A vision of the future: evaluating the benefits afforded by optronics

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Abstract — The frequency of submarine operations being completed in shallow littoral waters is increasing. A critical task when completing such operations 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.

1 Introduction and Background

The frequency of submarine operations being completed in shallow littoral waters is increasing [1]. This is for a variety of purposes including scientific research, surveillance, and coastal protection [1]. This presents a number of challenges for submarine command teams including a reduced effectiveness of some sensors, constraints on manoeuvrability, and increased risk of grounding [1, 2]. In such situations, visual data collected from the periscope mast is critical to the command team for safe operation, remaining undetected, and effectively completing mission objectives [3, 4]. However, the use of the periscope mast incurs a risk of counter-detection, therefore mast exposure must be minimised in order to maintain stealth [4].

When first introduced, the periscope served as the primary attack sensor [3]. It was not until the 1970s that thermal imaging and laser range finding was introduced, paving the way for sensor upgrades, which eventually led to the introduction of the optronics mast [5, 6]. The optronics mast revolutionised submarine construction; previously the periscope was designed such that when the mast was lowered it was housed completely within the submarine [7]. This imposed several constraints on submarine design including control room positioning and configuration [3]. The optronics mast permitted greater flexibility in control room positioning and layout and introduced automated programmes such as quick look round (QLR) and snapshot [3, 6, 8]. Use of automated functionalities such as QLR permit a full 360 degree sweep in a few seconds and require minimal operator intervention [3, 8]. This can minimise mast exposure time, increasing stealth, without reducing own submarine safety [4]. However, automated functionality can reduce the overall performance of the system [9].

1.1 Automation

Once an operator has selected an automated functionality such as QLR or snapshot, they are only required to intervene in the case of error [3]. In such situations the human operator assumes a supervisory role, intervening only when appropriate, or completing the work the automation cannot, such as review of collected data [10]. 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 [11, 12].

When using an optronics mast, a key decision to be made by the operator is whether to use the automated functionality; this choice can have implications for system performance. The success of a system is reliant on a good partnership between a human operator and automation [11, 12, 13]. Stevenson [3] notes that there has been a “reluctance” to use automated functionalities permitted by the optronics mast (e.g. QLR and snapshot); potentially due to operator familiarity with existing drills, or concerns over reliability and performance. It is critical to understand what benefits such functionalities afford to a submarine command team, and whether the utility of such technology is being fully realised.

1.2 Aims

Advanced technologies are often implemented without formal assessment from a sociotechnical perspective. It is critical to understand what benefits the automated functionalities of optronics afford to a submarine command team and whether the utility of such technology is being fully realised. The current work had two primary aims:

- Assess contemporary operation of the optronics mast;
- Design and test novel, standardised procedures for optronics mast use, informed by system capability and advice from subject matter experts (SMEs).

2 Approach and Method

A human-in-the-loop study was conducted in a high fidelity simulator using trained Royal Navy (RN) Personnel (n = 35). Participants were arranged in teams of three, 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.

A battery of measures were selected to evaluate current (Baseline) use of optronics with regard to operator workload, system usability, 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 the new operating procedures.

2.1 Materials and Equipment

The method used in the current work has been used previously to examine submarine command and control teams in a high fidelity simulator [14]. Three high definition cameras were used to record operator screens, and all communications between operators were recorded using three Dictaphones with clip on microphones. Additional measures, including paper versions of the System Usability Scale (SUS) [15], were collected following completion of each scenario. The SUS examines a user's subjective rating of a tool or devices' usability. It is a ten item scale that is combined to produce a single score, with a high score indicating good usability [15].

The study protocol received ethical approval from the University of Southampton Research Ethics Committee (Protocol No: 10099) and MODREC (Protocol No: 551/MODREC/14).

2.2 Procedure and Design

Participants were pseudo-randomly allocated into teams of three operators based upon qualification. Each team had a qualified OPT, an OOW, and an OPSO. The positions of Ship Control (SHC) and Radar Electronic Support Measure (RESM) were simulated by members of the technical team at the simulator. 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. Due to security restrictions further information about the scenario cannot be provided.

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, this enabled naturalistic behaviour to be captured. In the Experimental study, participants completed the same scenario but were provided with standard operating procedures concerning mast usage which was deemed by SMEs to be safe but pushing the boundaries of contemporary operation. More information on the nature of procedures cannot be provided due to security restrictions.

2.3 Analysis

The restrictions associated with processing sensitive data mean that not enough of the data has currently been processed to afford statistical analysis, which is planned as part of future work. Instead a case study approach is used to provide an overview of the findings of the study to date.

3 Research Findings

3.1 Baseline Case Studies

The baseline data revealed great variability of optronics usage across teams despite operators completing the same scenario. The OPSO had the highest SUS scores of all operators in the baseline study (see figure 1 and table 1).

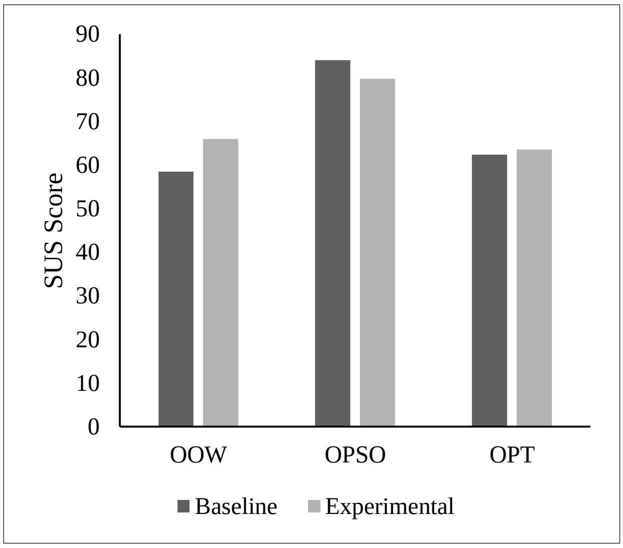

Fig. 1. SUS scores

Table 1. System Usability Scale for Baseline and Experimental Teams (scale of 0 -100)

	Baseline	**Experimental**
OOW	58.50	65.99
OPSO	84.00	79.75
OPT	62.38	63.50

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 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, and used no automated functionality (see figure 2 and table 2). This meant the mast was raised for approximately 83% of the scenario length. 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 (see figure 2 and table 2).

Table 2. Baseline Study Mast Exposure Time (seconds)

	Manual	Automated	Total
Team A	898.65	0	898.65
Team B	173.93	84.37	258.3

Despite Team A having the mast raised for the greatest length of time, they did not complete the greatest number of manual set-ups. Team A completed a total of six target set-ups, of which five were completed manually (see figure 3). Contrastingly, Team B completed two target set-ups using data collected using autonomous functionality, and one manual target set-up (see figure 3). 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 where the OOW would utilise the periscope to ascertain a range on the contacts of interest, in order to calculate a look interval.

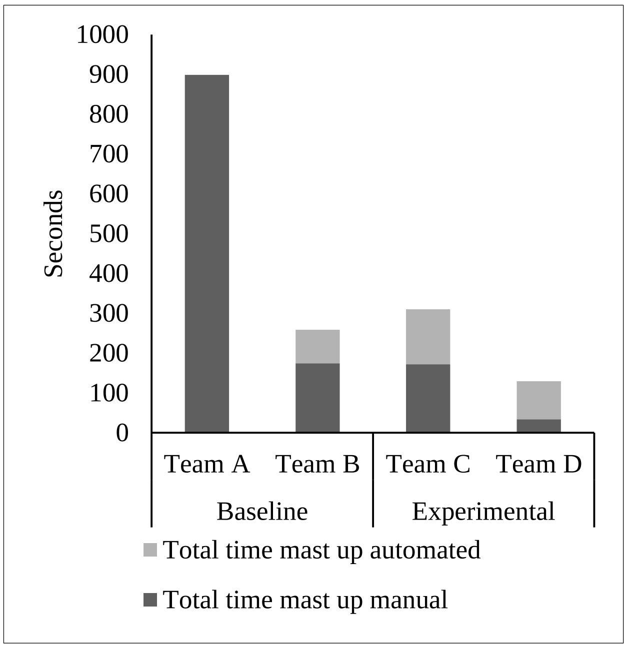

Fig. 2. Mast Exposure Time (seconds)

3.2 Experimental Case Studies

In the experimental phase of the study, the utilisation of automated optronics functionality (i.e. not available using periscope) greatly increased. There was also greater standardisation of use, resulting in comparable levels of operator workload, accompanied by greatly reduced mast exposure times. Furthermore, the usability scores for the OPT and OOW increased, suggesting the utilisation of specialised functionality actually made the system easier to use (see table 1 and figure 1). The SUS scores of the OPSO remained the highest of the three operators.

Table 3. Experimental Study Mast Exposure Time (seconds)

	Manual	Automated	Total
Team C	172.18	138.04	310.22
Team D	33.41	95.99	129.4

The Experimental data revealed teams were using the optronics mast as prescribed and in a much more standardised fashion. In the Experimental case studies automated functionality was used much more frequently. This led to drastically lower total mast exposure times. The case studies presented below were selected to match the same criteria as for the baseline study; longest (Team C) and shortest (Team D) total mast exposure.

Team C had the longest mast exposure times of all experimental teams (see figure 2 and table 3). However, this was of comparable levels to the shortest baseline teams (see figure 1). Team D had the shortest mast exposure time of all experimental teams, with a total time of 129.4 seconds (see table 3). Despite having the mast raised the longest of all experimental teams, Team C completed the fewest number of target set-ups (see figure 3). For both Team C and D, all target set-ups were completed using data collected from the optronics mast using automated functionality.

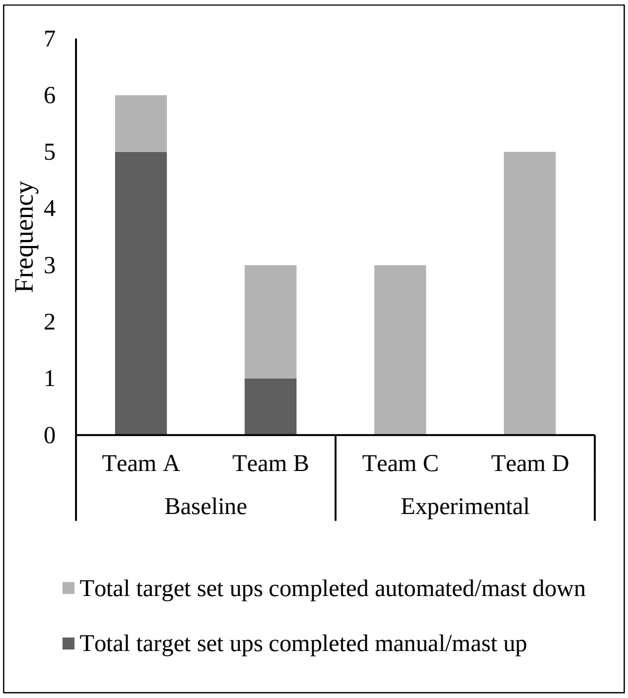

Fig. 3. Target set-ups completed

4 Discussion

The baseline data revealed great variability of optronics use across teams, despite the same scenario being completed. This indicates a lack of standardised use of optronics. In the baseline study, the optronics mast was raised for extended periods in manual mode. When gathering visual data, minimisation of mast exposure is critical for safety and remaining covert [4]. Automated features such as QLR and snapshot [8] 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 [3].

The utilisation of specialised optronics functionality greatly increased in the experimental study. This was reflected in the greatly reduced mast exposure times, which would reduce the risk of counter-detection [4]. Furthermore, the SUS scores for the Optronics operator increased in the experimental study, suggesting the usage of specialised functionality made the system easier to use. This highlights the importance of using a system as it is intended (i.e. uptake of all functionality) not only to maximise utility afforded by new technologies but also to prevent legacy ways of working from negatively impacting performance.

5 Lessons Learned

The current work has revealed that training, standardisation of use and novel procedures has the potential to greatly increase the potential benefits afforded by technology that is currently operational. It is common in many domains for such technologies to be implemented without full examination of their utility from a sociotechnical perspective. The current work highlights the importance of such an approach in helping to ‘maximise what you have’. A number of recommendations can also be made regarding the design of the technical aspects of the optronics system based upon feedback from users and data collected as part of the study. It is critical that the operators are considered in the technical design process as this will likely afford greater uptake in usage of technological upgrades.

6 Conclusions

The submarine control room is a highly complex system that represents a high state of maturity, but this does not mean that the system cannot be improved. The 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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