g. mass rescue at sea or avalanches), threats from potential chemical, biological, radiological and nuclear (CBRNE) material, personal security-related aspects (e.g. ongoing life-threatening violence (PLIVO)), all these issues were brought up, which made the ambulance work more complex and the actors more dependent on their network.

Hereby, the interviews showed, how much importance is given to communication systems and pre-installed procedures and hierarchies. As an example, while more common ambulance tasks rely on the self-responsibility of an actor, some of the above aspects require specialized knowledge connected to roles with the legitimacy and responsibility to decide over others.

S09, for instance explained the legitimacy of a leading role for cooperation on operational level if both ambulance, police and fire brigade needed to mobilize:

Det er gjerne politiet som oppretter den talegruppa, for det er de som har styringen med det. Så da setter de en radio i den. Så da kan vi kommunisere bare med ambulansen i en talegruppe, og så kan de også kommunisere med sentralene her og med hverandre i den andre talegruppa. [It is often the police who create that speech group, because they are the ones with the control. So they put the radio on. So then we can only communicate with the ambulance in one speech group, and then they can also communicate with the centers here and with each other in the other speech group].

An example concerning safety and relying on another tactical actor was given by S11:

jeg sa til første redningsmann… så gikk han og snakket med en person som var i skredet og undersøkte litt og så ble vi enige om at jeg også skulle ned, så ble jeg heist ned. Og da hadde vi på oss snøskredsekk og sender/mottaker og søkestang og alt vi trengte for å lete og grave. Men da ble redningsmannen

Table 1. List of interview partners

Source Acronym	Organization	Position	Organizational Level (Tactical, Operational, Strategic)
S1	Nord University	Study program leader / faculty for ambulance and health-sciences	-
S2	Nordland Hospital	Assistant leader of Emergency Room	tactical
S3	Nordland Hospital	Specialized nurse / in charge of training- and exercise	tactical
S4	Ambulance of Nordland Hospital	Leader of ambulance	tactical
S5	Ambulance communication center (AMK) of Nordland Hospital	Leader of AMK	operational
S6	Nordland Hospital and AMK	Specialized nurse (coordinator at ER, 113-operations AMK)	Tactical
S7	Ambulance of Nordland Hospital	Leader of Ambulance, Bodø region	-
S8	Nordland Hospital and AMK	Professional 113-operations AMK	operational
S9	Nordland Hospital and AMK	Specialized nurse, professional 113-operations AMK	operational
S10	330 Squadron	Rescue operator	Tactical
S11	Nordland Hospital / 330 Squadron	Medical doctor both at 330 Skvadronen and Nordland Hospital	Tactical
S12	330 Squadron	Pilot, helicopter operations lead	Tactical
S13	Nordland Hospital and AMK	Specialized nurse (coordinator at ER, 113-operations AMK)	Tactical
S14	Nord University	Specialized ambulance, Observer/Conducteur at Exercise NORD for paramedics and ILH position	Tactical
S15	Nordland Hospital / Vesterålen	Specialized ambulanc, Observer/Conducteur at Exercise NORD for ILH position	Tactical
S16	Ambulance of Nordland Hospital	Spec. ambulance, ILH role at Exercise NORD	tactical

sendt ned først for at han har større forutsetninger for å gjøre sånne vurderinger og for å bevege seg i snøskredet enn det jeg hadde, før han fant ut at det var trygt, og så kom jeg ned. Så både egen og gruppesikkerhet er viktig. [I said to the first rescuer ... then he went and talked to a person who was in the landslide and investigated a bit and then we agreed that I should also go down, then I was taken down. And then we had avalanche backpacks and transmitter / receiver and search bar and everything we needed to search and dig. But then the rescuer was sent down first. He had greater preconditions for making such assessments and for moving in the avalanche than I had before finding out it was safe, and then I came down. So both self and group security are important]

Updates on Current and Future Complexity

The second premise is more connected to the wellbeing of the patients. After the obligatory assessment of the first responders on the criticality of patients (mostly procedure-driven), and after bringing the patient to a safe spot and calling the necessary resources, recurrent information gathering and situation update is performed. This process, together with gathering subtle cues from the environment, is necessary in order to paint a shared mental model of potential worst case scenario for the situation.

If the shared mental model is not painted, examples show, that actors from different sub-organizations would have different situation awareness. S11 stated:

Sånn tilbake til det snøskredet som jeg var ute på for noen uker siden. […] midt i hendelsen, en time etter at vi hadde vært der for eksempel, så ville nok vi på skadestedet, de på politiets operasjonssentral, de på AMK, de på HRS ville sitte med forskjellig situasjonsforståelse. Fordi at det blir veldig mye prat på nett og det blir vanskelig at alle får med seg alt. [Back to the avalanche I was out a few weeks ago. […] In the middle of the incident, an hour after we had been there for example, then we probably would have been at the scene of the injury, those at the police operations center, those at the AMK, those at HRS all would have different situation awareness. Because there is a lot of talk on the web and it becomes difficult for everyone to get everything done.

S04 gave a good insight on how important SA updates were for patients with critical situation:

Det er jo å gjøre de samme vurderingene på nytt flere ganger gjennom et oppdrag. Måle blodtrykk gjentatte ganger, måle pulsen, følge med på EKG, overvåkning rett og slett [It is, after all, to make the same assessments again several times through a mission. Measure blood pressure repeatedly, measure heart rate, monitor ECG, simply monitor…]

The above example may be used to reflect on the dynamic elements in the management process of each actor's tasks. Even though they often follow clear procedures and have a general mental model on what to do, additional information both from patients, from colleagues (horizontally, vertically, diagonally) and the environment may require some of the actors to restructure their tasks.

While a path of recurrent gathering of information increases the *TC* at present, it potentially decreases each individual's future task complexity. This is done by providing necessary additional information and other resources to enable the shortening of future pathways or distribute sub-goals to available additional resources. An example by AMK S05 provides a good understanding:

så er det jo det potensielle i dette her du må prøve å forestille deg i tillegg, alle eventualiteter. For eksempel sender vi et helikopter ut til en plass det går an å kjøre så sender vi alltid en ambulanse, for du vet aldri om at det helikopteret verken får landet eller få tekniske problemer. Så vi er alltid at vi kjører dobbelt. Det er en sånn både/og. Du må jo alltid ha prosedyreverk i bunnen som sier noe om hvordan det skal gjøres. Men så lenge du har det så har du muligheten til å være kreativ og finne løsninger som ikke passer inn i det verket, så lenge du har det i bunnen. Vanskelig å forklare. [Then

there is a possibility that you must additionally try to imagine all eventualities. For example, we send a helicopter to a place that can be reached by car and we always send an ambulance, because you never know. The helicopter might not be able to land or get technical problems. So we always have a backup. It's either or. After all, you always have to have procedures at the bottom that say something about how to do it. But as long as you have the procedures you have the opportunity to be creative and find solutions that do not fit exactly to the procedure. As long as you have the procedure as a basis. Difficult to explain.]

The data showed that all actors were aware of the limitations of every-day resources and that receiving additional resources was often the most critical issue. It means that with lack of resources, there were tasks that were too complex for the existing actors and what they had available. Information management could help to mobilize a share of relevant alternative resources. For instance, there was a so-called "catastrophe alarm" across the sub-organizations. This would transmit an automatic information and warning to all sub-organizations to mobilize extra resources, which would in turn increase both physical resources and capabilities to increase the information flow and the situation awareness.

Complexity and Sub-Paths, -Ties, and -Goals

When it came to the overall complexity of the organization of ambulance work at exercise Nord, there was a multitude of actors from different sub-organizations. This network was described by S11 to include:

112, altså politiets operasjonssentral, AMK-sentralen, 1-2-3 ambulanser, hvor hver enkelt har et håndsett radio, 1-2-3 leger, redningsmann, Røde Kors kan melde seg inn i tilsvarende gruppe, redningshundene…det blir ganske mange. og da kan det være vanskelig å få oversikt over alle som er der. [the police operation center, the AMK-central, 1-3 ambulances, where each one has a handset radio, 1-3 doctors, rescuers, the Red Cross can join a similar group, the rescue dogs ... there are quite a few. And then it can be difficult to get an overview of everyone who is there]

This is a quote about the different stakeholders' sub-organizations, but one should keep in mind that, in addition, inside each sub-organization there could also be a multitude of specialists. The trauma-team at the emergency room, which is the latest stage this study looks at, is a good example. When we observed them gathering to take care of a young patient, a plethora of actors was summoned – among others anesthesiologist, an anesthesia nurse, surgical nurses, reception nurses, a general surgeon, an orthopedic surgeon, a neurosurgeon, a radiographer, a porter, a radiologist, a bioengineer and support personnel such as doctors in education and observers. Altogether our observer counted close to 20 persons who had mobilized to receive the patient.

In order to handle these logistic challenges, it seems that all the actors in the ambulant field are operating with a shared mental model of an overall goal related to their task – namely saving the lives or health of most possible people. On a daily basis, in most of the cases complexity is in a range that is manageable by all with the spectrum of procedures. With these procedures in mind, S05 from AMK stated that "Vi tenker ikke så komplekst når telefonen ringer inn, vi tenker veldig sånn systematisk abcde… enkelt" [We don't think so complex when the phone rings, we think very systematically abcde ... easy]. A statement that strengthens this point was given by S13: "det kan gå fortere rett og slett på grunn av at de har jo det samme triagesystemet i ambulansene" [it can go faster simply because they have the same triage system in the ambulances].

When a case becomes more complex, however, it should be noted that - according to our observations - reaching major goals under *TC* mostly worked out by dividing the major goals into sub-goals. The less common the set of sub-goals, the less likely that procedures are available. Also,

more persons may be assigned similar tasks. This leads to a decrease of the clarity of sub-goals, a decrease of the necessary ties as well as a decrease of the paths to reach the sub-goals. S05 described this process well by stating that:

målet er jo veldig enkelt: vi skal redde flest mulig liv. Så for oss er det ikke så vanskelig. Og det gjelder jo for brann og politi også. Så er det en stor hendelse så er det det vi skal gjøre. Men vi har jo alltid delmål for at vi skal lykkes best mulig i en sånn prosess. Veldig ofte store hendelser så… et av delmålene vil alltid være å ikke skape flaskehalser som gjør at du må sluse mennesker igjennom en masse sjekkpunkter før du kommer fram til de som faktisk kan gi dem behandling. Og det vil jeg jo kalle delmål. Så vi har mange sånne punkt underveis i en hendelse. [the goal is very simple: we want to save as many lives as possible. So for us, it's not that difficult. And that applies to fire and police as well. If it is a big event then that's what we're going to do. But we always have sub goals to succeed in such a process as best we can. Very often in big events... one of the sub-goals will always be to not create bottlenecks that require you to lead people through a lot of checkpoints before you reach those who can actually treat them. And I would call that a sub-target. So we have many such points along the way in an event]

While S05 painted a rather clear picture of how several actors and sub-goals could result in decrease of task complexity, other sources mentioned the opposite: They stated how different actors could have different type of sub-goals, which in turn would raise complexity. This may make it more difficult to achieve overall *SA* and have a complete shared mental model. Conversely, predefined procedures may have the potential to provide better shared mental model, as expressed by S14:

Jeg tror at en av de største utfordringene i helsevesenet i dag, altså i ambulansetjenesten i dag, det er det at vi ikke har forhåndsdefinerte ledere. Sånn at ved en reell hendelse så er det en risiko for at første enhet til stedet har en relativt fersk ambulansearbeider som tar rollen. Og det står jo i tiltaksboka vår at mer erfaren personell kan komme inn og ta over rollen, men det ligger ikke noen automatikk i det. Og vi har ikke noen retningslinjer på det. Sånn at mange ganger på mindre skadested så har jeg nok sett det at vi har litt uerfarne og uautoritære ledere som forsvinner litt og ikke tør å stikke seg fram og ta ansvar. [I think that one of the biggest challenges in the health care system today, I mean the ambulance service, is that we do not have predefined leaders. So in case of a real event, there is a risk that the first unit of the site has a relatively fresh ambulance worker taking the role. And it says in our action book that more experienced personnel can come in and take over the role, but there is no automaticity in it. And we don't have any guidelines on that. So many times at a minor injury site, I have probably seen that we have a bit of inexperienced leaders with less authority who disappear a bit and do not dare to step forward and take responsibility.]

The above quote represents an exception within the ambulance section, other response organizations such as military, police and fire-brigade rely more on procedures for predefined on-scene leaders. Also in the presented study, on many positions there had been established institutionalized roles and hierarchies. Also, there were ad hoc- platforms and methods for learning. These would be directed both towards individual *SA* capabilities as well as shared *SA* via shared procedures and mental models. Yet, in many of the positions there were not sufficient back up resources to free people to do substantial training and learning of specifically complex tasks.

Likewise, also when it came to debriefing and defusing to create shared awareness and mental model of the operations after a difficult case involving (too) complex tasks, many informants stated that more such options would be welcome. This showed that some sub-organizations did have structures for debriefing and defusing in place, while others were struggling due to lack of time and resources.

One testimony showing that there could be greater focus on more debrief was given by S13:

Jeg føler at det er blitt mindre og mindre å lære av det man gjør, fordi at man får ikke… man ser pasienten, man hører pasienten i et bitte lite tidsvindu, man vet ikke hva som skjedde før, man får et lite resyme, så sender man ut ressurser og får hjelp av pasienten, og så vet man ingen ting, vi får ingen feedback på hvordan det går med pasienten. Og det er jo veldig utilfredsstillende, for vi mister jo den læringsbiten, at man vet om man faktisk gjør rett eller… [I feel that it has become less and less to learn from what you do, because you do not get… you see the patient, you hear the patient in a tiny window of time, you do not know what happened before, you get a short summary. So you send out resources and get help for the patient, and then you know nothing, we get no feedback on how the patient is doing. And it is very unsatisfying, because we lose that learning bit, that you know if you are actually doing right or…]

In conclusion, the present study showed that deeper insights on learning could provide further knowledge related to *SA* and *TC*, and how organizations may prepare for it.

INFORMATION QUALITY AND TASK COMPLEXITY

Relevance of Information

Specific knowledge elements which are stored somewhere in the system – either via mental models in guidelines, rituals, procedures or habits, but also elements specifically stored by each actor – were relevant for this study. These types of information could be retrieved and applied when necessary. In this study, particularly as regards the assessment of risk and safety, but also when it came to finding out what to do with patients or where to get further resources, all actors had specific roles and responsibility. This helped them to assess and provide relevant information for the ongoing processes.

As an example, the helicopter rescuer (Redningsman) reflected on his/her responsibilities connected to how to salvage persons from a ship. S10:

For hvis jeg hadde brekt en arm på båten så hadde på en måte de vært overlatt til seg selv, for da hadde vi ikke hatt noen backup. Mens i havet så er det… selv om bølgene var store så var det ikke… havet er ikke så hardt, det er litt mykere enn stål, så… [Because if I had broken one arm on the boat then in a way they would have been left to themselves, because then we would have had no backup. While in the sea it is ... even if the waves were big... the sea is not so hard, it is a bit softer than steel, you understand.]

While this piece of information concerning logistics was to be assessed by the rescue operator, other positions in the crew were in charge of other aspects. For instance, questions concerning the approach on medical issues were taken care of by the medical doctor on board. S11 gave a good insight into responsibilities by different roles at the 330 squadron:

Hvis det er medisinske oppdrag hvor de vil diskutere om man skal bruke helikopter eller legebil så ringer vi til legen på vakt. Og så bestemmer jeg. Og så… er det helt åpenbare medisinske hendelser hvor AMK melder til HRS [Joint Rescue Coordination Center] at de vil ha et helikopter, og da sender HRS da alarm til oss. Og så er det da helt åpenbare redningsoppdrag hvor HRS får en melding som da… hvor de da sender oss ut direkte. Men hvis det skal diskuteres, altså hvis det er en diskusjon rundt skal/skal ikke osv. så er det legen… [If there are medical assignments where they want to discuss whether to use a helicopter or medical car then we call the doctor on duty. And then I decide. And then ... there are obvious medical events where AMK reports to the JRCC [Joint Rescue Coordination Center] that they want a helicopter, and then JRCC sends an alert to us. And then there are completely obvious rescue missions where JRCC gets a message... where they then send us out

directly. But if it is to be discussed, that is if there is a discussion about should / should not etc. then it is the doctor who decides.]

It should be stated that our data demonstrate how these aspects are additionally connected to issues of background and professionalization. Both observation and interviews showed how further experience and background created further capability. Also teamwork and integration into the team via workshops and exercises seemed to do something to increase legitimacy and trust. This, in turn, seemed to affect task complexity, albeit more on a perceptive - or subjective - level rather than objectively measurable. Tasks were characterized as complex by S05 when:

Det er skadepotensialet eller risikoen vi utsetter våre ansatte for. Og en del prosedyrer de da må følge på det området som går på beskyttelsesutstyr og du har lov å gjøre sånn og sånn og ikke sånn. Jo større skadepotensial, jo mer komplekse blir prosedyrene. [It is the potential injury or risk that exposes our employees. And some procedures the employees have to follow are about protective gear. The greater the potential for injury, the more complex the procedures become.]
Also it was mentioned that "Du har prosedyrene, men de er jo bare en liten byråkratisk del i alt dette her. Det er jo erfaringer, utdanningen, personlighet, kombinasjon av mennesker, hvor mange mennesker, altså kompleksiteten, det er jo så vanskelig at det er bare noe du må forholde deg til og vite at det er der. Men det er jo det… alt påvirker jo, sånn at det samme vaktlaget i dag kan jo ha helt annerledes i morgen." [You have the procedures, but they are just a small bureaucratic part of all this. After all, it is the experience, the education, the personality, the combination of people, how many people, that is the complexity, it is so difficult that it is just something you have to relate to and know that it is there. But that's it ... everything creates effects, after all, so that the same team today may have completely different tasks tomorrow.]

While experience is touched upon in some of the findings, a choice had to be made not to plough too deeply there, as it would go beyond the limits of the study.

Timeliness

Timeliness of information refers to the actor having available relevant information at hand when it is needed. This also means that some information should not be generated too early, as it would not be relevant by then, or it would take up too many of the capabilities connected to situation awareness. However, the studied sub-organizations showed that it was crucial that information be timely and more or less standardized in order to create a solid model of potential scenarios – particularly information by the first responders. This timely initiative was regarded as the main factor for success in the operations, as we can see from the following statement byS15:

Og når man da kommer fram så har man en inngangsverdi for å skaffe seg ytterligere presis situasjonsforståelse og mens de i større deler denne hvis man har den tidlig. Og da vil igjen det være en eksponentiell effekt av det, hvis situasjonsforståelsen kommer kjempetidlig så vil en [uklart] 38:20 tidlig, og bli oppfattet av flere tidlig. Og det er avgjørende for å lykkes egentlig. [And when you arrive then you have a start knowledge to gain even more precise situational understanding and it is profitable if you have it early. And then again it will be an exponential effect of that, if the situational understanding comes at a timely pace then understanding will be early, and will be perceived by several early. And it is crucial to succeed really.]

This first information prepared actors who will have to perform tasks connected to the patient on a later stage. Whether the informants were from ambulance drivers, the 330 helicopter squadron

or the hospital's emergency room, all stated that it helped to have a better comprehension of what they could expect.

However, as much as the timely accumulation of information was valued, it was highlighted several times that - in many case -, tasks have to be performed without access to complete information and situation awareness. As a result, the actors, even if they were aware of increased *TC* with potential information deficit, had to take action because of time scarcity. The following statement by S15 also provides a good insight:

En må organisere seg. Ikke overorganisere seg og ikke oversikkerthetstenke, men begynne å organisere seg sånn at kaosfasen blir kortest mulig. For kaosfasen er alltid der og det er bare å akseptere at den er der. Og da er vi over i driftsfasen. Og da er det så fort som mulig å få flest mulig folk ut i feltet for å redde liv. Gi fri luftvei, legge i sideleie, stoppe blødninger, forebygge hypotermi. [One has to be organized. Do not over-organize and do not think about uncertainty, but start to organize in such a way that the chaos phase (uncertainty) becomes as short as possible. Because the chaos (uncertainty) phase is always there and you just have to accept that it is there. And then we go over in the operational phase. And then it is to get as many people as possible, as fast as possible, into the field to save lives. Provide free airway, lay them on their sides, stop the bleeding, prevent hypothermia.]

While timeliness was so closely connected to the information variable used in this study, several aspects of time may prove to be a variable connected to complex tasks themselves (similar to professionalization); yet it would go beyond the limits of this study to expand further on this topic.

Information Coordination and Information Hubs

Previous findings of this study indicate that goals may be sectioned into sub-goals, which may impact task complexity. However, information flow is also sectioned. The data shows how important a structure and the sectioning of information coordination can be, particularly when it comes to incidents involving a lot of resources. The observed system even went as far as to provide two operational hubs which both coordinated information and the movement of medical resources.

During exercise NORD 2019, operational level land-based tasks were coordinated by the Ambulance communication center (AMK) (as part of the joint planning headquarters by ambulance, police, fire brigade - called SAMLOK- led by the Police), while the sea-based action was coordinated by the *Joint Rescue Coordination Center* (JRCC). This led to two almost individually driven networks, connected to each other only to a minor degree. Information on available resources and overall prioritization of either land- or sea-based patients by air-borne resources were coordinated by those two centers, with little or no exchange of information between tactical resources. S15 could shed som light on the challenges:

Sånn som det var lagt opp eller sånn som det ble i denne øvelsen så har du faktiske en landoperasjon og så har du en sjøoperasjon. Og innsatsleder politi er leder på land, og on scene coordinator er leder på sjøen. Så her hadde du på taktisk nivå to forskjellige operasjoner som foregikk parallelt som var veldig lite avhengig av hverandre. Ledelse for on scene coordinator det er hovedredningssentralen. Ledelse for det som skjer på landoperasjonen det er det vekselsentralene, altså politi, brann og helse. Så til og med på operasjonelt nivå så hadde du to operasjoner pågående som var ganske lite avhengig av hverandre. [As planned for in this exercise, you actually have a land operation and then you have a sea operation. And the chief of police forces is the leader on land, and the on-scene coordinator is the leader at sea. So here you had on a tactical level two different operations that were going on in parallel that were very little dependent on each other. The management for the sea-based on-scene coordinator is the Joint Rescue Coordination Center. Management for what happens at the land

operation are the coordination centers for police, fire and health. So even at the operational level you had two operations going on that were quite little dependent on each other.]

Nonetheless, S14 stated how important these platforms and potential information hubs were:

Og ved en stor hendelse, sånn som Øvelse Nord, hvor vi kanskje må jobbe på tvers av foretak på et nasjonalt nivå, da er det kjempeviktig at vi alle har en felles plattform som er lik for alle sammen. [And at a big event, such as Exercise Nord, where we may have to work across organizations at a national level, it is crucial that we all have a common platform that is the same for everyone.]

An absence of exchange between coordination resources on the tactical level, whether good or bad, was clearly displayed at the incident leader command site (ILKO) position for the land-based incident. The helicopter resources were all used in the sea-based action to lift people off the boat. Yet, both incident leader health (ILH) and the ILKO-incident leader stated that their *SA* was such that they critically needed helicopter resources to transport critically injured people to the hospital. However, it seemed they did not have the ability and legitimacy to contact the tactical resources of the sea-based action. In the words by ILH (S16):

på en måte at det ble to skadeplasser. Men for min del så tror jeg jeg hadde evig nok med den informasjonen som vi hadde på det skadestedet. Og ved ressursbehov osv. så føler jo jeg kanskje at så lenge jeg forholder meg til innsatsleder [Police] så er det hans jobb på skaffe til vei det som trengtes. Så jeg føler vel ikke at jeg hadde behov for å høre på det ute på ferga også [in a way there were two incident areas. But for my part, I think I had enough with the information we had at my incident site. And when it comes to resource needs, etc., I feel that as long as I relate to the incident leader [Police], it is his job to get what is needed. So I don't feel that I needed to listen to the information from the ferry as well]

Neither did the ILH feel that they were fully heard when they were in touch with AMK (land-based coordination), in order for them to negotiate more with JRCC (sea-based coordination) to free helicopter resources. Whether this was only ILH's perception, whether JRCC and AMK made the decision not to relocate the resources together based on available information, or whether one of the coordination hubs had more authority to decide over the resources not based on available information, can at this stage not be said. What can be assessed, however, is that information coordination and hubs were not providing satisfactory *SA* at tactical level, thus creating inefficient extra sub-paths when actors sought to find out more or tried to be heard.

The above paragraph indicates another important point when it comes to the information coordination function. It is connected to the authority and sound of information communication. While on an operational level it can only be speculated that this may be an issue, on a tactical level several sources stated that the degree of authoritativeness and loudness as well as the type of body language actors used to convey the information would influence the effect of delivering the information and the receivers' awareness of its relevance. S13, for instance, stated that *"noen er tunghørte og så snakker de litt høyere og så… Noen er mer ivrige og av og til så er det litt unødvendig prat, det er det"* [some do not listen so well and then they talk a little louder and then ... Some are more eager and sometimes there is some unnecessary talk, that's it.]

Also S14 offered an insightful observation:

Og det er klart at de som er litt sånn sammensunkne, litt forsiktige og stille, de når ikke like godt fram. Hvis du er rett i ryggen, brystet litt fram og bruker litt tydelig stemme så blir du lagt merke til. Det er veldig, veldig tydelig. Det har mye å si. [And it is obvious that those who are a little more

reserved, a little cautious and quiet, they do not reach as well. If you are straight in the back, chest slightly forward and use a clear voice then you will be noticed. It is very, very clear. It has a lot to say.]

Overflow of Unprocessed-Lack of Processed Information

The aspect which the information hubs try to overcome is not only the bare distribution of resources. The second objective of information hubs appears to be connected to the distribution of information, as is reflected by several different aspects.

On the one hand, there are actors who are presented with an overflow of information. In this case, actors may either have to deal with too much unprocessed or less-relevant information. If the time aspect in those situations is not critical, and the actors have enough resources to handle the information, they have the capability to create additional *SA* with the information. Yet, in case of lack of time or extreme focus on a task, this type of information may constitute a hinder and the information hubs may counteract this.

Similarly, when it comes to task complexity, the interviewees mentioned that they (as an actor) only had a certain amount of overall capability to give or receive information. This meant that wrong timing could lead to information being held or not getting through to the intended recipient. It could also mean that processes were interrupted if the communication was not going seamless, or if the recipient was currently occupied with a demanding activity. For instance, a helicopter pilot (S11) stated:

Du prøver å filtrere ut mye når du… hvis man hører mye på radio. Men samtidig så hender at vi bare sier at nå må vi… nå må dere slutte å prate til oss for vi… La oss si man står i en type sånn heiseoperasjon hvor man står og heiser på en båt som beveger seg. Da kan ikke piloten sitte og prate på radioen, da må… vi er opptatt med å fly, maskinisten og systemoperatøren er opptatt med å heise, og lege og redningsmann er opptatt med å heise inn eller heise ut. [You try to filter out a lot when you ... if you listen a lot to the radio. But at the same time we just say that now we have to ... now you have to stop talking to us before we ... Let's say you are in a kind of lift operation where you stand and lift on a moving boat. Then the pilot can't sit and talk on the radio, then ... we have to fly, the machinist and the system operator are busy hoisting, and the doctor and rescuer are busy hoisting or hoisting out.]

On the other hand, there may be actors who are presented with a lack of relevant information, when the system or network around them is not capable or aware of providing the relevant information. Another observed cause in the data was when the actors themselves were not capable of extracting the relevant processed information out of the patient or the logistics. In our material we found an array of examples, which also include an overflow of irrelevant information:

Jeg følte jo på en måte det hele tiden at jeg klarte stort sett ikke å få hodet over vannet holdt jeg på å si, i og med at jeg ble såpass nedjammet av informasjon. […]. Ja som du sier, tiden gikk jækla fort når du ble nedlesset av informasjon. [I felt, in a way, all the time that I was unable to get my head above the water, as I was loaded up by them with information. [...]. Yes as you say, time went by fast when you were overloaded with information.] (S16)

It can also mean a lot of irrelevant information and noise:

Men av og til så kommer det inn ting der som er uviktig, som ikke burde ha vært der men som jeg tror går på kapasiteten på hvor mange talegrupper kan det være på. Hvis du har bare en terminal så må du velge en der alt foregår. [But sometimes things are mentioned there that are unimportant - things which should not have been there. I think this affects the capacity of how many speech groups there can be. If you only have one terminal then you have to choose one where everything is going on] (S12)

In this light, a capability for the communication of information is particularly crucial. However, depending on the situation and the actor at hand, there are some factors that may impact on the transmission of the information. The study showed that, particularly when it came to oral communication, both sound and timing were a factor that affected the transmission of the information. This is demonstrated by an example from exercise Nord: on the tactical level, there was a lot of noise production due to helicopters flying in and out. This made the task of communicating for creating joint *SA* more complex.

Information Technology: Efficiency of Information Flow

In order to lower the potential for lack of timely and relevant information and overflow of irrelevant information, all organizations in the study had adopted technologies such as procedures, tools and IT-based decision support systems.

The multitude of these technologies shows how specialized some of the complex tasks are. Yet some tools observed in the study were jointly used in different organizations, as was the case for some more general practices. In general, it can be said that for most of the participants the principal aim of the technology, was to provide quicker relevant processed information if needed. Additionally, some technology was relevant to pass information from one actor to another, for log keeping and to provide brainstorm- or decision-making capability. Particularly when it comes to the passing on of information, several factors were raised concerning the technology.

First, there seems to be a current transition phase from physical to digital information systems. Information systems are also becoming more automatized. S13 highlighted the benefits of automatized IT through the following example:

4-6 år siden da var det et cruiseskip som gikk på grunn i Lofoten. Og det er klart at da er det lite med 3 personer. Men det gikk jo heldigvis bra. Men han som var ambulansekoordinator… jeg er sikker på han hadde flere hundre telefoner… nei det blir kanskje litt mye da, men kanskje 100 telefoner, og må ringe til alle mulige slags legekontor, han må ringe til kommunelege, han må ringe å få inn sykehusleger. Så det er et stort apparat som skal hentes inn. Men nå har vi denne UMS som vi… Uniformed Message System der vi sender ut digitalt, så der kan vi nå de fleste rett og slett med en melding på telefon. Og det blir letter det, det er det. [4-6 years ago there was a cruise ship that crashed in Lofoten. And obviously three people at the coordination center is little. But luckily it went well. But the ambulance coordinator ... I'm sure he had hundreds of phones ... no it may be a bit much then, but maybe 100 phones, and he needed to call all kinds of doctor's offices, he had to call the municipal doctor, he needed to call to get hospital doctors. But now we have this UMS... Uniformed Message System where we send out digitally, so there we can reach most people simply with a message on the phone. And it gets easier.]

Also S09 emphasized that:

Det er jo det med kartet som jeg sa, at vi får inn alle nye adresser i kartet. Ellers så har vi bra system synes jeg. Jeg har jo vært her så lenge at vi satt og skrev med penn og papir, så jeg synes jo det er helt fantastisk at vi har her og at alle ser hva de andre skriver. [When it comes to the map, we should get all new addresses in the map. Otherwise, we have a good system I think. I have been here for so long. We sat and wrote with pen and paper, so I think it is absolutely wonderful what we have now and that everyone sees what the others write.]

Like the interviewees stated above, in the past there were many situations were information had non-perfect connection points from one actor to the next. However, non-perfect connection points were still observed in this study.: This included potential loss of information and additional paths of

task performance which needed to be done. As an example, information had to follow a patient on a physical sheet (ambulance; hospital) at the same time as digital information on that same person existed in the online journal. This could produce doubletted versions. Also, copying physical documents into a digital database caused extra time and the information sometimes was not following the patient in real time. Although a smoother transfer of information depends on confidentiality, several actors stated that:

i hvert fall en stor gevinst er å ha et felles journalsystem, at man har samme journalsystemet pre-hospitalt, på legevakt og på sykehuset. For jeg tror veldig mye informasjon rett og slett forsvinner i og med at man ikke bruker det samme. For eksempel hvis man hadde hatt elektronisk journal, at det jeg skriver kommer direkte på sykehus for eksempel. For vi ser jo det at selv om jeg har fylt ut en fin og flott papirjournal så er det ingen som gidder å lese den, den blir bare lagt bort liksom. Og så er det kanskje viktig informasjon som… selv om du har sagt det så er det så mye som skjer samtidig at det forsvinner. [in any case, a great benefit is to have a common medical record system, that you have the same medical record system pre-hospital, at the emergency room and in the hospital. Because I think a lot of information simply disappears as one does not use the same. For example, if you had an electronic journal – what I write comes directly to the hospitals, for example. Because we see that even though I have filled out a nice and beautiful paper journal, no one bothered to read it, it just gets put away somehow. And then maybe there is important information that ... even if you said it, there is so much going on at the same time that it disappears] (S6)

Second, almost all actors were working with visualization tools such as maps, screens with overview tables, color codes, etc. On an operational level, the sub-organizations had fixed devices and were relying heavily on the visualization tools for their own situation awareness. On a tactical level, this was a different picture. In ambulance cars, the IT system with visualization was in place, however as soon as it came to the coordination function (e.g. Incident leader health (ILH)), mostly paper-pen and radio communication were used to manage information. One actor said:

jeg har stor tro på teknologi, men akkurat når det gjelder taktisk ledelse så skal taktisk ledelse være tett på, du skal bruke hjelpemidler som er lett å håndtere og som ikke tar kapasitet fra den taktiske lederen. Og så kan man se for seg droner, skjermer og hjelmkamera, you name it, men det vil ikke avhjelpe i den situasjonen her. Tvert imot, det vil bare medføre mer white noise og mer informasjonsinntrykk på de lederne som er der. Så bruk av audiovisuelle hjelpemidler i et taktisk innsatsleder-KO [kommando], det ser jeg ikke så veldig stor verdi i [I have a lot of faith in technology, but just when it comes to tactical leadership, tactical leadership should be focused, you should use tools that are easy to handle and that do not take the capacity of the tactical leader. And then you can imagine drones, screens and helmet cameras, you name it, but that will not help in that situation here. On the contrary, it will only cause more white noise and more informational impressions on the leaders who are there. So the use of audio-visual aids in a tactical incident leader, I don't see that much value here.] (S15).

Other areas on a tactical level, such as the 330 squadron, were also mostly focusing on radio communication when it came to information and situation awareness. In addition, however, they were using mms and mobile telephones to transmit pictures for a better understanding of the task. In the words of one of the informants:

For eksempel, skredkart. Få det skriftlig. Der har vi liten tilgang. Og så bilder. Hvis det er bilder av et skadested, for eksempel hvis du kan få det inn fra politi til HRS som kan sende det, om så bare per telefon, en MMS, det vil gi oss et godt mentalt bilde på hva som møter oss når vi kommer fram. Og det er veldig sjelden vi gjør. Og det er noe vi kan gjøre per i dag. Vi kan be… send oss et bilde, og

så får du… så kommer du fram enda bedre forberedt [For example, avalanche maps. Write it down. There we have little access. And then pictures. If there are pictures of an injury site, for example if you can get it from the police to the HRS who can send it, if only by phone, an MMS, it will give us a good mental picture of what is facing us when we arrive on site. And here comes something we very rarely do – and that's something we could do today. We can ask… send us a picture, and you will… then you will come even better prepared] (S12).

They were clearly open for more. As an example, the 330 staff was at times using body-cams to record their activity and achieve better debrief and learning possibilities – which in turn was intended to raise *SA* in the aftermath of incidents.

Third, the safety telephone network "Nødnett", which is a set of emergency radio communication lines, was a major resource to decrease the level of complexity and increase situation awareness, particularly when being used accordingly. Some of the informants compared "Nødnett" to the system before and stated how it made the process of information transmission easier:

Sånn at den digitaliseringen der vi kan snakke igjennom verktøyene til våre ressurser gjør jo at operatøren har kapasitet på å gjøre mer, kan bruke tiden sin mer dedikert. Bare utviklingen av nødnettet har jo gjort det at kapasiteten til operatøren kan brukes på andre ting enn å sitte og ringe i telefon. [The digitization where we can talk through tools to our resources makes the operator have the capacity to do more and use his time more dedicated. Just the development of the emergency network has already meant that the capacity of the operator can be used for things other than sitting and calling on the phone.] (S05)

Yet, they also maintained that it was very important to keep focusing on the relevancy, the timeliness and the quality of the information, otherwise the perceived level of *TC* seemed to increase again. This is somewhat connected to the need by all actors of a joint mental model of what was worth informing about. In case irrelevant information or unprocessed information was delivered, this could have the same disturbing effect as factors from the external environment such as helicopter noise, wind etc., as they all put challenges on the *SA* around the actor.

Fourth, this study revealed how important the coordination function was for the whole network of actors in order to limit task complexity, an issue which is further expanded in the chapter on Information "coodination and Information" hubs. Additionally, further capabilities to manage situations requiring a cooperation of health, police and fire brigade- resources ("trippelvarsling") were important. In our material, the point was raised several times that it had increased these capabilities to integrate the operational centers of the three organizations in one building (the so called SAMLOK). Interviewees from the Ambulance communication center (AMK), pointed out that this had helped to get more direct feedback from each other and that SAMLOK had increased the overall understanding of each other's organizations and tasks. In a way, it both established a joint mental model and increased the base of information on how to cooperate, defined the boundaries of each organization and what could be expected of each other. S13 stated:

Ja det er jo ting de ikke forteller oss og vi har jo ting vi ikke kan fortelle dem. Vi hadde et sånn… sist gang vi hadde kursdag så hadde en sånn samling med politi, brann og vi fra AMK-sentralen [som er alle del av SAMLOK]. Og det blir jo nyttig, fordi at vi hadde vår advokat, politiet hadde sin advokat. Og det er klart at begge parter har nytte av å skjønne at man har forskjellig regelverk eller lovverk å forholde oss til. Men av og til så blir jo politiet litt overgitt at de ikke får informasjonen de trenger. Eller de føler de trenger. De føler de skal ha. Men enkelte ganger har ikke vi lov å opplyse om noe. Og det er klart at de kan bli sinte, men det er det som vi må forholde oss til. [Yes, there are things they do not tell us and we have things we can not tell them. We had one issue like that ... the last time we

had a training day, we had such a gathering of police, fire and us from the AMK Central [which are all part of SAMLOK]. And it will be useful, because we had our lawyer, the police had their lawyer. And it is clear that both parties benefit from recognizing that we have different regulations or laws to deal with. But sometimes the police are a little surrendered that they do not get the information they need – or they feel they need – they feel they should have. But sometimes we are not allowed to disclose anything. And it's clear that they can get angry, but that's what we have to deal with].

DISCUSSION

The present study analyses *SA* under task complexity. It establishes a model (see Figure 1) where the variable 'information quality' plays a more central role for *TC* than has previously been indicated by studies such as Hærem et al. (2015) and Campbell (1988). The first part of the findings enabled us to modify and extend the model by Hærem et al. (2015) and Campbell (1988) in the context of situation awareness. The second section postulated the importance of looking more in depth at information when discussing the model of task complexity.

Figure 1. Situation awareness under task complexity–the role of information quality
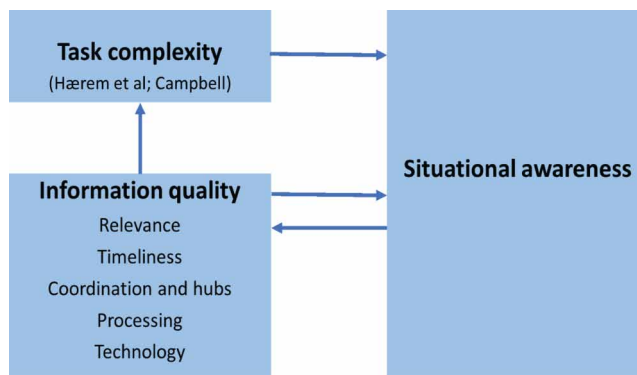
How Situation Awareness Connects to Information and Task Complexity

Looking back at the studies by Seppänen et al. (2013), Hærem et al. (2015) and Campbell (1988), it becomes clear that the variables 'task complexity' and 'situation awareness' should be dependent of an information variable. We have endeavoured to illustrate this point clearly in the present study. Findings include the description of an avalanche operation where S11 mentioned how the different actors, even after some time, *"ville sitte med forskjellig situasjonsforståelse"* [would have different situation awareness]. In addition, the set of sub-tasks by several actors - which needed to be performed to actually acquire enough information to understand some aspects, e.g. *"at det var trygt"* [that it was safe]- was crucial. In other words, one string of information can be connected to an awareness of the overall joint mental model of the situation for all the involved actors compare (Coffey, 2012; Rimstad et al., 2014). At the same time, information may contribute to connect to a multitude of tasks for the organizations and sub-tasks which need to be performed by individuals depending on assessed criticality and *SA* (Gerdtz & Bucknall, 2001).

The study is consistent with literature in areas where additional *SA* capability is needed (Chung, 2005; Endsley, 2017; Gerdtz & Bucknall, 2001), or at least potentially needed. The "potentially needed" seems to be a key aspect to the performed research study, as actors constantly needed to assess criticality and how urgent tasks were. They had to update their assessment on capabilities and

gain an awareness of what the worst case scenario could look like. In general, the study also confirms what (Coffey, 2012; Rimstad et al., 2014) state, namely that the networks of actors (both within and with other sub-organizations) are important sources of information to gain situation awareness.

Yet, the other aspect which was often raised first, is safety and risk awareness of the actors. This part of *SA* provides additional important strings of information that in the end make the actors' tasks more complex. Procedures and communication standards, such as those for potential chemical, biological, radiological and nuclear (CBRNE) material, as well as personal security-related aspects (e.g. ongoing life-threatening violence(PLIVO)), shall provide additional support. Co-dependency of actors (e.g. "*både egen og gruppesikkerhet er viktig*» [both one's own security and group security is important] *(S11)*) increases. While the theory related to *SA* does not refer to safety, studies such as Endsley (2001) and Wright et al. (2004) pinpoint the importance of *"elements in the environment"*.

Finally, it is also via Endsley (2001) and Wright et al. (2004) that the connection between information, *TC* and *SA* can be explained. The connection is by a large degree determined by a dynamic element (Gaba et al., 1995), as was also stated in our material by S04: "*Det er jo å gjøre de samme vurderingene på nytt flere ganger gjennom et oppdrag*" [It is, after all, to make the same assessments again several times through a mission.]. Information from the environment, the current situation and the potential future situation (Wright et al., 2004) acquired by the actors provide understanding of the *TC* and of what potential tasks are. Further, this will feed the *SA* variable (within the ambulance network), which in turn itself is dependent on a set of other actors' task complexities as well as on the information which is already available in the system. The accumulated *SA* will consequentially convey more and new information to the actors.

Understanding Task Complexity

Central to *TC* by (Campbell, 1988; Hærem et al., 2015) are path-, tie- and goal dependency. The current study is equally capable of demonstrating how these attributes contribute to task complexity. Particularly when it comes to path- and goal dependency, the findings shed light on how the organization is exposed to, and has to handle, *TC* – as it is exemplified by all the procedures that are in place to streamline the potential paths and increase goal awareness (cfr S05 "*vi tenker veldig sånn systematisk abcde… enkelt"*) [we think very systematically abcde ... easy].

In addition, the findings offer considerable insights into the multitude of actors involved, the array of actions they undertake, as well as the myriad of sub-structures (e.g. land- and sea-based operations during exercise Nord) and sub-goals. These factors divide the complex system into several complex tasks for sub-groups (e.g. trauma-team in the emergency room) and individuals, who at times are competing for the same resources and stating clearly how critical their task is. There is a distinct echo of Campbell (1988) here, where both conflicting interdependence and presence of uncertain or probabilistic links are part of what defines task complexity.

The existence of information cues is discussed by Hærem et al. (2015). Even though they somewhat integrate information into tie-dependency, they also hint – somewhat controversially -that, theoretically speaking, information cues should be a variable besides task complexity. The current study agrees to this statement, as the multitude of the findings show how *TC* can be influenced by information cues going far beyond what is discussed by Hærem et al. (2015). To be more precise, Hærem et al. (2015) seem not to take account of the double-edgedness of the information variable; perhaps this is the reason why they refrain from adding information to their formula, and use ties instead. However, the findings of this study compel us to dig deeper into the apparent information variable, and into the role of *SA* under task complexity.

Establishing the Information Variable

Our type of assessment is similar to the discussion by Schoonhoven et al. (1980), who point out that the role of information, when confronted with a complex task, is to acquire more knowledge about the actual objective of the task. In our material, this can be questions related to sub-goals, such as 'Is it

safe here', 'is the patient or the group of patients in a critical situation', 'are there available resources, when will they arrive', 'who is responsible for what', etc. The established procedures or processes already provide a base of information designed to handle parts of the *TC* at hand.

Whereas Weick and Sutcliffe (2015) demand that these processes be not overly simplified the present study only agrees to some extent. Yet, our sources do include statements such as "så lenge du har det [base av prosedyrer] så har du muligheten til å være kreativ og finne løsninger som ikke passer inn i det verket, så lenge du har det i bunnen" [But as long as you have the procedures you have the opportunity to be creative and find solutions that do not fit exactly to the procedure. As long as you have the procedure as a basis.] (S05). However, in case of increase of the TC and shortage of time, several informants also mention how in such situations the procedures help to get the most done "så fort som mulig" [as quickly as possible], so the procedures should be as simple as possible.

Nonetheless, what is most prevalent in the current study is connected to information quality, on a par with (Lee et al., 2002; Nelson et al., 2005), as well as to the discussion in the theory section of how processed the information is at different stages (see Wood (1986), Campbell (1988) and (Xia & Lee, 2005). The findings in our material show that a diversity of attributes connected to information also can impact *TC* in different ways.

It is the term of *IQ* as presented by Lee et al. (2002) that can describe this diversity. While many categories have been created for framing *IQ* (Lee et al., 2002), it appears that the one with the upmost priority in this study is the category of contextual information. Relevance of information is also a central category. This is why specific knowledge elements stored within the actors are so important. They will feed in information based on "erfaringer, utdanningen, personlighet, kombinasjon av mennesker, hvor mange mennesker, altså kompleksiteten" [it is the experience, the education, the personality, the combination of people, how many people, that is the complexity] (S05), rather than overwhelming the other actors with irrelevant information as described by Wood (1986) and Campbell (1988). Likewise, the findings show that trained authority, legitimization and understanding of the *TC* at hand can help if there is actually a chance for overwhelmedness due to too much non-relevant information ("nå må dere slutte å prate til oss [...] vi er opptatt med å fly, maskinisten og systemoperatøren er opptatt med å heise, og lege og redningsmann er opptatt med å heise inn eller heise ut" [now you have to stop talking to us [...]we have to fly, the machinist and the system operator are busy hoisting, and the doctor and rescuer are busy hoisting or hoisting out.] (*S11*). Hereby, *SA* of one actor's capabilities and understanding of the joint mental model seems to support the legitimization to declare what is relevant and what is not.

This resonates well with the timeliness aspect of information, as time seems to be connected to the relevance of the information. This means, for instance, that the very same information which the helicopter crew would cut out during the lifting operation in the above example, a few minutes before or after could have been very relevant, or at least receivable in different manners (compare Wright et al. (2014)). Timeliness seems rather subjective, as the actors themselves may be differently in need of a certain information at a certain time. However, what appears to be of great importance in order to frame *SA* connected to a joint mental model is the timely, first acquisition of information on the site of an incident. S15 states: "Og da vil igjen det være en eksponentiell effekt av det, hvis situasjonsforståelsen kommer kjempetidlig så vil en [uklart] 38:20 tidlig, og bli oppfattet av flere" [And then again it will be an exponential effect of that, if the situational understanding comes at a timely pace then understanding will be early, and will be perceived by several early. And it is crucial to succeed really.].

However, how do actors make use of this timely information. In order to keep track of the relevant information and to inform actors in a timely manner, the present study enables us to observe the importance of the role of information-hubs. These hubs have several functions, including the decrease of *TC* by coordinating sub-tasks. Actors per sub-network become fewer, procedures of each other's organizations become more familiar and ways of working more predictable. All of this also activates

increased capability for *SA* on one field, but decreases *SA* of the system on some levels as a whole (the sum of several hubs).

These information hubs can be very centralized sub-organizations (Ambulance communication center (AMK) and Joint Rescue Coordination Center (JRCC)), they can be certain actors/individuals (Incident leader health (ILH)) or they can be a form of technology. What they all have in common is that they are intersections where processed and unprocessed information gets sorted and is made available for other actors. Processed information of quality stands in contrast to the information cues description by Hærem et al. (2015), Wood (1986) and Campbell (1988), as the latter will rather decrease the potential *TC* of the actor. This may be illustrated by the contrast between the first, processed on-site report that will convey processed information to the network of actors, versus each actor having to process everything again themselves.

Technology emerges as a major aspect. Two streams on technology described in the theory section come into play. The first technology are procedures and checklists ("Du må jo alltid ha prosedyreverk i bunnen som sier noe om hvordan det skal gjøres." [You always have to have procedures at the bottom that say something about how to do it.] (S05)) which support goal orientation and the understanding of the work to be performed (Schoonhoven et al., 1980). The second type of technology (Gorman et al. (2000) is related to assuring a focus on increased IQ and larger capability to manage information. The barrier-free fusing of these technologies ("jeg tror veldig mye informasjon rett og slett forsvinner i og med at man ikke bruker det samme." [Because I think a lot of information simply disappears as one does not use the same.] (S6)) is an ongoing process connected to mobilization of information technology (Hajiheydari & Hanafizadeh, 2013). In succession to this, finalizing the ongoing digitalization process and understanding when and where support tools can bring better task management for complexity and higher degree of situation awareness, are ongoing processes. Such processes, and initiatives such as SAMLOK (joint planning headquarters by ambulance, police, fire brigade) also increase the potential of the shared mental model. Our findings indicate that an actor has only a certain amount of capability to make use of further information per body-sense (e.g. visualization tools, Nødnett [emergency net], etc) and information technology can help to make use of all these, particularly when exposed to *TC* and to the need for greater situation awareness.

CONCLUSION

Our findings reveal that an information variable plays a significant role when describing a model for *SA* under task complexity. Also, *SA* acts as a mediator in the model, since it is connected to the information. This study describes such connections by considering the literature on *TC* on the one hand (Campbell, 1988; Hærem et al., 2015), and on *SA* on the other hand (Endsley, 2001; Wright et al., 2004). We have presented these findings in the model in Figure 1: "Situation awareness under *TC* – the role of information".

Our research shows that some factors do have an effect on *TC* and situation awareness: particularly, information relevance, information timeliness, the existence of information coordination and information hubs, processed information and information technology. We gather all of these factors within the *IQ* variable. As regards situation awareness, the concept of shared mental models comes in, showing that the overall awareness of goals as well as the resources and work processes within the system (including across sub-organizations) can indeed have an impact on the actors' information basis.

The case concerns the ambulant organization of Nordland hospital (with its sub-organizations and actors) and included the observation of their participation at exercise Nord 2019. A limitation is that conclusions from such a type of case study may not be generalized (Eisenhardt & Graebner, 2007). Nevertheless, several of the findings can be expected to be promising within other areas, such as research on mental models, emergency management literature and IT studies.

First, our study points out how shared mental models in guidelines, rituals and procedures - but also elements specifically stored by each actor - can widen *SA* under task complexity. *SA* may

increase the basis of what type of information can be regarded as relevant. Second, the study describes the dynamic element of a constant need for gathering timely and relevant information for situation awareness, in order to handle task complexity. Third, the study unveils how information technology feeds information with relevant quality to the actors, and – in this respect - how important the right choice and means of technology is.

There are, of course, limitations as well as room for future studies. For instance, this study does not come to grips in any in-depth manner with the concept of learning, whereas further insights on this process could provide further knowledge related to *SA* and task complexity, and ways in which organizations may prepare for it. Also, although the theory section as well as some of the findings touches upon the role of professionalization, a choice had to be made not to pursue this strand any deeper, as it would go beyond the limits of the study. Future research should look at a potential professionalization variable in relation to a *TC* model.

Finally, this study has established the role of information in the light of *SA* under task complexity.

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