SubSafe——A Game-based Training System for Submarine Safety

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Abstract. SubSafe is a game-based submarine safety training system developed by UK that presents end users with an interactive, real-time three-dimensional model of a real submarine. The research presents background and main functions of SubSafe. Evaluation of the training effectiveness and some enlightenment is also presented.

1 Introduction

On October 5, 2004 Canadian Submarine HMCS Chicoutimi (an ex-UK Upholder Class SSK) was running on the surface through heavy seas to the northwest of Ireland. The submarine was struck by a large wave and some 2,000L of water entered the vessel through open fin hatches. The water caused electrical shorting in the vicinity of the captain's cabin and the ensuing fire disabled nine members of the crew as a result of smoke inhalation. Unfortunately one of the crew later died.

There is another incident occurred on-board HMS Tireless in March 2007. Tireless was taking part in under-ice exercises north of Alaska, together with a US submarine. During what should have been a routine lighting of a self-contained oxygen generator (SCOG)—part of the survival equipment in the submarine's Forward Escape Compartment—the generator exploded, killing two crew members and seriously injuring a third. The submarine's crew managed to manoeuvre the vessel to thin ice, some 2 miles away, at which point she was able to surface safely and implement ventilation procedures.

These two incidents drove the motivation to reassess the traditional way in which British submariners are trained, particularly with regard to their spatial knowledge relating to the layout of safety-critical systems and items of life-saving equipment.

Working collaboratively with Rolls-Royce and Rolls-Royce & Associates (RR&A), Vickers Shipbuilding and Engineering Limited (VSEL, now part of BAE Systems) began their venture into VR in 1993 with the ambitious goal of modelling complete submarine environments. After years of unremitting efforts, Human Factors Integration Defence Technology Centre (HFIDTC) at the University of Birmingham developed SubSafe for the United Kingdom (UK) Ministry of Defence (MOD) in 2009.

SubSafe is a prototype interactive 3D training tool that presents end users with an interactive, real-time three-dimensional model of a Trafalgar Class SSN, moored at a virtual reconstruction of part of HM Naval Base in Devon port (refer with: Fig. 1). Designed to supplement legacy training media currently in use by Royal Navy (RN) submarine qualification (SMQ) instructors. SubSafe also provides a virtual vessel for SMQ student "visits", for those occasions when no real boats are alongside, or, when they are not in an appropriate condition to support on board learning, due to refit status. Navigating decks and compartments (refer with: Fig. 2) in a "first-person" game style, SMQ students have access to all decks forward of Bulkhead 59, comprising over 30 compartments and 500 objects – including major safety critical items, such as fire extinguishers, hose units, high-pressure air valves, and emergency breathing system masks.

Royal Australian Navy also developed The location and scenario training system (LASTS) to evaluate the exploitation of computer games technologies in the training of submariners joining Collins Class submarines. In 2012, Royal Canadian Navy e-learning Centre of Expertise (NeLCoE) in Quebec City developed the Canadian Virtual Naval Fleet (CVNF), a game-based, desk-top virtual

environment (VE) to provide procedural and spatial knowledge of large vessels (e.g. the Victoria Class Submarine), which are not always available for training[1][2].

Fig1. External view of the virtual SSN in SubSafe

Fig2. SubSafe SSN interior view

2 The Function of SubSafe

2.1 Inhance Spacial Awareness

Spatial awareness is a cognitive ability that enables one to be aware of one's location in space, both statically and dynamically. It consists of three distinct elements—''landmark'' knowledge, ''route'' knowledge and ''survey'' knowledge.

Experimental statics show that SubSafe could enhance user's spatial knowledge relating to the layout of safety-critical systems and items of life-saving equipment. Users expressed their increased confidence in performing their tasks because of the spatial familiarization and enhanced situational awareness that they received through using SubSafe. They used it to investigate the scene and to plan strategies, so that during the incidents they were able to concentrate on the rescue instead of finding their way through unfamiliar spaces. Cognition and Virtual Reality Laboratory at the Catholic University of America have also evaluated the potential of VR to foster route and survey knowledge of unfamiliar places.

2.2 Safety Training in SMQ Courese

The main purpose of SubSafe is to enhance students' abilities to locate safety-critical items of equipment onboard a Trafalgar class submarine platform during "walk-round" tests held in the final week of their seven-week SMQ(D) course. SMQ students have access to all decks forward of Bulkhead 59, comprising over 30 compartments and 500 objects – including major safety critical items, such as fire extinguishers, hose units, high-pressure air valves, and emergency breathing system masks. It also enables the student to move around the compartment and to launch more detailed images of specific locations and equipment "cut-away"models(refer with: Fig3), showing key processes when required (e.g.emergency high-pressure air blow cause and effect)

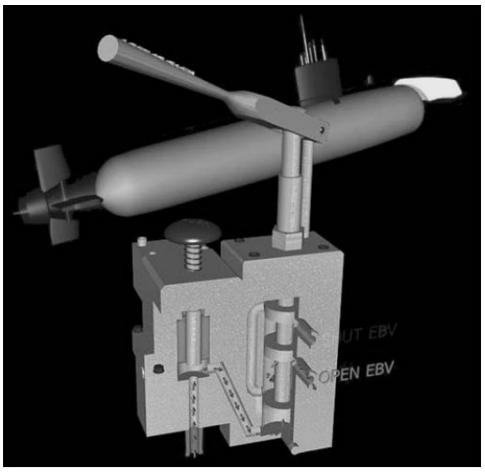

Fig3. An animated‘‘cutaway’’ model of an emergency control blow valve

2.3 Submarine Qualification Test(SMQ)

The Submarine Qualification Procedures(SMQ) course include two phases. The 10 week course phase is known as SMQ Dry(Submarine Qualification), the sea phase is known as SMQ Wet, in a maximum of 3 months, taking place at the Royal Navy’s submarine training school at HMNB Clyde near Faslane, Scotland. The final, oral assessment takes place in a 3D virtual environment (SubSafe), mirroring the final assessment that will be employed on board at the end of the ‘wet’ phase of training. Once passed, the student is ‘safe for sea’ and able to progress with On Job Training (OJT)[3].

SMQ is designed to instil the required standards of absolute professionalism demanded by the Service’s ethos. Candidates are required to demonstrate an intimated and instinctive knowledge of more than the 30 complex engineering systems which operate their nuclear submarine and keep its crew safe. The knowledge of each individual system is tested by departmental Senior Rates before each candidate is allowed to attempt their Submarine Qualification Board, presided over by a Submarine qualified Officer and Warrant Officer. SMQ classes are made up of sailors from the various departments on board, from chefs to marine engineers. Students are often under 18, so the training environment has to be as vibrant and modern as possible, SubSafe meets the need.

Complete the Submarine Qualification Procedures(SMQ) course means having acquired the expertise and knowledge at sea to become fully qualified submariners. Students completed the traditional submariner ceremony of receiving their dolphin badges in a glass of rum, which they drink while catching their badges between their teeth.

2.4 Equipment Maintenance and Repairing

In the mid-1990s, the Human Factors team conducted two short studies with the University of Nottingham and VR Solutions Ltd. of Salford to evaluate the potential of VR for resolving submarine maintenance engineering problems, thereby reducing time spent within hazardous operational environments. A ‘‘desktop’’ VR demonstrator based on Superscape’s Virtual Reality Tool-kit (VRT) simulated submarine spaces and included key landmark features such as ladders, piping, electrical generation machinery and switchboards. Viewpoints could be created that simulated the viewpoints of different sizes of engineers’ virtual ‘‘bodies’’ whilst standing, kneeling and lying prone. Additional research addressed the design of a virtual ‘‘toolbox’’, in order to simplify the process of dismantling, repairing and refitting of equipment.

2.5 Escape and Rescue Training

Interest in the SubSafe project has also stimulated the development of other concept demonstrators, including a “serious game” implementation of a submarine rescue scenario, where the user has to rendezvous and dock a rescue submersible with a disabled Kilo Class submarine using a typical gaming hand controller whilst viewing simulated underwater images through the submersible dome and external CCTV cameras. Consideration is also being given by the RN’s Submarine Escape

Training Tank (SETT) personnel to using SubSafe to support the teaching of procedures for entering, flooding and draining the FEC escape tower.

3 The Evaluation of Training Effects

The evaluation of SubSafe includes over a year of experimental trials undertaken in collaboration with the RN's Submarine School. The key objective was to evaluate the effectiveness of the SubSafe spatial awareness trainer as a supplement to current SMQ(D) classroom-based training. In total, eight trials and questionnaire feedback were completed, with 113 SMQ(D) students taking part in the study. Participants' ages ranged from 17 to 38 years, with a mean age of 22.83 and a standard deviation of 4.38. 87.6% of participants were players of computer/video games. Participants were divided into 4 groups:

1.Control Group, who were not given access to the SubSafe system.

2."Passive Presentation" Group, who received an instructor-led presentation of SubSafe using a data/video projector and screen to illustrate the layout of the boat and the location of safety critical items of equipment (refer with: Figure.4).

3."Free-Roam" Group, who were given hands-on, first-person access to SubSafe and were required to navigate the virtual submarine model in real time, searching for the same specific items of safety-critical equipment as had been presented to the Passive Presentation Group.

4."Enhanced-Passive"Group,with a further presentational mode, relate to such topics as High-Pressure Air, Emergency and Built-In Breathing Systems (EBS and BIBS), Ventilation, Submarine Escape, Trim, Bilge and Ballast, and so on [4][5].

Fig4. SubSafe classroom ("passive") presentation

Table 1. Mean Scores on the Walk-Round Test

Condition	Mean	Standard Deviation	n
Control Group	24.19	1.877	26
Passive Group	25.43	0.920	28
Free-roam Group	25.33	0.994	30
Enhanced-passive group	25.86	0.743	29

Statics (refer with: Table 1) revealed that use of the simulation during classroom training significantly improves the final "walk-round" performance of students (onboard an actual submarine) when compared to that of a control group. Significant attitudinal changes have also been recorded, with participants responding more positively to the notion of using games-based simulation in mainstream RN training after exposure to SubSafe.

4 The Enlightenments

4.1 Applications on Mobile Platforms

One branch of the Royal Navy has even invested in Sony Play Station Portables (PSPs) to encourage the development of new styles of on board learning. The Unity3D/iPod project (refer with: Figure.5)mentioned above is relevant here, especially with regard to the human factors issues of interacting with small, mobile computing platforms.

Fig5. "SubSafe Mobile" – implemented using an iPod Touch

A decision was made in 2009 to bring SubSafe2 more under the control of the HFI DTC by "transferring" the digital assets into a more flexible 3D toolkit and rendering engine, Quest3D. The new SubSafe environment (refer with: Figure.6) can be distributed as a single, relatively small executable file (license-free) and can deliver a much higher-fidelity visual and auditory virtual world than before. Exploiting Quest3D also supports the development of additional functions, from smoke, fire, compartment flooding and hydraulic burst effects to the presence of programmable avatars. From an experimentation and usability evaluation perspective, the Quest3D implementation also supports a much wider range of interface modifications than before (such as a variable first-person field of view, control over through-boat motion speed, object interaction styles, multimedia and performance metrics integration and the use of numerous forms of interactive hardware technologies).

Royal Navy also consider future extensions of the research into other submarine training domains, including periscope ranging and look-interval assessment skills, survival systems deployment training and the planning and rehearsal of submersible rescue operations.

Fig6. weapons stowage compartment images from SubSafe2

4.2 Game Culture Influences on Defense Simulation

The games culture helps a lot to manage the expectations and engagement of future military-simulation users. Many young recruits have been put in front of simulators using older technologies, and have said: "We can do better than this at home." That way, you lose hearts and minds instantly. But if you show them something that looks the part, such as the Call of Duty series of action games, you instantly have their attention.

4 Conclusions

Suffered from two submarine incidents, Royal Navy spent more than 10 years to develop Virtual Environments for submarine safety training. It confirms the significance and value of adopting strong human-centred design methodologies early in technology-based training programs to ensure submarine safety. Close engagement with end users, a program like SubSafe is a good example of what can be achieved in part-task naval training applications using gaming technologies.

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