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Corresponding author: Lars Berntzen Arholm (larsarholm95@gmail.com)

Research performed at: MARIN (Maritime Institute of the Netherlands)

Graduation specialisation: Applied Cognitive Psychology, Leiden University

Current occupation: Human Factors intern at MARIN

Supervising autonomous maritime vessels: Enhancing situational awareness in Shore Control Centre interfaces

Introduction

The introduction of autonomous vessels could revolutionize the maritime industry. However, automation is difficult to perfect and autonomous systems still need to be supervised by humans (Endsley, 2017). In the maritime setting, this will be done by human operators in Shore Control Centers (SCCs) (MacKinnon et al., 2015).

To ensure that operators monitor and/or control autonomous vessels in a safe manner, they must be situationally aware. Multiple factors affect situational awareness (SA). First, complacency, occurring when automation seems to function perfectly, leading to automation bias (Parasuraman & Riley, 1997). Operators fall 'out of the loop' (OOTL), making them slow to realize that their intervention is required. When they do intervene, their performance is reduced (Endsley, 2017; Endsley, 1995a). The automation bias increases when automation is perceived as robust, leading to the 'automation conundrum': better automation gives worse human performance (Endsley, 2017).

A second factor is workload. High workload makes the operator less situationally aware, as they become unable to fully perceive all the presented information, making it difficult to fully comprehend and project the situation. Providing an operator with too little information leads to cognitive underload, reducing SA. This study aimed to research how SA can be enhanced in SCC interfaces. Empirical research in this area is currently lacking (Man et al., 2018). Using MARINs first version SCC interface, we looked at operators' SA, how the interface should be improved to further enhance operators' SA, and how the number of vessels monitored affects an operator's workload and SA. It was hypothesised that the operators would not be sufficiently situationally aware and that many features had to change, due to the first version being created without user-testing. Further, that as the number of vessels increased, SA would decrease through the increased workload.

Method

For this study, MARIN developed an SCC interface, inspired by the MUNIN (Maritime Unmanned Navigation through Intelligence in Networks) setup (MacKinnon et al., 2015), and modified to fit inside MARINs maritime simulator software 'Dolphin'. The MUNIN interface is the main setup used in other studies (Man et al., 2015; 2018). It consisted of the following displays: (1) An ECDIS (Electronic Chart Display and Information System, electronic sea map); (2) a RADAR; (3) a conning display; (4) a control window (switch between manual/ autonomous control); (5) a vessel status display.

Table 1 lists characteristics of the 13 male participants, recruited through MARINs and the researcher's network. A diverse sample of age and background was chosen to represent a wide spectre of possible future users.

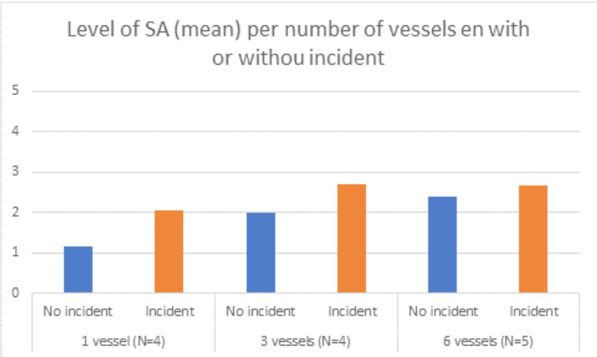
The participants completed four scenarios. In scenario 1 there was no incident, while in scenario 2 through 4 an incident was simulated. The order of these incident-scenarios was randomized for each participant. Each participant was randomly assigned a number of autonomous vessels (1, 3 or 6) to monitor throughout all scenarios. The simulated incidents (based on real-world incidents) were: a violation of COLREGS (The International Regulations for Preventing Collisions at Sea), a suddenly appearing vessel (simulating ECIDS/ RADAR failure) and a rudder failure.

The quantitative measures collected were: perceived SA, perceived workload, reaction time, usability and performance on Close Point of Approach (CPA). Qualitative data consisted of experiment observations (comments and behaviours) and a semi-structured post-interview about user requirements after all scenarios were completed.

Results

To analyse the number of monitored vessels, the perceived SA and perceived workload, a one-way

Supervisors:
- Guido Band, psychology professor, University of Leiden
- Gerrit van der Want, senior project manager, MO department, MARIN
- Colin Guiking, Human Factors expert, MO department, MARIN
- Hans Huisman, Human Factors expert, MO department, MARIN



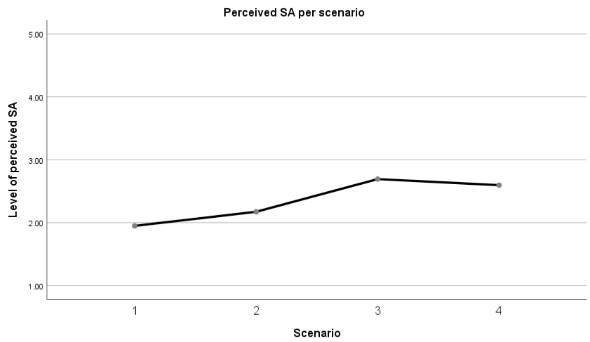


Figure 1: Perceived situational awareness per number of vessels without and with incident. A lower number indicates higher perceived SA.

ANOVA was conducted. Figure 1 displays SA per number of vessels and with or without incident. A significant main effect difference was observed for perceived SA, $F(2,10)=4.48$, $p=.041$, $\eta2=.47$, and for perceived workload, $F(2,10)=5.27$, $p=.03$, $\eta2=.51$. The posthoc test indicated a significant difference between 1 and 6 vessels for both perceived SA, $p=.05$, and perceived workload, $p=.04$, but no significant difference between 3 and 6 vessels. These results show that when a participant monitors more than 1 vessel, perceived SA decreases, and perceived workload increases.
To see if perceived SA and perceived workload differed between scenarios, a repeated-measures ANOVA was conducted. The difference in perceived workload was not significant $F(3, 36)=.86$, $p=.47$, however, for SA a significant difference was observed $F(3, 36)=3.65$, $p=.02$, $\eta2=.23$. The LSD posthoc test indicated that perceived SA was significantly higher in scenario 1 compared to scenario 3 ($p=.007$), and 4 ($p=.01$). Participants' perceived SA significantly higher in the non-incident scenario 1 than in two of the incident scenarios, scenario 3 and 4.
The main user requirements mentioned were: more transparency on the autonomy of the vessel, lack of prompts (e.g., a close-distance prompt for ships approaching closely), a more accessible CPA function and high saliency for RADAR and vessel status display.

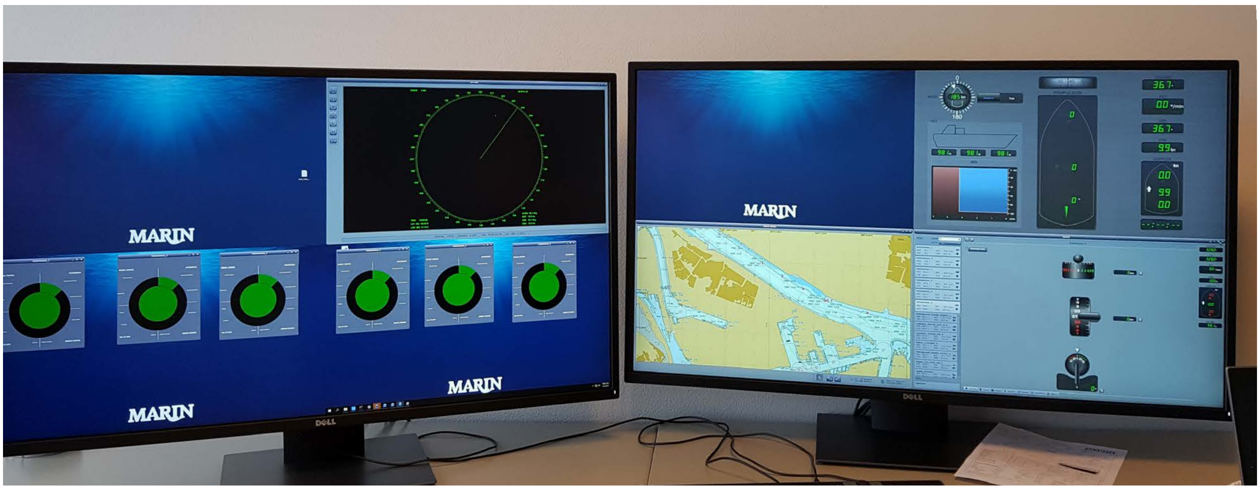


Figure 2: The evaluated interface.

Figure 3: The main researcher and supervisor demonstrating the interface and the eyetracking equipment.

Conclusion and implications

With the used SCC interface, operators' perceived SA and workload were not supported sufficiently, especially when monitoring more than one vessel and in case of an incident. Since monitoring only one vessel could increase chances of cognitive underload, it is recommended to improve the support of monitoring multiple vessels. Also, there is a need for an optimised interface for urgent situations. This could be achieved by fulfilling the following requirements: clear mode of automation, feedback on the next action and higher saliency for RADAR, vessel status display and CPA information. Achieving these requirements should countribute to safer monitoring and controlling of autonomous vessels through enhanced operator SA.

Summary of article

Autonomous ships are being developed, but it is difficult to make them perfect, making human supervision necessary in Shore Control Centers (SCCs). We tested an SCC interface and found that participants were only able to monitor 1 vessel in case of no ship-incident without becoming less situationally aware and experiencing more workload. However, participants with 1 vessel became bored more easily. Therefore, a better interface is needed. Based on comments by the participants and relevant literature, an improved interface should contain a clearer mode of automation, better feedback on the next action and more salient positioning of the most important displays.

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Table 1. Characteristics of participants (N=13)

Age	Mean (SD)	43.31 (17.34)
	Min/Max	21 / 72
Years of experience	Mean (SD)	18.67 (15,22)
	Min/Max	0.5 / 52
Function (N)	Student	3
	Current mariner	3
	Prior mariner	5
	Vessel Traffic Service	2