Human centred solutions to optimise human performance in the undersea domain

Abstract — Managing crew fatigue and subsequently increasing operational effectiveness is a significant challenge to ensure optimum decision making under challenging circumstances, part of this is ensuring the environment is designed to meet user needs. Human centred solutions have developed a multi discipline approach to understanding the user needs and developing effective solutions via an iterative process of user engagement, design development, physical and virtual prototyping and applied sleep research methods.

1 Purpose and benefits

The capacity for operators to assimilate and understand the data provided by complex systems is severely tested in 24/7 environments. Added to this the demands of high workload, stress, and extreme fatigue impair cognitive performance and increase errors during operationally-critical tasks. Decision superiority is essential for threat mitigation in a global operating environment and sub-optimal decision-making during combat can be catastrophic. The huge personal, financial and tactical cost of high workload, stress and fatigue for combat missions must be addressed if we are to perform better and faster than our adversaries. The new combat edge comes, not only from technology, but from optimised operators that can make superior decisions in an information dense and complex undersea environment.

Between 2017-2019 the design team at the University of South Australia developed design exemplars to support the development of the design assurance methods The work was conducted for the Australian Defence Science and Technology group in order to develop a human-centred design and assurance methodology for submarine habitable spaces to inform the Australian Department of Defence as part of their ongoing work with defence suppliers to design Australia's future submarines.

2 Introduction

The myth of the warrior, that fatigue and stress can be overcome by adequate motivation, has influenced military operations in the past [1]. This attitude is changing and the need to improve habitability aboard submarines in order to improve the performance of crews is well established. In a military operating environment there are many stressors, in addition to actual warfighting, ranging from reduced sleep, shift-work, social pressure, environmental conditions and operational environments frequently involve long work hours and less than optimal sleep environments [2]. A lack of rest results in less than optimal cognitive performance [3]. Habitability cannot be compromised to other elements without impacting crew performance [4] and '…improvements in cabin design could have significant effects on crew fatigue and overall effectives. [5].

This paper describes the human centred methods developed and implemented to improve shipboard habitability and therefore increased operational effectiveness for Australia's current and future submarines

3 Approach

Our human centred approach draws on expertise from industrial design, augmented / virtual reality (AR/VR) and bio-behavioural psychology. A process has been developed to optimise habitable spaces and improve human-machine interface and the implementation of technology such as automation and robotics in 24/7, round the clock operations. We use a range of human-centred design and co-design methods to investigate the user needs, wants, activities, habits, physical requirements and psycho/social needs. We work closely with the Royal Australian Navy Submarine Force to embed their ideas into the centre of the design cycle. Physical models and Virtual Reality are used as part of an iterative process, along with digital-human-mannequins (DHMs) within CAD software and human simulation software such as JACK and RAMSIS to evaluate the design.

Human-centred design (HCD) is a framework for product development that involves the human perspective in all steps of the design process. The HCD is a design process that emphasises user engagement methods such as observation, interviews as well as participatory design and co-design and contextual design techniques for investigating and describing the interactions between people and their environments [6].

This included:

- the application of standards, anthropometric data and maritime habitability guidelines.
- the use of DHMs based on the 2015 Anthropometry survey of the Royal Australian Navy (ASRAN) [7] at all stages of the process.
- The consideration of psychological and physiological dynamics in the design and integration of elements to optimise cognitive performance.

At the core of the process was ongoing consultation and engagement with submariners to understand the environment and context, what people do and how they conduct their activities. This involved focus groups, guided tours of facilities, co-design workshops and feedback on design proposals via physical models and virtual reality. This was facilitated with the use of AR/VR tools to simulate and demonstrate the environments to stakeholders for their input and feedback.

A second element of the project was the application of anthropometry to ensure the best physical fit of the environment to the user population. This utilised the ASRAN data gathered specifically to support Navy ship building in Australia.

4 Results and Discussion

The outcome is a set of design concepts for berths and cabins and the mess and galley for current and future submarines. These design proposals demonstrate an integrated approach for implementing user-centred design methods alongside anthropometric design and assessment tools. The process involved submariner input and feedback at all stages, so the designs make best use of space and improve habitability. AR/VR was vital for the design development process and user engagement practices. By taking a human centred approach and implementing psychological and physiological considerations in the design, the submariner's cognitive performance and decision making can be optimised. This has implications for enhancing effective human machine interface, giving operators a combat edge. A range of living and operational environments were assessed including sleeping berths, cabins and galleys:

4.1 Sleeping Berths and Cabins

The six berth cabin, Figure 1, includes the following features:

- A tapered berth and cabin to provide more room around the upper body in the berth and more space in the cabin.
- A sliding panel instead of a curtain at the head of the berth for improved sound and light blocking.
- A variety of cabin and berth lighting options to suit various use scenarios with colours to match the occupant's circadian rhythm.
- Improves air-conditioning outlets.
- Boot and towel drying spaces.
- A range of storage options in the cabin and berth.

Fig. 1. The berth and cabin

4.3 Mess and Galley

The mess, Figure 2, includes the following features:

- An arrangement that allowed for a range of use scenarios including meals, recreation, briefing, damage control and triage.
- Tables that can be easily reconfigured to suit different requirements.

Fig. 2. The junior and senior sailors mess

The galley, Figure 3, includes the following features:

- A space for appliances that can be changed out as technology changes.
- An arrangement that accommodates the works flows and zones areas according to functions such as cooking, serving and scullery.

Fig. 3. The galley

4.3 Design Assurance Methodology (DAM)

The DAM provides a framework for conducting HCD for navy and submarine environments and an assurance process for the design process and outcomes. It includes a method for the application and assessment of anthropometry.

5 Future Work

The work conducted thus far has been informative and the human centred approach will continue to be developed. Further research will be conducted exploring ship motion impacts in alternative accommodation arrangements. Designs will be tested empirically in an experimental environment to quantify cognitive and physiological benefits and impact on fatigue and subsequently operational effectiveness.

6 Conclusions

The project resulted in the development of an innovative human centred process including applied anthropometry and psychological and physiological dynamics. We used creative methods and a rigorous, quantifiable approach that can be applied to many different scenarios such as mess/galley, console and enclosure design, human machine interface and control/maintenance/operation room layout to optimise human performance. In addition it resulted in the development of practices for the use of virtual reality and augmented reality tools as part of the design process.

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Dr Peter Schumacher is a Senior Industrial Design Lecturer. He has extensive experience in human-centred design, user engagement strategies, qualitative research, design development, physical and virtual prototyping and communication. His design practice is focused on complex confined human environment design developing designs from initial research to detail design and implementation.

Professor Siobhan Banks is an expert on the impact of irregular work schedules and sustained operations on psychological and physiological fatigue. Providing "Science for the Workplace" solutions to improve productivity and safety, Banks has specific knowledge to optimise cognitive performance in operational settings, human machine interface, and human factors.