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Optronics: Examining future scopes

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ABSTRACT

A critical task when completing submarine operations in shallow littoral waters is the collection of visual data for safe navigation. Contemporary submarines complete this task using optronics masts. However, a question remains as to whether advancements afforded by such technologies are being fully utilised. The current work assessed optronics mast usage by expert operators to examine new ways of working to maximise the utility of the technology afforded.

KEYWORDS

Optronics, Automation, Submarine control room

Introduction

The frequency of submarine operations being completed in shallow littoral waters is increasing for a variety of purposes including scientific research, surveillance, and coastal protection (Binns, 2008). In such situations, visual data collected from the optronics mast is critical to the command team for safe operation, remaining undetected, and effectively completing mission objectives (da Silva Vieira, 2016; Stevenson, 2005). However, the use of optronics incurs a risk of counter-detection, therefore, mast exposure must be minimised to remain undetected (da Silva Vieira, 2016).

The optronics mast revolutionised submarine construction. Its predecessor, the periscope mast, was designed such that when the mast was lowered it was housed completely within the submarine (Armstrong, 1998). This imposed several constraints on submarine design including control room positioning and configuration (Stevenson, 2005). The optronics mast permitted greater flexibility in control room positioning and layout, introduced automated programmes such as Quick Look Round (QLR), and snapshot (Armstrong, 1998; Stevenson, 2005). Use of automated functionalities require minimal operator intervention and can minimise mast exposure time, increasing stealth without reducing own submarine safety (Armstrong, 1998; da Silva Vieira, 2016; Stevenson, 2005). However, automated functionality can reduce overall system performance (Miller, Funk, Goldman, Meisner, & Wu, 2005).

Mast Automation: Functionality and Adoption

Once an operator has selected an automated functionality, such as QLR or snapshot, they are only required to intervene in the case of error (Stevenson, 2005). In such situations, the human operator assumes a supervisory role, intervening only when appropriate, or completing work the automation cannot, such reviewing collected data (Bainbridge, 1983). The use of automation can be highly efficient; by delegating tasks to a non-human agent, human capabilities can be extended, and overall system performance can be improved (Endsley & Kiris, 1995; Lee & See, 2004). A key decision to be made by the operator when using an optronics mast is whether to use the automated functionality; this choice can have implications for system performance. Stevenson (2005) noted that there has been a “reluctance” to use automated functionalities permitted by the optronics mast; potentially due to operator familiarity with existing drills, or concerns over reliability and equipment performance. Advanced technologies are often implemented without formal assessment from a sociotechnical perspective. Thus, it is critical to understand what benefits such functionalities affords to a submarine command team, and whether the utility of such technology is being fully realised. The current work had two primary aims: (1) Assess contemporary operation of the optronics mast and (2) Design and test novel, standardised, procedures for optronics mast use, informed by system capability and advice from Subject Matter Experts (SMEs).

Approach and Method

Participants, Materials, and Equipment

A human-in-the-loop study was conducted in a high-fidelity simulator using trained Royal Navy (RN) personnel (n = 35). Participants were pseudo-randomly allocated into teams of three, consisting of an Officer of the Watch (OOW), an Operations Officer (OPSO), and an Optronics Operator (OPT). Due to the availability of qualified personnel, some operators participated in more than one scenario. However, each team had a unique OPT who had Optronics experience, both in the simulator and onboard.

The method used in the current work has been used previously to examine submarine command and control teams in a high fidelity simulator (Stanton, 2014). Three high-definition camcorders were used to record operator screens, and all communications between operators were recorded using three Dictaphones with clip-on microphones. The study protocol received ethical approval from the University of Southampton Research Ethics Committee (Protocol No: 10099) and MODREC (Protocol No: 551/MODREC/14).

A battery of measures was selected to evaluate current (Baseline) optronics usage, regarding operator workload, system usability, trust in automation, information flow, picture accuracy, and mast exposure time. The findings of the Baseline study, along with examination of system capabilities and advice from SMEs, were used to inform the design of novel operating procedures. The second phase of the study (Experimental) required completion of the same scenario using novel operating procedures.

Procedure, Design, and Analysis

An independent groups design was used, in which different participants were recruited for Baseline and Experimental testing. In the Baseline study, operators completed the scenario without instruction being provided concerning optronics use, enabling naturalistic behaviour to be captured. Each scenario lasted approximately 18 minutes, and each team completed the same scenario. Briefly, the scenario featured four vessels, one fishing vessel and three merchant vessels. In the Experimental study, participants were provided with standard operating procedures concerning optronics usage that were deemed by SMEs to be pushing the boundaries of contemporary operation, whilst maintaining safety. Minimal training was required for operators to adopt the new procedures successfully, owing to their experience and a job requirement to adapt to new procedures as necessary. More information on the nature of procedures cannot be provided due to security restrictions. These restrictions also increase data processing time, and as such a reduced data set is presented here as a case study to provide an overview of the findings to date. Future work will perform robust statistical analysis on all processed data.

Research Findings

Baseline Case Studies

The Baseline data revealed great variability of optronics usage across teams despite operators completing the same scenario. It was observed that the optronics mast was being used in a similar manner to a traditional periscope mast, with little utilisation of automated functionality. The case studies presented below, see Figure 1 and Table 1, represent the teams with the longest (Team A) and shortest (Team B) overall mast exposure times. Team A had the optronics mast raised for a total of 898.65 seconds (approximately 83% of the scenario), and used no automated functionality. In comparison, Team B had the optronics mast raised for a total of 258.3 seconds (approximately 24% of the scenario), of which 173.93 seconds was in manual mode.

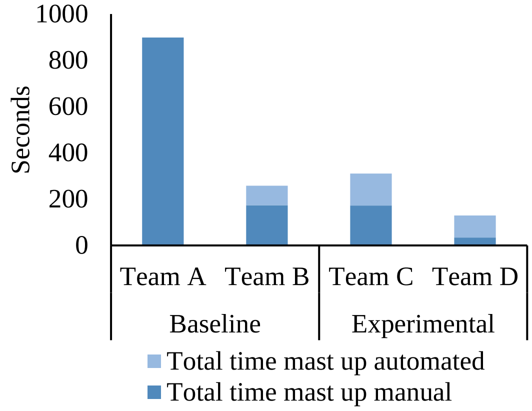

Figure 1: Mast Exposure Time (seconds)

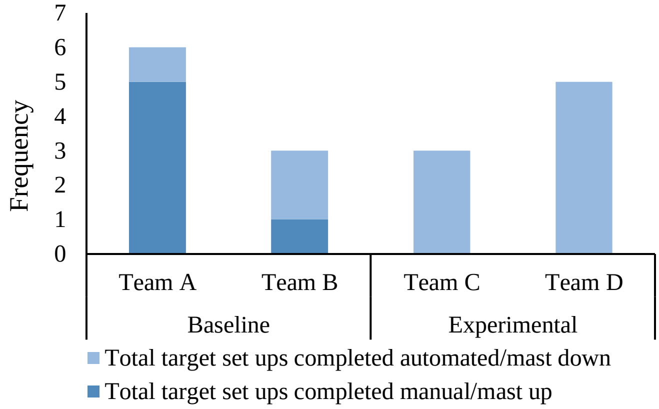

Figure 2: Target Set-ups completed

Despite Team A having the mast raised for the greatest length of time, they did not complete the most manual set-ups. Team A completed six target set-ups, of which five were completed manually (see figure 2). Contrastingly, Team B completed two target set-ups utilising data collected using autonomous functionality, and one manual target set-up. Team B had the lowest number of target set-ups of all baseline teams. Rather than completing target set-ups, Team B were the only team to undertake a ‘Range for me’ drill. This drill was designed to emulate a periscope drill, in which the OOW would utilise the periscope to ascertain ranges on the contacts of interest in order to calculate a look interval.

Table 1: Mast Exposure Time (seconds)

Condition	Team	Manual	Automated	Total
Baseline	Team A	898.65	0	898.65
	Team B	173.93	84.37	258.3
Experimental	Team C	172.18	138.04	310.22
	Team D	33.41	95.99	129.4

Experimental Case Studies

Utilisation of automated optronics functionality (i.e. not available using periscope) greatly increased in the Experimental condition. The Experimental data revealed teams were using the optronics mast as prescribed and with more standardisation. The case studies presented below were selected to match the same criteria as the Baseline study. Team C had the longest mast exposure time of all experimental teams. However, this was of comparable levels to the shortest Baseline teams (see Figure 1 and Table 1). Team D had the shortest mast exposure time of all Experimental teams, with a total time of 129.4 seconds (see Table 1). Team C completed the fewest number of target set-ups, despite having the mast raised the longest (see Figure 2). For both Team C and D, all target set-ups were completed using data collected using automated functionality.

Discussion and Conclusions

The Baseline data revealed great variability of optronics use across teams, despite the same scenario being completed, indicating a lack of standardised use of optronics. In the Baseline study, the optronics mast was raised for extended periods in manual mode. This was undesirable, as when gathering visual data, minimisation of mast exposure is critical for maintaining safety and covertness (da Silva Vieira, 2016). Automated features such as QLR and snapshot (Armstrong, 1998) were rarely utilised in the Baseline study, with operators opting to use the optronics mast manually, or conduct drills based on those from a traditional periscope. This may be due to familiarity with existing drills, which are based upon legacy operating principles (Stevenson, 2005). Utilisation of specialised optronics functionality greatly increased in the experimental study. This was effective at reducing mast exposure times, which would reduce the risk of counter-detection (Armstrong, 1998). Future work will examine tactical picture accuracy to determine the effect of specialised optronics functionality on task performance. Furthermore, the Dictaphone recordings will be used to conduct Event Analysis of Systemic Teamwork (EAST) to understand the effect of utilising specialised optronics functionality on team communication.

The submarine control room is a highly complex sociotechnical system that represents a high state of maturity, but this does not mean that the system cannot be improved. It is important that systems be used as intended not only to maximise utility afforded by new technologies, but also to prevent legacy ways of working from negatively affecting performance. However, technologies in many domains are implemented without full examination of their utility from a sociotechnical perspective. The current work highlights the importance of a sociotechnical approach in helping to 'maximise what you have'. It was revealed that training, standardisation of use, and novel procedures have the potential to greatly increase the benefits afforded by currently operational technology. Implementation of new technologies has the capacity to reduce potential shortfalls, but only if the utility afforded by such upgrades is fully realised. It is critical that a sociotechnical approach is adapted for both the design, evaluation, and implementation of new technologies to ensure that maximal benefit is afforded.

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