Slaying the SA-Demons – Humans vs. Technology – A Content analysis

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ABSTRACT

This paper examines Situation Awareness (SA) and the application of Endsley's SA-Demons in different contexts and research areas. We perform content analysis to examine how they are used, and to what degree they are perceived as stemming from human-error or weaknesses in technology and if any suggestions for mitigation are primarily focused on the human or the technology side. Based on our findings, we propose Universal Design as a tool that can counter the effects of the SA-Demons by improving the usability and accessibility of SA-supporting technology and thereby removing barriers to SA, rather than challenging the users to overcome not only barriers that are a result of the complexity of the situation itself, but also additional barriers that are caused by inferior and suboptimal design of the technology in use.

Keywords

SA-Demons, situation awareness, crisis management, human-errors, universal design, content analysis.

INTRODUCTION

Situational Awareness (SA) is essential in critical missions such as in hazardous industries and in command-control centres monitoring critical activities in different sectors such as airspace, aviation, and transport. It is of particular interest in the Emergency Management (EM) domain, and scholars have examined different aspects that can improve SA e.g., by developing technology assistants such as GIS technology (Opach et al., 2020), decision support systems (Van de Walle & Turoff, 2008). SA is important for gaining common operational pictures (Wolbers & Boersma, 2013), EM responder collaborations (Seppänen et al., 2013), and for social media crisis communications (Pogrebnyakov & Maldonado, 2018).

The concept of SA was made popular by Endsley (1995), who studied safety in aviation, especially for decision making and analysing human-errors and performance. However, this concept is applicable to similar challenges faced by land-based human supervisory control (Stanton et al., 2001), like in the critical infrastructure sectors, public transport monitoring, nuclear, and other activities in complex dynamic environments.

Endsley (2016) introduces further the SA-Demon concept, defined as "factors that work to undermine SA in many systems and environments". She highlighted eight SA-Demons, including Data overload and Errant mental models. Recently, SA has been examined and connected with "situational disabilities" that can occur in disaster situations (Gjøsæter et al., 2019, 2020a), and that can hinder the establishment of SA through exacerbating inherent barriers in technology and increasing the likelihood of human-errors.

There seems to be a tendency to point at human factors rather than on technology design as the source of incidents and loss of SA, although recent socio-technical perspective on SA may suggest that SA-Demons emerges from the interactions between the system and the operator. Numerous studies in Human-Computer Interaction (HCI) show that usability and accessibility issues can have severe consequences for people's ability to use technology efficiently. However, the efforts to map how different studies have examined the SA Demons in critical missions such as safety and EM are still limited. Most studies tailor SA-Demons into a specific application domain. Thus, this study tries to fulfil this gap by providing an overview and the directions of the existing SA-Demon studies.

The purpose of this study is to analyse how the SA-Demons have been applied in various domains and to investigate the perceived source of the problem in terms of humans vs. technology. We, therefore, define the following research questions:

- In which contexts are the concept of SA-Demons used?
- To what degree is human factors or technology singled out as the primary cause of loss of SA?

To investigate these research questions, we perform content analysis on systematically selected literature, using the text analysis tool KH Coder.

STUDY CONTEXT

SA pioneer Endsley (2000) highlights SA as a major design goal for designers and developers of operator interfaces, automation concepts and training programmes in fields such as aircraft, air traffic control, power plants and advanced manufacturing systems. Salmon et al. (2007) point out that SA is extensively handled in the literature as an individual construct described from an individual perspective, while SA in collaborative environments presents more of a challenge both in theory and in practice. While team SA concerns the level of SA each team member needs to do their job as part of a team, shared SA concerns to what degree all members of a team share the same SA.

SA command-and-control in EM is of particular interest in our study, and the complexity of information combined with the rapidly shifting states of urgency presents extraordinary challenges to SA both from a human factors and technology perspective. These situations also tend to demand individual as well as shared SA. Evaluating SA in such environments can be challenging. Salmon et al. (2006) reviewed measurement techniques of SA for command, control, communication, computers, and intelligence (C4i) environments, and compared a set of SA measurement techniques against a set of human factors methods criteria. They find that current SA metrics are inadequate for these complex environments and recommend either a new approach to evaluating SA in C4i that takes into account its environment complexities and the combined requirements for individual, group and shared SA, or a carefully selected battery of combined techniques.

According to Endsley and Garland (2000), the challenge in SA is not lack of information but rather to find what information is needed when it is needed. SA involves perceiving and comprehending large sets of rapidly changing data. There are several factors that can hinder the establishment of individual, team, and shared SA. Endsley (2016) introduced the eight *SA-Demons* that represent factors that can hinder the establishment of SA. For example, Errant mental models concern how incomplete or wrong mental models can lead to poor comprehension and projection. Like SA has been researched extensively in different domains, SA-Demons have been applied to a range of domains, including maritime accidents (Stratmann & Boll, 2016), urban conflicts (Metcalfe et al., 2011), power systems operation (Panteli & Kirschen, 2015), and EM (Agrawal et al., 2020).

Stanton et al. (2010) examine different viewpoints on the origin of SA, from the psychological angle where it is all in the mind, the engineering perspective where tools and technologies provide SA, and finally the ergonomic perspective where it is the interaction between the user and the artifact that is in focus, and SA is seen as distributed cognition. The authors advocate seeing SA as distributed cognition arising from the socio-technical systems.

Gjøsæter et al. (2019, 2020a) have investigated Endsley's SA-Demons and their relationship with *Situational Disabilities* that can occur in a disaster situation and that can act as barriers to the establishment of SA by making the actors more vulnerable to usability and accessibility barriers in the technology and thereby increasing the chance of human-error. The authors further recommend UD as a method for removing these potential barriers, and thus taking a technological approach to solving a problem that has tended to be approached through training of humans rather than improving the technology and making it more useable in different situations.

METHOD

We consider the importance of focusing on two different aspects of SA barriers: 1) Factors that reinforce or reduce the SA-Demons (such as key issues, relationship of findings; 2) Areas where attention to SA-Demons will be important (e.g., who is the main subject, evaluation method, and expected improvements). To investigate this, we employed the content analysis method. Initially, we applied a systematic search for collecting sample articles for analysis in Google Scholar and Scopus published between 2011-2020. We used Endsley AND Demons AND "situational awareness" OR "situation awareness" as keywords.

In Google Scholar, we received 377 hits. We excluded patents, books, thesis and dissertations, non-English articles, unrelated topics, and non-peer-reviewed, which provided 73 articles. Title and abstract were manually checked, focusing on whether the papers explained the SA-Demons or purely analysed factors that support SA. Thus 52 articles remained. Scopus search resulted in 23 hits. When we went deeper by examining abstracts and keywords, we got only 5 hits, which then merged with the results from Google Scholars. After duplication control and in-depth reading, we analysed 32 articles. The papers included in our analysis is listed in the Appendix.

Content Analysis (CA)

In EM, CA is not new, e.g., Englund and Arnberg (2018) applied the technique for analyzing survivors' experiences after a disaster. Fisher Liu (2009), Gallagher et al. (2007) employed CA on news releases during the hurricanes Katrina and Rita. CA is a method of analysing written, verbal, or visual communication that can be applied using qualitative or quantitative data, using both inductive and deductive approaches (Elo & Kyngäs, 2008). Stemler (2000) summarizes the method as a systematic, replicable technique for compressing text into fewer content categories based on explicit coding rules. The technique has also been applied for e.g., coding of actions observed in videotaped studies. The central feature of the qualitative and quantitative CA method is how to systematically categorise textual data in order to make sense of it. The process of CA can be seen in Figure 1.

Hsieh and Shannon (2005) introduce three approaches to qualitative analysis, i.e., *conventional* (coding is derived directly from the text), *directed* (analysis starts with a theory or other research findings as guidance), and *summative CA* (the analysis involves counting and comparisons of keywords contents before interpreting them). The differences among these three approaches lie in the coding procedure, origins of codes, and threats to trustworthiness. Our work adopted the third approach, where we identified and quantified certain words in the texts to comprehend the context use of the words, with the intention to explore. The focus is more on discovering the underlying meaning of the text before interpreting the existing text qualitatively further.

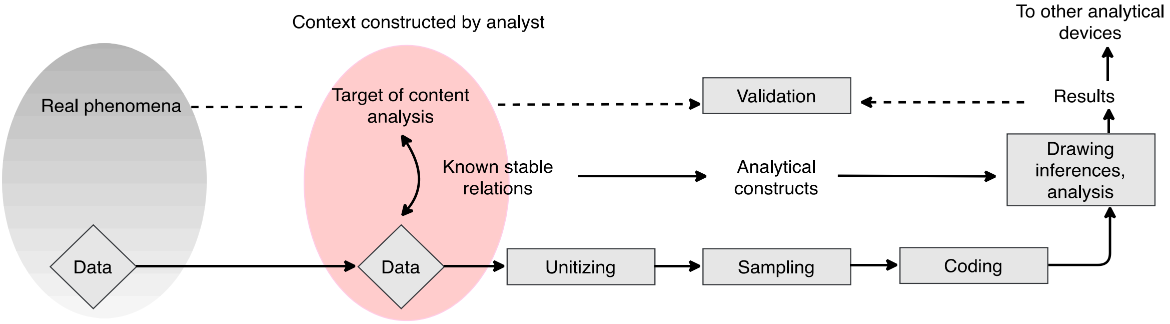


Figure 1. Content analysis adapted from (Krippendorff, 2018)

Computational Analysis Support

Computational analysis of this work was performed using KH-Coder to understand the importance of topics and content of SA-Demons in literature. It is a computer-aided tool for quantitative content analysis, text mining, computer linguistics, and visualization (Higuchi, 2016). We included the title, abstracts, and introduction parts of all selected 32 papers and merged them into a single document text file. Each unique paper had a tagged title for identification. We considered title, abstract, and introduction sufficient to understand the context, research purposes, and usage of the SA-Demons concept in the literature.

The analysis began with the pre-processing stage by removing punctuation marks and stop-words which provide no added meaning to a sentence. Conjugated or inflected forms of words, such as verbs or adjectives, were extracted as their word-stems. For instance, catch, caught, catching, would be transformed into "catch." We applied the following rules: ignore the preposition, adverbs, space, and "force" to ignore words that have high occurrences and add noise to our analysis such as "paper," "abstract," "introduction," "et al.," "article."

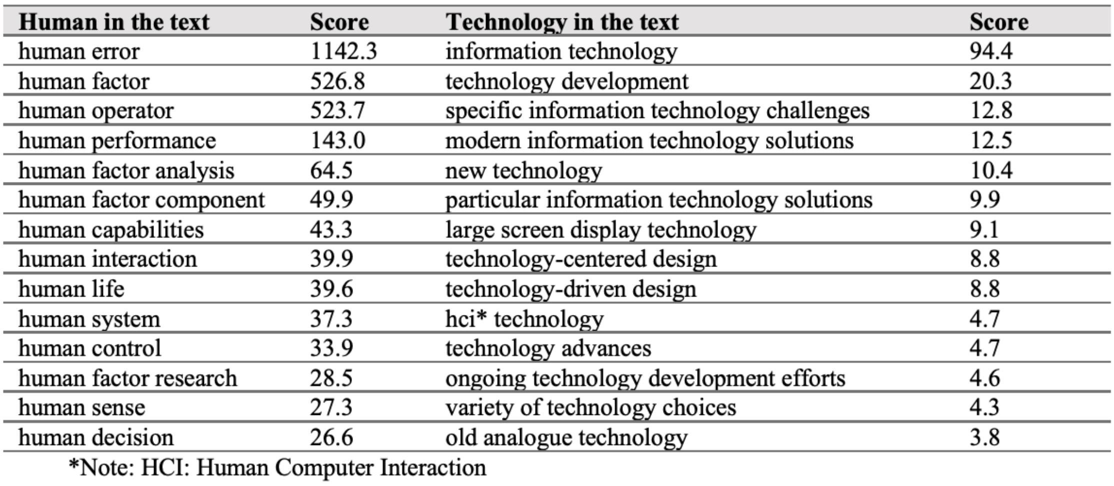
KH-Coder automatically extracts clusters of words that *often occur together*—e.g., "taxonomy of situation awareness errors" using *TermExact*. It could happen that the same word is clustered into three clusters, such as "taxonomy," "situational awareness" and "errors," or that unintended word clusters emerge. However, each word cluster was scored, thus the highly scored clusters were believed to be reliable (Higuchi, 2016). KH-Coder counts a frequency word list and ranks based on the frequency of its occurrence. We also merged some terms, e.g., "situation awareness" and "situational awareness," or the same words in singular and plural, to avoid unnecessary clustering duplications or word counting. There are multiple features in KH-Coder. In this article, we only employed one feature, i.e., co-occurrence network., with two algorithms, i.e., *graph modularity* and *betweenness centrality* that aids to conceptualise the content following an algorithm leaning on co-occurring frequency and distance of the words in the text.

RESULTS

Results on Technology vs. Human Factors

The collection of texts used in this analysis consists of 942 sentences, 221 paragraphs, and 24,664 expressions. After pre-processing, it resulted in 2,263 clusters. We searched for words among the clusters associated with "human" and with "technology," to understand their usage context. We found 72 clusters were associated with "human", while only 14 clusters were associated with technology. Table 1 shows the top 14 clusters to "human" and an exhaustive list of "technology". In many articles, the most used human-related cluster of words is "human-error", "human factor," and "human operator". The technology-related cluster of words is mostly related to technology development and technology solutions. This table confirms our assumption stated in the Introduction that literature has tendencies to emphasise human dimensions when it comes to incidents or emergencies, rather than looking at the technologies, e.g., if UD principles are adopted.

Table 1. 14 Top Clusters of Human and Technology



Human in the text	Score	Technology in the text	Score
human error	1142.3	information technology	94.4
human factor	526.8	technology development	20.3
human operator	523.7	specific information technology challenges	12.8
human performance	143.0	modern information technology solutions	12.5
human factor analysis	64.5	new technology	10.4
human factor component	49.9	particular information technology solutions	9.9
human capabilities	43.3	large screen display technology	9.1
human interaction	39.9	technology-centered design	8.8
human life	39.6	technology-driven design	8.8
human system	37.3	hci* technology	4.7
human control	33.9	technology advances	4.7
human factor research	28.5	ongoing technology development efforts	4.6
human sense	27.3	variety of technology choices	4.3
human decision	26.6	old analogue technology	3.8

*Note: HCI: Human Computer Interaction

Results on SA-Demons

To present and analyse the results of SA-Demons, we applied co-occurrence with graph modularity and graph centrality approaches.

Co-occurrence With Graph Modularity Approach

The co-occurrence network extracts text that frequently co-occurs, visualized as circles with connecting lines with different thicknesses to demonstrate the relative strength of the association between terms measured by correlation, both in Figure 2 and 3. We selected only terms that have correlation >0.2. In fact, higher correlation thresholds such as 0.3, 0.4 or 0.5 yield very little occurrences, i.e., 12, 4, and 2 cases, respectively. Thus, it will be hard to use them for a meaningful analysis. Taking the correlation threshold below 0.2 would be too weak to consider, and most of 24,664 expressions fall below 0.2.

The software builds the graphics according to an algorithm affected by word frequency in the text, thus, the arrangement of the word-fragment concepts in the graphics are independent of researchers' interpretation of concepts appearing in the data. Automatic colour-coding highlights different term clusters within the network, although they are indicative (Higuchi, 2016). Figure 2 was generated using modularity sub-graph technique, which is widely used as a measure for how good a clustering is in social network analysis, for "community" identification or community structure in a network. However, here, the network refers to sets of interrelated text found in the articles. Figure 2 illustrates six clusters extracted from our samples of articles.

Cluster 1 (green) groups topics related to *human factor, error, and accident* with correlations of most words between 0.22-0.37. The word "demon" also appears here, although the occurrence is relatively low compared to e.g., human factor or human operator. The word "SA-Demons" has been used for analysing the *design problems* (Agrawal et al., 2020; Stratmann & Boll, 2016). The word is linked as *cause of demons* (e.g., D'Aniello & Gaeta, 2018; Pandurino et al., 2013; Salotti, 2018; Sands & Chidambaram, 2016) that leads to inadequate (Fortmann et al., 2016), or erroneous (Huggins & Prasanna, 2020) situation monitoring behaviour. The word is also used in connection to *issues* that can hinder the SA development, (Gjøsæter et al., 2020a; Salotti & Suhir, 2019; Stauffer et al., 2017).

Cluster 2 (yellow) shows themes related to *SA* (correlation 0.9) and *information decision* (Correlation 0.31). SA as a concept occurs 330 times. Under these themes the following keywords are used: information support, information technology and processing, technology needs, technology development, decision making, decision management, and effective actions. For technology development context, Agrawal et al. (2020) addresses design challenges of human-autonomous-machines interaction. Boll et al. (2020) study the automation in the context of non-classical HCI in the command-and-control systems. Brown (2016), Chen et al. (2014), D'Aniello and Gaeta (2018), and D'Aniello et al. (2017), Gruenefeld et al. (2018), and Sharma et al. (2019) analyse the information overload and loss of SA leading to human-errors in various areas such as aviation sector, human-robot interaction, container management, air-traffic control, fleet management system, and maritime, respectively. Braseth and Øritsland (2013) introduce the concept of "Information rich design" for tackling the readability challenge and large-scale displays intended to provide better SA. MacFarlane and Leigh (2014) tailor it as information management and shared SA.

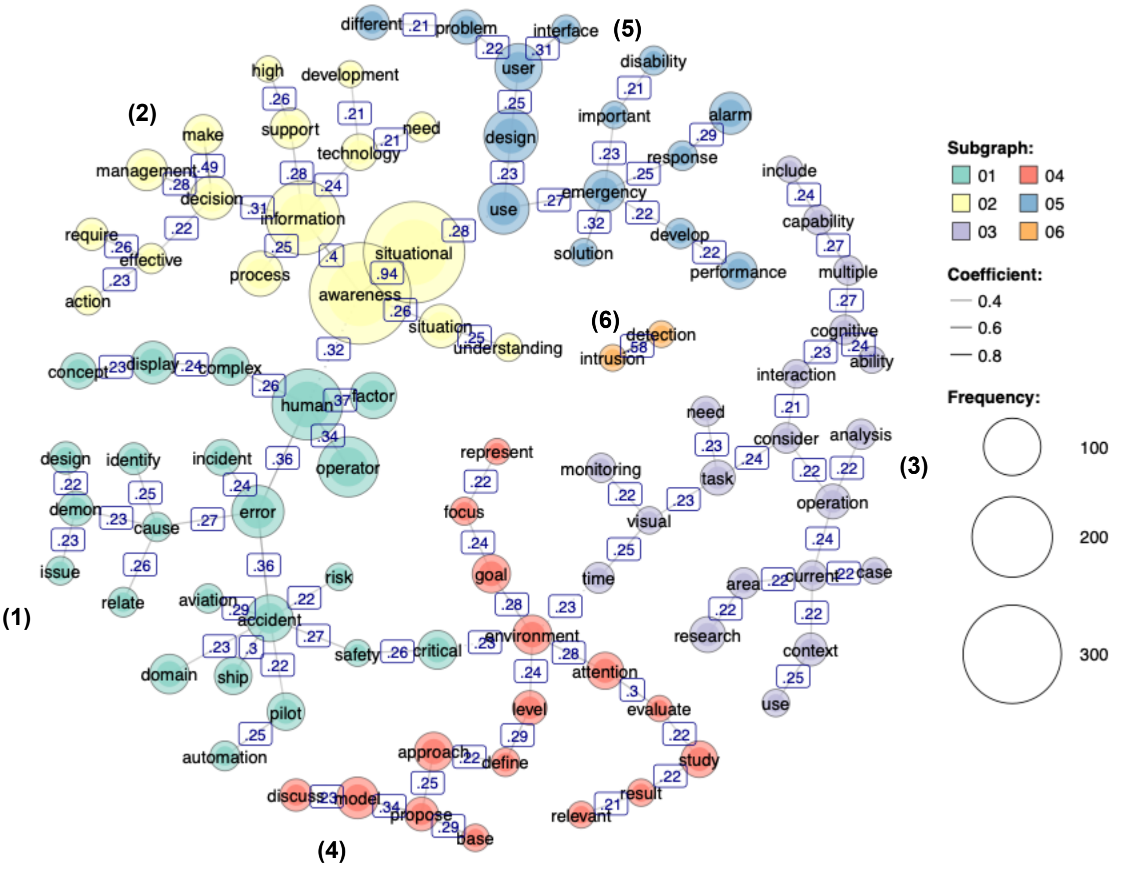


Figure 2. Co-occurrence Network, Subgraph modularity

Cluster 3 (purple) shows topics related to the *mental process of achieving SA*, with the correlations range between 0.21-0.27. They form a network where the "consider" node is a core connecting the words "interaction" (and further cognitive, multiple), "task" (followed by visual, monitoring), and "operation" (with current, case, context). Under this cluster, the authors discuss the cognitive loads that can burden operators (e.g.,Memar & Esfahani, 2018). Brown (2016) shows how the cognitive load determines the working memory of operators and pilots, either causing reduced SA (Chen et al., 2014), or understand the environment correctly (D'Aniello et al., 2019).

Cluster 4 (red) is related to *the study purposes, goals and approaches or ideal system features*. The strength of the correlation in Cluster 4 is between 0.21 to 0.35. The following goals were found in our literature: Developing multiple-stakeholder-based design processes for human-autonomous UAV (Agrawal et al., 2020; Gjøsæter et al., 2019), performance monitoring and evaluation (Hancock & Higley, 2014; Metcalfe et al., 2011; Panteli & Kirschen, 2015).

Some approaches mentioned in the literature are experiments (Chen et al., 2014), scenario-driven and participative approach (Agrawal et al., 2020), adaptive selection goal approach (D'Aniello et al., 2019), SAGAT methodology (D'Aniello et al., 2017), and Goal-directed task analysis (GDTA) (Sharma et al., 2019). Several studies highlight the user-centred design approach, including human-robotics interaction, human complex system interaction, human autonomous agent interaction and UD (Gjøsæter et al., 2020a; Hanus & Wu, 2012; Huggins & Prasanna, 2020; Illankoon & Tretten, 2020; Kristoffersen, 2020). Both qualitative methods such as analysis of incident documents (Stratmann & Boll, 2016), interview (Huggins & Prasanna, 2020) and quantitative methods (D'Aniello & Gaeta, 2018), Bayesian network (Salotti, 2018; Salotti & Suhir, 2019), or mathematical model (Hancock & Higley, 2014) are found in our samples of articles. Some studies are design-oriented, (Braseth & Øritsland, 2013; Gjøsæter et al., 2020a), or technology development-oriented (Ebrecht & Schmerwitz, 2015; Stratmann et al., 2019; Stratmann et al., 2018).

Cluster 5 (blue) is connected to *emergency and user*, with coefficient correlation between 0.21 to 0.32. Surprisingly, only four articles out of thirty-two that are actually discussing EM. The "emergency" concept has been adopted for referring to the scenario (Agrawal et al., 2020), UD of ICT for EM and the issue of situational disabilities (Gjøsæter et al., 2019, 2020a), and EM controller and decision making in emergency operation centres (Huggins & Prasanna, 2020). While the use of term "user" has been associated with user of the study for technology testing and user interface (Stratmann et al., 2019; Stratmann et al., 2018).

Cluster 6 (orange) shows a correlation between *intrusion and detection* (0.68), where these two concepts mostly are used together. The terms of intrusion mentioned 21 times related to information fusion for intrusion detection system found in Hall et al. (2015), network intrusion detection (Hancock & Higley, 2014), cyber-criminal intrusion (Hanus & Wu, 2012). While the use of the term detection is more varied, such as "automating the detection and diagnosis of SA (Hancock & Higley, 2014), accuracy of target detection (Memar & Esfahani, 2018). Overall, these combinations were found in the literature focusing on emergencies and incidents in cybersecurity.

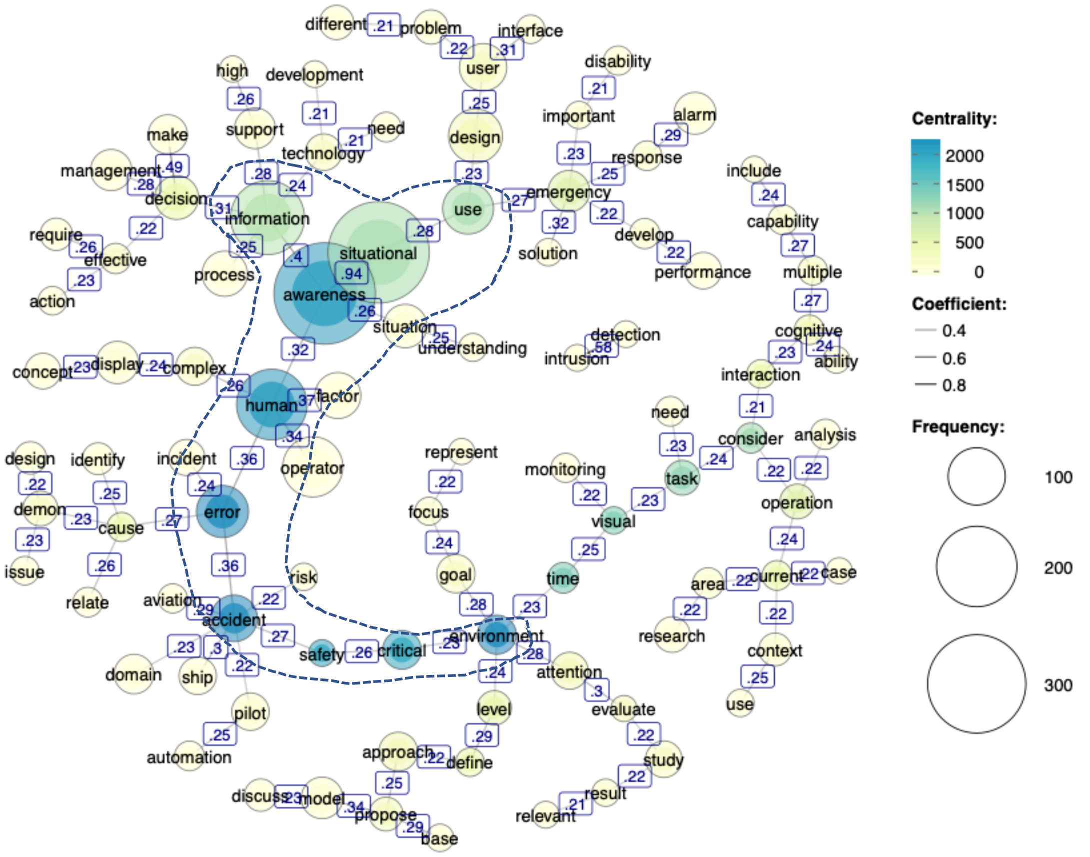


Figure 3. Co-occurrence Network with Betweenness Centrality

Co-occurrence with Graph Centrality Approach

The centrality is a concept that have been used in a major social network analysis. The most frequently used measures are degree, betweenness, closeness, and eigenvector. Centrality used for showing "who" occupies critical positions in the network, although in our case, it is again about text and centrality of concepts. Figure 3 shows betweenness centrality which quantifies the number of times a node (here, a concept, text) act as bridge along the shortest path between two other nodes.

We observe that only few words are central, indicated by dark blue colour that link the awareness, human-error, accident, safety, and critical environment. The occurrences of words do not always correspond to its centrality, e.g., "operator" occurs more than "safety", "critical" and "environment" but not central as a concept. This figure is nicely extracting an illustration of main story lines derived from all 32 articles included in this CA.

DISCUSSION

On SA-Demons

Researchers have treated SA-demon topic in three ways. *First*, some articles thoroughly discuss overall SA-Demons. Agrawal et al. (2020) suggest solutions that can fight against all eight SA-Demons in the design of multi-drones response context. The authors introduce three new demons i.e., 1) *Transition failures across graphical and physical user interfaces*, as the operator should be able to handle the physical and graphical control. The confusion and errors can originate from the transition from one to another interface. 2) *The Socio-technical Cyber-Physical-System communication failure*, due to high-degree of communication between human-to-human, human-to-UAV vice-versa, and UAV-to-UAV, causing confusion, uncertainty, and reduced SA. 3) *Enigmatic Autonomy*, risk of errors because the autonomous system can change its behaviour, thus the human operators need to comprehend the configurations, including permissions of the autonomous systems. It is one of the most comprehensive adaptation of SA demon concept into emergency response found in existing literature. although these concepts should be treated cautiously, as they need more validation. Gjøsæter et al. (2019) portray the SA from the lens of UD to analyse how these SA-Demons can appear in different stakeholders, presented as various personas in disaster scenarios. Moreover, Gjøsæter et al. (2020a) discuss the applicability of the recognition prime decision theory, where SA-Demons can occur in various stages of decision making. Stratmann and Boll (2016) thoroughly analyse over five-hundred maritime accidents to rank which SA-demon is the most prevalent.

Second, some studies emphasise only particular SA-Demons to be applied in a specific case. Kristoffersen (2020) examines "out-of-the loop" syndrome as a vital "demon" to automation of vessels. This syndrome happens when the operator´s awareness is not aligned with the state of the automated system. Braseth and Øritsland (2013) discuss *inaccurate mental model, cognitive tunnel vision,* and *data overload* demons, in the monitoring activity because of using smaller displays. Large scale displays are proposed for improved SA, which, however, may cause *data overload* and *requisite of memory trap* demons. The authors suggest a flat, externalized in-the-world-display layout in the control room as a solution. Fortmann et al. (2016) use demon as something that distract the human-operator, manifested as *boredom* and *attention tunnelling*. Pandurino et al. (2013) examine only *attention tunnelling, misplaced saliency, errant mental model, requisite memory trap*, and *data overload*, which has been referred to as "Endsley principles" in designing user interface, but in great detail.

Third, some papers treat SA-Demons less central. For example, Illankoon and Tretten (2020) focuses rather on in-depth analysis of judgemental biases as leading factors causing safety accidents. People are assumed to make judgements automatically, triggered by simple rules that ignore information, causing heuristic biases and emphasise the role of human interaction to defeat SA-Demons. Metcalfe et al. (2011) refer to *cognitive tunnelling* and *out of the loop syndrome* demons concerning the 360^{0-} display system design, without discussing this further. In the power system control setting, SA-Demons *workload and data overload* commonly occurred (Panteli & Kirschen, 2015), or factors to be addressed in a system design to mitigate them without further elaboration (e.g.,D'Aniello et al., 2017).

On Technology vs. Human Factors and Loss of SA

Apparently, the selected literature tend to either lean to the human dimension or to the technology as a reason for reduced SA. Although technology may be a reason for incidents, the solutions focus more on the human part. Indeed, some scholars address the concern about this tendency, to search for the human-error when critical incidents were analysed. Recent studies (Boll et al., 2020) suggest studying the *interaction part* of human with complex systems, including the *integration of various devices* deployed for safety critical environment, stakeholders involved in the design, development, training, maintenance, and certification of these systems. This is indeed beyond what researchers normally see as a part of interaction: operator-system-environment (Metcalfe et al., 2011).

Agrawal et al. (2020) perceive the SA-Demons as technological design flaws that do not function well with human operators. While human fallibility and limitations are related to the different demons, it is also clear that the fallibility and limitations can be triggered, depending on the design of the socio-technical system. Under the socio-technical approach, the problems of the SA-Demons lie not on either side of the humans vs. technology gap, but in the *interaction* between them, and in the usability of the user interfaces. Thus, HCI design principles with user-centred participatory design is the approach taken by the authors to counter the SA-Demons. Gjøsæter et al. (2019, 2020a) recommend UD as a tool for mitigating the SA-Demons. They indicate that there is a parallel between the SA-Demons and *situational disabilities* that can affect users in extreme situations, and therefore recommend UD with a participatory human-centred design process to facilitate SA.

Kristoffersen (2020) underpins the viewpoint that the human-error term should no longer be utilized, and use *design-induced errors* instead. The reason is that the systems are often poorly designed for the operators' physical and mental limits. The operator is often not blameworthy when human-errors occur as the operator is doing his best within the system that is designed. Human-errors is not always about an operator making mistakes, but also about working condition such as having too few manpower for the job that causes fatigue. The answer to this human-induced error is automation (e.g., in vessel operation) that can reduce human-errors considerably due to *fatigue, attention span and information overload*. However, it comes with a new concern if new technologies will introduce new kinds of human-errors (e.g., algorithm-induced errors, monitoring operation). To tackle these automation challenges, Kristoffersen (2020) suggest replacing technology-driven design with human-centred design to reduced the human-errors.

Implications

Human factors are considered as the main contributor to SA errors, while digital technology is considered as a solution to enhance SA (Endsley, 2001). However, technology can also be a contributor to human-errors or SA errors. Poorly designed technology such as bright colours and flashing lights on digital interfaces can overwhelm human operators, overcrowded interfaces and complicated interactions can cause cognitive overload. In addition, humans are a diverse group of users of technology and have different abilities, capacities, strengths, and weaknesses. These differences impact how they interact with technologies in different situations. Technology design should take this diversity into consideration (Salas et al., 1999).

UD principles which ensure high-level of usability and accessibility can play a key role in technology design for supporting SA (Gjøsæter et al., 2020b) by reducing cognitive and data overload, preventing errors, and minimizing fatigue. For example, an indoors navigation app which helps users to find the way to the nearest emergency exit should allow users to pre-define the output modality (text, audio, video) and minimize the number of actions required for the user to get instructions from the app (UD Principle 2 – Flexibility in Use). An application that provides overview and warning to personnel in a control center should avoid showing several overlapping warning pop-up windows on the screen or using the same warning sound for different types of warnings (UD Principle 4 - Perceptible Information). A mobile application used by first responders for communication in a fire situation should ensure that the buttons have a larger distance, so that the user does not press the wrong button by mistake (UD Principle 5 – Tolerance for Error).

CONCLUSION

Our analysis shows that humans are to blame in most SA errors and technology is much less involved in discussion of understanding the demons. However, with the increasing adoption of digital technology in EM, it is necessary to understand the role of digital technology in SD and SA and apply UD principles when designing SA-supporting technology to ensure a high-level of usability and accessibility.

Human-centred or participatory design should be adopted so stakeholders are involved in the entire process and their challenges, needs, requirements, goals, and workflow are considered (Endsley, 2016). Such approaches can ensure that the system model matches the stakeholders' mental model and contribute to reducing human-errors and design-induced errors when interacting with SA-supporting technology.

Can UD mitigate the SA-Demons by improving the technology and facilitate a better interaction between system and operator? Gjøsæter et al. (2019), examine and connect SA with Situational Disabilities. Since the effects of these have similarities with traditional disabilities, it is natural to apply UD for mitigating them. Gjøsæter et al. (2020a) elaborate this and outline how an information system process model of SA can be adapted as a basis for designing information support systems for SA. That study further supports our current finding that the root of the SA may not primarily be lack of training or focus among users, nor inadequate technology, but the interface and interaction between users and technology in the socio-technical system. This is a challenge for which UD and Human-Centred participatory design is well-suited.

There are opportunities for future research such as to investigate 1) the causes of human-errors when technology is involved and contributes to human-errors, 2) the key technological challenges that need to be addressed, 3) design of technology to reduce human-errors and enhance SA, 4) user-oriented information presentation and the technology design that support user interactions through different modalities and devices. One limitation in this study is that only title, abstract and introduction have been analysed, since this is where we expect to find statements about how the authors intend to handle the topics of SA and the SA-Demons in their research.

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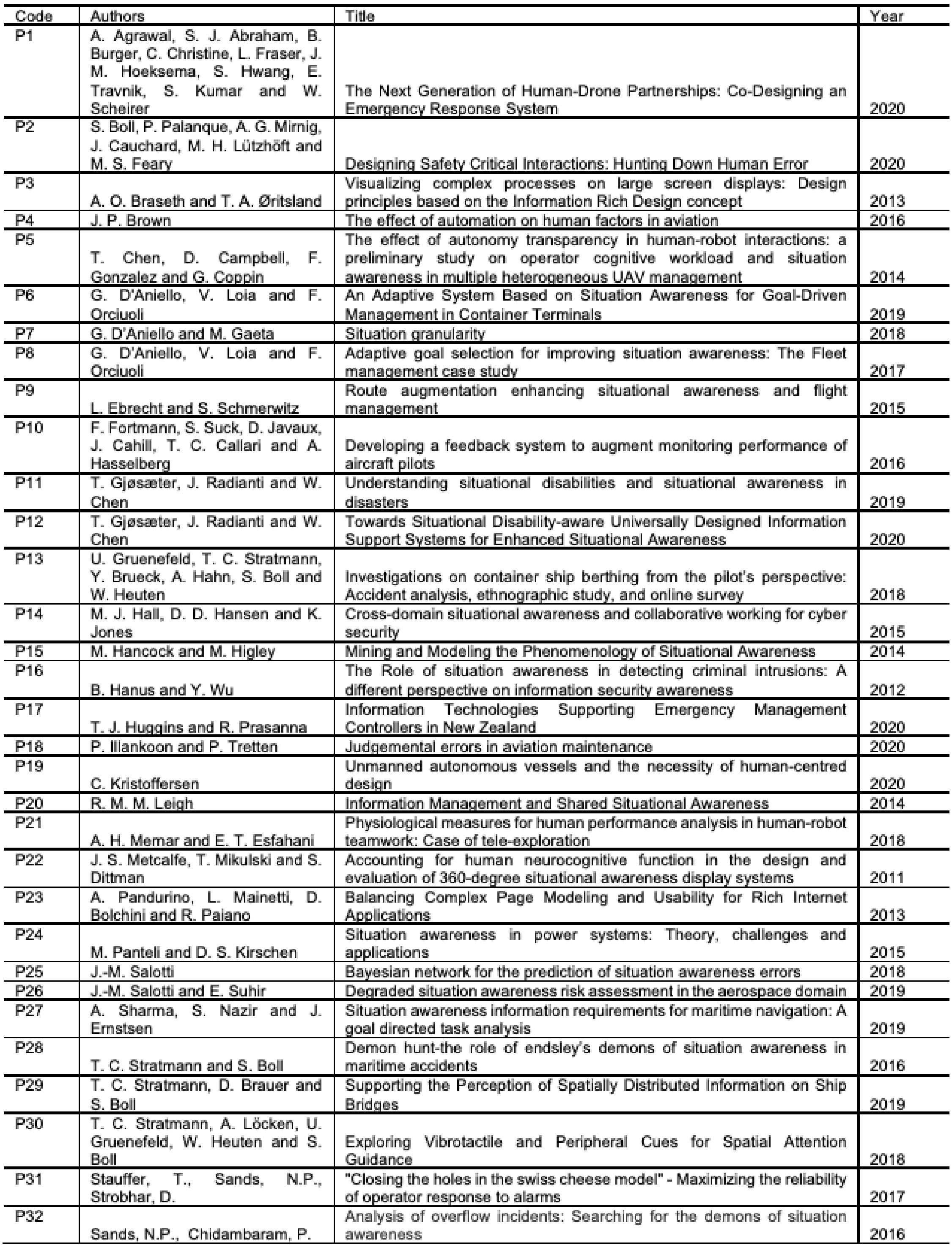
APPENDIX A – LIST OF ANALYSED PAPERS



Code	Authors	Title	Year
P1	A. Agrawal, S. J. Abraham, B. Burger, C. Christine, L. Fraser, J. M. Hoeksema, S. Hwang, E. Travnik, S. Kumar and W. Scheirer	The Next Generation of Human-Drone Partnerships: Co-Designing an Emergency Response System	2020
P2	S. Boll, P. Palanque, A. G. Mirnig, J. Cauchard, M. H. Lützhöft and M. S. Feary	Designing Safety Critical Interactions: Hunting Down Human Error	2020
P3	A. O. Braseth and T. A. Øritsland	Visualizing complex processes on large screen displays: Design principles based on the Information Rich Design concept	2013
P4	J. P. Brown	The effect of automation on human factors in aviation	2016
P5	T. Chen, D. Campbell, F. Gonzalez and G. Coppin	The effect of autonomy transparency in human-robot interactions: a preliminary study on operator cognitive workload and situation awareness in multiple heterogeneous UAV management	2014
P6	G. D'Aniello, V. Loia and F. Orciuoli	An Adaptive System Based on Situation Awareness for Goal-Driven Management in Container Terminals	2019
P7	G. D'Aniello and M. Gaeta	Situation granularity	2018
P8	G. D'Aniello, V. Loia and F. Orciuoli	Adaptive goal selection for improving situation awareness: The Fleet management case study	2017
P9	L. Ebrecht and S. Schmerwitz	Route augmentation enhancing situational awareness and flight management	2015
P10	F. Fortmann, S. Suck, D. Javaux, J. Cahill, T. C. Callari and A. Hasselberg	Developing a feedback system to augment monitoring performance of aircraft pilots	2016
P11	T. Gjøsæter, J. Radianti and W. Chen	Understanding situational disabilities and situational awareness in disasters	2019
P12	T. Gjøsæter, J. Radianti and W. Chen	Towards Situational Disability-aware Universally Designed Information Support Systems for Enhanced Situational Awareness	2020
P13	U. Gruenefeld, T. C. Stratmann, Y. Brueck, A. Hahn, S. Boll and W. Heuten	Investigations on container ship berthing from the pilot's perspective: Accident analysis, ethnographic study, and online survey	2018
P14	M. J. Hall, D. D. Hansen and K. Jones	Cross-domain situational awareness and collaborative working for cyber security	2015
P15	M. Hancock and M. Higley	Mining and Modeling the Phenomenology of Situational Awareness	2014
P16	B. Hanus and Y. Wu	The Role of situation awareness in detecting criminal intrusions: A different perspective on information security awareness	2012
P17	T. J. Huggins and R. Prasanna	Information Technologies Supporting Emergency Management Controllers in New Zealand	2020
P18	P. Illankoon and P. Tretten	Judgemental errors in aviation maintenance	2020
P19	C. Kristoffersen	Unmanned autonomous vessels and the necessity of human-centred design	2020
P20	R. M. M. Leigh	Information Management and Shared Situational Awareness	2014
P21	A. H. Memar and E. T. Esfahani	Physiological measures for human performance analysis in human-robot teamwork: Case of tele-exploration	2018
P22	J. S. Metcalfe, T. Mikulski and S. Dittman	Accounting for human neurocognitive function in the design and evaluation of 360-degree situational awareness display systems	2011
P23	A. Pandurino, L. Mainetti, D. Bolchini and R. Paiano	Balancing Complex Page Modeling and Usability for Rich Internet Applications	2013
P24	M. Panteli and D. S. Kirschen	Situation awareness in power systems: Theory, challenges and applications	2015
P25	J.-M. Salotti	Bayesian network for the prediction of situation awareness errors	2018
P26	J.-M. Salotti and E. Suhir	Degraded situation awareness risk assessment in the aerospace domain	2019
P27	A. Sharma, S. Nazir and J. Ernstsen	Situation awareness information requirements for maritime navigation: A goal directed task analysis	2019
P28	T. C. Stratmann and S. Boll	Demon hunt-the role of endsley's demons of situation awareness in maritime accidents	2016
P29	T. C. Stratmann, D. Brauer and S. Boll	Supporting the Perception of Spatially Distributed Information on Ship Bridges	2019
P30	T. C. Stratmann, A. Löcken, U. Gruenefeld, W. Heuten and S. Boll	Exploring Vibrotactile and Peripheral Cues for Spatial Attention Guidance	2018
P31	Stauffer, T., Sands, N.P., Strobhar, D.	"Closing the holes in the swiss cheese model" - Maximizing the reliability of operator response to alarms	2017
P32	Sands, N.P., Chidambaram, P.	Analysis of overflow incidents: Searching for the demons of situation awareness	2016