Development of a Behavioural Markers System for Maritime Autonomous Surface Ship Operations

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SUMMARY

A prototype Behavioural Markers System (BMS) is being developed for the operation of Maritime Autonomous Surface Ships (MASS) to assess operators' non-technical skills for working in a Remote Control Centre (RCC) and assess the behaviours of machine teammates. This paper outlines the initial prototype BMS it includes behavioural markers (BMs) for humans working within a human-machine team, as MASS systems are using higher levels of automation and are changing how the operators will interact with the automated systems. The BMS will also be extended to BMs for machine teammates which could be used in the design and evaluation of future MASS systems. Future work will focus on the further development of the prototype BMS adding further BMs for human-machine and machine-human interactions.

KEYWORDS

Non-technical skills, behavioural markers system, human-machine team, maritime autonomous surface ships

Introduction

As MASS are a relatively new technology there are currently no standards and competencies that have been developed for MASS operators to support their training. The BMS being developed aims to support MASS operator training through the development of future standards and to support the design and evaluation of future MASS systems by also exploring the behaviours of machine teammates in addition to the human teammates' behaviours. As the development of the technology is increasing MASS systems are using higher levels of automation and the role of the operators is to predominantly supervise these machine agents (Scharre, 2015; Vagia, Transeth, & Fjerdingen, 2016). Therefore, it will be necessary to ensure that MASS operators are not only trained to work with their human teammates within an RCC (e.g., payload operators and RCC supervisors), but are also able to work effectively within a human-machine team as their machine teammates take on higher-level tasks. MASS operators will need to develop their non-technical skills (e.g., their communication or leadership skills), which can be defined as their cognitive, social and personal resource skills to complement their technical or taskwork skills to increase the performance and safety of the team (Flin, O'Connor, & Crichton, 2008). However, other mitigation strategies will need to be applied to ensure the overall safety of MASS systems; training in non-technical skills

will only partly address this issue (Lynch et al., 2023; Salmon, Hulme, Walker, Waterson, & Stanton, 2023; Young & Steel, 2017). Nevertheless, it has been highlighted that current human to human models and methods for understanding teamwork need further development to be appropriate for the application to human-machine teams (Roberts et al., 2022).

Method

An initial set of BMs for human teammates was developed using evidence from existing BMSs that have been developed in other domains including: maritime (da ConceiçÌo, Basso, Lopes, & Dahlman, 2017; Gatfield, 2005; O'Connor et al., 2002; O'Connor, 2011; Oil Companies International Marine Forum, 2018; Saeed, Wall, Roberts, Riahi, & Bury, 2017), aviation (Hamlet, Irwin, Flin, & Sedlar, 2023; Kontogiannis & Malakis, 2013; O'Connor et al., 2002; Tsifetakis & Kontogiannis, 2019), medicine (Michinov, Jamet, Dodeler, Haegelen, & Jannin, 2014; Mitchell et al., 2011), petrochemical (Crichton, Moffat, & Crichton, 2017), rail (Naweed & Murphy, 2023) and fire and rescue (Butler, Honey, & Cohen-Hatton, 2020). The initial set of BMs included eight main behavioural categories, these were closed-loop communication, decision-making, leadership, performance monitoring, backup behaviours, adaptability, shared mental models and situational awareness and fifteen sub-categories. The main behavioural categories were developed from categories in the BMSs outlined above and then the relevant categories were renamed using some of the core components and mechanisms of teamwork outlined by Salas, Sims, and Burke (2005).

Eight of the identified sub-categories from the human-human behavioural sub-categories were identified as relevant to human-machine interactions and the BMs in these sub-categories were adjusted to make them relevant for human-machine interactions. A main behavioural category trust was then added to the BMS due to its relevance to human-machine teams and an additional subcategory within the shared mental models category to reflect the need for understanding the roles and limitations of machine teammates as well as human teammates. Trust is an important part of how an operator will interact with a machine teammate (Lynch, 2022). The operator will need to develop a shared mental model so that they have an understanding of the roles and limitations of their machine team members as well as their human team members (Gisick et al., 2018; Lynch, Banks, Roberts, Radcliffe, & Plant, 2022; Lynch, 2022). It will be important that the operator has an understanding of the division in work and roles between themselves and the automated systems and that they are relying on and using the automation appropriately when operating MASS (Lynch, 2022). Each behavioural sub-category will then be assessed for its relevance to machine-human interactions to understand what behaviours will be required for machine teammates and how a machine teammate's behaviour could be evaluated during a MASS systems' development.

Summary

In summary, a BMS is being developed for the operation of MASS from RCCs to assess operators and MASS systems. The BMs could be used to assess an operator's interactions with their machine teammates and to inform the development of new training standards and competencies. It has been already shown in the maritime domain that non-technical skills are an important part of the system with mariners receiving non-technical skills training through Bridge Resource Management to reduce safety risks (Fjeld & Tvedt, 2020). The prototype BMS will be used as an assessment tool for MASS operators undergoing training in a RCC, to initially investigate how BMS could be used to assess human-machine teams and provide future non-technical skills training in highly automated domains. The BMS will also be used to explore the applicability of using BMs to assess the machine-human interactions within a human-machine team, which could be used in the design and evaluation of future MASS systems. This prototype BMS will be developed with subject matter experts to ensure that the BMs identified apply to MASS operations from an RCC and it will also

require validation through observations of MASS operations to explore the utility of the BMS for operator and also how the machine-human BMs could be applied to evaluate MASS system. Further work is needed to explore what additional behaviours may be required to assess both humanmachine and machine to human interactions to extend this prototype BMS. Also, it will be necessary to explore what behaviours additional behaviours a machine teammate may need to work effectively with human teammates.

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