Post-print version of the paper Danielsen, B. E., Lützhöft, M., & Porathe, T. (2021). In International Conference on Applied Human Factors and Ergonomics (pp. 463-470). Springer, Cham.

Still unresolved after all these years: human-technology interaction in the maritime domain

Brit-Eli Danielsen[1], Margareta Lützhöft[2]
and Thomas Porathe[1]

[1] NTNU Department of Design, Kolbjørn Hejes vei 2b, 7491 Trondheim, Norway
[2] HVL, Department of Maritime Studies, Bjørnsons gate 45, 5528 Haugesund, Norway
brit-eli.danielsen@samforsk.no

Abstract. Over the last decades there has been a steady increase in digitalized products, applications and services introduced to ship's bridges with the intent to reduce workload and increase safety. However, new technology come with unexpected effects. The current study involves data collected from field trips on board five ships and semi-structured interviews with 21 seafarers. The results show that the human-technology interaction on ship bridges still is a challenge for the seafarers. However, the seafarers see it as part of their professional role to manage and adapt to the equipment or system they have at hand to get the job done. In this paper this ability to handle and make sense of technology is analysed through the notion of seamanship. To find ways to reduce the gap between technology-as-used and technology-as-designed future research should be directed towards the many stakeholders involved in ship bridge design.

Keywords: Human-technology interaction · Maritime domain · Ship bridge design · Seamanship · Sensemaking

1 Introduction

Over the last decades there has been a steady increase in digitalized products, applications and services introduced to ship's bridges with the intent to reduce workload and increase safety. However, new technology may come with unexpected effects, as Bainbridge pointed out already in the 1980's [1]. Technology and automation does not simply replace human work, it also changes the tasks it was meant to support and creates new possibilities and forms of "human error" [2, 3].

An accident in Singapore Strait in 2017 may serve as an illustration. A warship was overtaking a tanker when the warship had a perceived loss of steering. Onboard the warship bridge steering could be controlled from four Integrated Bridge and Navigation Systems (IBNS) as well as one in the emergency aft steering compartment. During transfer of the propulsion control from one bridge station to another, the steering was also accidently included. The helmsman declared he had no steering and the commanding officer ordered manual emergency steering to be taken over by the aft emergency steering compartment. The ship had two steering emergency-override-to-manual buttons (called the "big red button" by Navy crewmembers), one on the cen-

tral steering console on the bridge and one in the aft emergency steering compartment. Pushing the button would immediately transfer steering control to the station where the button was pushed. However, the bridge crew though that by pressing the bridge "big red button", steering was sent to the emergency steering compartment in the aft. So, when the commanding officer ordered steering to be taken over by the aft compartment, the aft crew pushed their button and gained control. Almost simultaneously the helmsman pushed the bridge "big red button" thinking he had sent the control to the aft, while in reality retaking control to his bridge console. Hence, the aft crew who thought they had control, did not and the helmsman thinking he had no control stopped trying to steer. Meanwhile, the vessel unintentionally turned to port into the path of the tanker and collided. The design of the IBNS was identified as a contributing factor to the accident [4].

The maritime sector is diverse and consist of many stakeholders that in some way influence ship bridge design. In this paper we look at the sharp end, how seafarers handle and make sense of technology on the bridge through the notion of seamanship.

The paper is structured as follows: in the next section, we present the theoretical foundation for the analysis, Section 3 outlines the methodological approach for the study. The results and discussion are presented in Section 4, followed by the conclusions in Section 5.

2 Theoretical Foundation

This section presents the theoretical foundations for the analysis, sensemaking and seamanship.

2.1 Sensemaking

The concept of sensemaking is influential in organization studies. Sensemaking is the transient process through which people assign meaning to issues, events or to their environment [5]. Sensemaking is triggered by *cues* that are actively extracted from peoples lived experience. The cues are noticed based on previous experience or existing cognitive frames. The cues are "seeds from which people develop a larger sense of what may be occurring" [5]. The cues are interpreted, and action is taken. The actions create a slightly different or new environment to continue to make sense of, a process known as enactment [5, 6]. This is an ongoing cycle where "people construct provisional understandings that they continuously enact and modify" [6].

Sensemaking is often described as triggered when people confront events or issues that are somehow surprising, confusing or violate expectations [5, 6]. However, sensemaking also occurs non-episodically during routine work. This is a form of mundane or *immanent* sensemaking where "people go on doing the things they routinely do without deliberately thinking about how they do them." [7]. Sandberg and Tsoukas [7] connect immanent sensemaking to absorbed coping, something especially found amongst experts that are "as one" with their work, continuously acting in response to their sense of the situation.

Sensemaking is both an individual process going on in peoples' head as well as a social process where people actively shape each other's meanings [5]. Weick [5] ar-

gues that even individual sensemaking is influenced by the actual or implied presence of other organizational members.

As "people can make sense of anything" [5] there is an infinite number of factors that can influence sensemaking. *Technology* is one factor that has been found to trigger sensemaking about the technology itself, how to respond and engage with it as well as influence how sense is made of professional relationships and professional identity [7]. *Identity* is another central factor influencing sensemaking. People will often attempt to make sense of events in ways that respond to their need of maintaining a consistent, positive self-conception [8].

2.2 Seamanship

The professional culture among seafarers is denoted *seamanship*. This is a notion without a specified or agreed-upon definition. The term is used in several different areas, from textbooks and maritime regulations to accident investigations and in the media. These understandings are not necessarily consistent with how seafarers understand or use the term [9]. According to Knudsen [10] seamanship is "a blend of professional knowledge, professional pride, and experience-based common sense", as well as having a social and ethical dimension.

Antonsen [11] conducted a survey on the meaning of good seamanship with 258 seafarers. The most frequent characteristic given was the ability to maintain social relations and community, followed by work performance, in this case referring to working safely and with high quality. Other responses included individual properties, such as being independent, responsible and reliable, and competence - mainly referring to practical sailing experience.

Good seamanship is mainly developed through experience. Traditionally, seafarers training from novice to expert has been based on practice and a learning process based on socialization [12]. The developed experience and knowledge form a basis for using *common sense* and exercising *good judgement* which are central aspects of seamanship [10, 13]. *Troubleshooting* is another part of this picture, and according to Lamvik [14] it is a necessary, expected and highly appreciated aspect of seamanship. To be able to find solutions and make do with whatever you have at hand is important when spare parts or other forms of help are miles or days away.

Professional identity is central to seamanship, for instance in the sense that it separates "real seafarers" from those who are not, mainly the people in onshore organisations [9]. Professional identity is dynamic, and the traditional notion of seamanship has probably changed over the last decades due to technology development and proceduralisation [13].

3 Method

This study has a qualitative approach as the interest is in the seafarer's view of the design of technology they work with on the bridge. The main topic for the data collection concerned the informants experience and opinions about the technology available mainly on the ship bridges they currently worked on, but they would also refer to previous experiences from other ships they had worked on. The questions were open-

ended allowing the informants to speak freely about different aspects of their work on the bridge. The questions included how design of technology hamper or support their daily tasks, what kind of influence seafarers have on design and equipment available, as well as their take on the notion of seamanship.

3.1 Procedure

Data was collected onboard five ships, including observation and interviews with a total of 21 officers. An overview of the data collection and methods is given in Table 1. One researcher visited two offshore supply vessels while they were sailing on the Norwegian continental shelf. The ships were built in 2014 and 2016. Both vessels had four officers onboard that participated in the study. Two researchers performed shorter visits onboard three passenger ships, built in 1983, 1993 and 1996. Semi-structured interviews were performed with two officers on each passenger ship. A focus group interview was performed between lectures, with six coastal vessel officers, participating in a course at a Norwegian education facility. Two researchers performed a semi-structured interview with a master mariner and lecturer in nautical studies.

Table 1. Overview of methods and data collection performed.

Location	Method performed	Approx. time (hrs)	Informants
Two offshore supply vessels	Observation. Informal unstructured and semi-structured interviews.	100	8 officers
Three passenger ships	Observation. Semi-structured interview.	4	6 officers
Onshore	Focus group interview.	1	6 officers
Onshore	Individual semi-structured interview.	2	1 officer
Total: 5 ships			Total: 21 officers

3.2 Data management and analysis

The audio recorded interviews were transcribed verbatim. The transcriptions and field notes were read several times, followed by coding of the data material with the help of NVivo software. Coding reduced the data by systematically examining the texts line by line and assigning a descriptive code for each segment. The generated codes were grouped into categories that were subsequently reviewed and organized. Two of the resulting themes are presented and discussed in chapter four. All quotes are translated from Norwegian. The data collection and management has been approved by NSD – Norwegian centre for research data.

4 Results and Discussion

This section will discuss two themes developed from the data that was found to be related to sensemaking, seamanship and technology on the bridge; 1) Seamanship as seafarers see and 2) Adaptation of, and adaptation to, bridge design.

4.1 Seamanship as seafarers see it

The informants describe seamanship much in the same way as previous research have reported. They emphasize individual capabilities where experience is crucial, in the sense that education may be a foundation for seamanship, but it is mainly developed over time through experience. They also highlight performing work properly, thinking ahead, as well as continuously performing your own safety assessments. Social relations are described as important both internally on the ship, but also involves acting considerately and politely towards other vessels and people encountered at sea.

A recurring theme also in our data is to use *common sense* and think for yourself, as in using your own *good judgement*. The informants describe their sensemaking as trusting your own competence and experience in the form of seamanship to be able to notice the relevant cues in the environment and continuously make sense of the situation at hand. Seamanship in this sense was described by one informant as to "recognize situations where you know alarm bells should be going off in your head, that's something you acquire over time". The specificity of each situation requires situated solutions and was specifically described as 'not necessarily doing things by the book'.

When seamanship was discussed in relation to working with technology on board the informants described it as the ability to assess the whole situation and not only the reality as presented on screens: "that you actually pay attention to what is happening outside and around you and not being busy with 300 screens overburdened with information and alarms". Several informants mentioned that they thought newcomers pay too much attention to screens and that looking outside the windows is something they have to learn. To look outside is important, not only to assess the whole situation, but the screens may also take too much focus by presenting information that is not seen as important or necessary for work execution. Another part of seamanship expressed was the ability to sort out the important information from the abundance of information available on the bridge. Although working with information technology is an important part of the job, part of developing seamanship is to balance the attention between information presented on screens and other types of information available in the work environment. The ability to handle technology by adapting to it was very clearly expressed by one informant as "to adapt to the system is seamanship in practice".

4.2 Adaptation of, and adaptation to, design

The technology available on the bridge triggers seafarers' sensemaking about the technology itself and how it can be used to accommodate their job. The technology also triggers sensemaking about "the others" - the people in land organizations that are responsible for designing and implementing the technology on board.

On board the older ship bridges we observed many examples of poor design. The informants interviewed on shore describe the same problems. Some are directly connected to human perception such as lacking the possibility to dim screens and other lights that impair their night vision, or too many alarms having similar sounds. Regarding usability, consoles are cluttered with little grouping of functions, too many buttons, whereof many not functioning, and buttons and levers are too small and cumbersome to work with. There are issues like poorly functioning touch screens, lengthy menus to navigate through and too much unnecessary info on screens. Poor ergonomics is evident as we observed officers climbing on consoles or standing on pallets to reach necessary equipment. These issues still exist despite the knowledge, guidelines and to some extent regulatory requirements on ergonomics and usability that are available today.

Alongside poor design another interesting finding was observed – adaptation of the technology. The adaptations include self-made covers for dimming screens, partly covering screens to cover unnecessary functions, covers over non-functioning buttons, pallets to stand on, lengthening of levers, written notes, and adding equipment like computer mouse. This *adaptation of design* may be seen as part of seafarers sensemaking of the technology at hand. When workplace design is poor, seafarers make it work through *adaptation of design.* We know that identity is a core factor influencing sensemaking. The professional identity as a seafarer involves the pride taken in doing a good job as well as being excellent at troubleshooting. The adaptations are seen as necessary to avoid making mistakes and get the job done in a safe and practical manner. “You do modifications because you know the bridge will not be replaced” as one informant puts it. This statement refers to the fact that modifications are necessary, but it also illustrates the belief that despite the seafarers’ dissatisfaction, the equipment will not be changed. Being excellent at troubleshooting and finding creative solutions may in this sense be a double-edged sword. For “the others” – the people in land-organizations the equipment on board may seem to be working well, or at least well enough.

The poorly designed technology also triggered sensemaking about “the others” - those who design, develop, and install equipment on ship bridges. The descriptions of poor design were followed by frustration and the impression that the people on shore who make design decisions do not have the knowledge or understanding of what is needed on board, clearly illustrated by statements like ‘It probably worked well in the office’.

The two offshore supply ships were equipped with a recently developed integrated bridge concept where the manufacturer had emphasized end-user involvement during the development. In general, the informants working here describe the bridge as “well arranged”, “you have everything you need around you” and that after working with this bridge they could not imagine going back to a conventional bridge again. The visual impression of this bridge environment was very tidy, clutter-free and very few adaptations were observed. The crew appeared to have the necessary equipment readily available when they were seated in their main working position.

The concerns that *are* raised regarding the integrated bridges are mainly on a higher level, such as the integration makes it hard to understand, or gain control over, what is going on behind the screens. Another concern is that integrated bridges make the crew more dependent on the land-organizations. It is not possible for them to perform

maintenance or small adaptations as everything must be programmed into the bridge system by the manufacturer. This comes with a cost and thereby often is not prioritized. This challenges the seafarers' independence, responsibility and competence, all central parts of seamanship.

One informant described the difference between the new integrated bridge he was currently working with and an old ship he had worked on previously. He explains that it took some time for him to "get used to" this bridge system. Although the old ship was analogue and cumbersome to work with it did not bother him at the time because he "was used to it". However, after getting used to the integrated bridge, he now prefers the new system. "Getting used to" reflects sensemaking both as a learning process as well as an adaptation process.

It is reasonable to assume that many of the things that do not work well and cannot be adapted could lead to new and possibly suboptimal ways of working. *Adaptation to design*, where seafarers adapt their work to the system is a more tacit and invisible response than the *adaptations of design*. However, as the quote "to adapt to the system is seamanship in practice" illustrates this is also part of the notion of seamanship.

There was no systematic feedback loop from seafarers to land-organizations regarding design found in our field studies. If there was a feedback loop, the adaptations that seafarers perform could function as clues for designers, engineers and implementers of design. However, the adaptations are mostly quite small, individual or specific solutions to daily encountered problems and fixing these things may not mean that the system improves as a whole. As one informant put it "I don't know what I want, I only what I don't want". As such, the adaptations should not be treated as direct design input, rather a sign that the overall system is not working. To improve design on a system level would require more thorough research like longitudinal ethnographic studies that could reveal adaptations to design as well as user needs on a system-level.

5 Conclusion

This study found that seafarers see it as part of their professional role to manage the equipment or systems on the bridge to get their job done in a safe and practical manner. The necessary adaptations they do may not be visible to stakeholders on land as there is no system in place for feedback from operations. Inadequate design is most vividly described and observed on older retrofitted bridges. Retrofitted bridges seem to some extent to develop randomly over time as equipment is replaced or added. The newer bridges have fewer physical adaptations, and the design is more positively referred to by the crew. Still the technology development with layers of integrated systems is perceived as a cause for concern where they lose sight of the real world behind the screens.

There is a gap between those who design, develop, and install equipment on ship bridges and the end-users – the seafarers. This is a finding that resonate with similar research over decades. To reduce the gap between technology-as-designed and technology-in-use, future research should study the blunt end of design. If the interest and influence the many maritime stakeholders have in ship bridge design are revealed, it

should be possible to find where in the design process human-centred design activities can be introduced.

Acknowledgments. This work is supported by the SMACS (Sensemaking in Safety-critical Situations) project financed by the Norwegian Research Council, Grant no. 267509.

References

1. Bainbridge, L., Ironies of automation. Automatica, 19(6): p. 775-779 (1983).
2. Strauch, B., Ironies of Automation: Still Unresolved After All These Years. IEEE Transactions on Human-Machine Systems (2017).
3. Lützhöft, M., "The technology is great when it works": Maritime Technology and Human Integration on the Ship's Bridge. Linköping University Electronic Press (2004).
4. NTSB, Collision between US Navy Destroyer John S McCain and Tanker Alnic MC, Singapore Strait, 5 Miles Northeast of Horsburgh Lighthouse, August 21, 2017. National Transportation Safety Board (2019).
5. Weick, K.E., Sensemaking in organizations. Foundations for organizational science. Thousand Oaks, California: Sage (1995).
6. Maitlis, S. and M. Christianson, Sensemaking in Organizations: Taking Stock and Moving Forward. The Academy of Management Annals, 8(1): p. 57-125 (2014).
7. Sandberg, J. and H. Tsoukas, Making sense of the sensemaking perspective: Its constituents, limitations, and opportunities for further development. Journal of Organizational Behavior, 36: p. S6-S32 (2015).
8. Weick, K.E., K.M. Sutcliffe, and D. Obstfeld, Organizing and the process of sensemaking. Organ Science, 16(4): p. 409-421 (2005).
9. Bye, R., Antonsen, S. and Lamvik, G. Godt sjømannskap - ferdigheter og yrkesidentitet. In Antonsen, S., Kongsvik, T. (eds.) Sikkerhet i norske farvann, Gyldendal Norsk Forlag AS: Oslo, Norway (2015).
10. Knudsen, F., Paperwork at the service of safety? Workers' reluctance against written procedures exemplified by the concept of 'seamanship'. Safety science, 47(2): p. 295-303 (2009).
11. Antonsen, S., The relationship between culture and safety on offshore supply vessels. Safety science, 47(8): p. 1118-1128 (2009).
12. Bye, R.J. and A.L. Aalberg, Why do they violate the procedures?–An exploratory study within the maritime transportation industry. Safety science, 123: p. 104538 (2020).
13. Kongsvik, T., et al., Re-boxing seamanship: From individual to systemic capabilities. Safety Science 130: p. 104871 (2020).
14. Lamvik, G., A. Wahl, and M.P. Buvik, Professional culture, work practice and reliable operations in shipping. Reliability, Risk and Safety, Taylor & Frances Group, London (2010).