Pragmatic and hedonic experience of virtual maritime simulator

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Abstract

Virtual training is resource effective and sometimes only option for practicing complex situations in hazardous environment. Maritime training and certificates are regulated by standards yet recently opened for virtual training possibilities. In this paper, we study how maritime students experience a new gamified VR training environment in their common training episodes at sea. We introduce a unique, state-of-the-art system for training maritime scenarios, and 25 students' subjective comparison to their experiences in traditional maritime simulators. They evaluated the efficiency in learning and the pragmatic quality of the new system only slightly below traditional simulators. The hedonic quality was evaluated much higher than of traditional. The new system was considered also more engaging and realistic. In the latter, users seemed to value more the realism of the visual environment than the realism of using the ship controls.

Keywords

Virtual reality, game-based learning, safety training, maritime, user experience

1. Introduction

Interests in remote and virtual training has increased rapidly due to recent pandemic, which prevented face to face meetings and closed training centers. Training in virtual environments is resource effective and in hazardous environment the only option for practicing complex situations.

That is a case in maritime education all over the world: Simulated scenarios in cave rooms [1] are the backbone of educating new seafarers, the people who can navigate and steer large passenger ships and container vessels safely in any sea. Simulations are also an important part of life-long training of more experienced sea captains, who currently need to land and use their spare time for additional training.

Maritime training and certificates are regulated by standards, which purpose is to ensure that the simulations provide an appropriate level of physical and behavioral realism as well as agreed body of knowledge and assessment objectives. Maritime industry has recently modified their standards to cover cases where the simulator can be also cloud-based, fully artificial and asynchronous [2]. This has opened new opportunities for online virtual training systems in maritime context. In the search of contemporary and relevant topics for the field of game-based learning [3], maritime safety and training represents one: There are continuous fear of large environmental catastrophes due to shipwrecks like the one in Suez Canal [4]. Could game-based learning paradigm improve safety training and learning in maritime across continents and cultures?

Virtual reality (VR) is considered here as a technology that can significantly improve seafarer's performance and competence with the adaptation of maritime applications developed for design simulation and gaming. For example, mobility of head-mounted VR equipment allows training independent of time and place, even when the ship is sailing at the sea. From safety and business perspective, this opportunity is more effective compared to booking a simulator room at land. However, from the user perspective, it is

7th International GamiFIN Conference 2023 (GamiFIN 2023), April 18-21, 2023, Lapland, Finland.
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unknown how seafarers themselves receive such VR training possibility.

In this paper, we study how maritime students experience a new VR training environment in their common simulator training episodes. We introduce a unique, state-of-the-art system for training maritime scenarios, and students' subjective comparison to their experiences in traditional simulators. To our understanding, there are currently no scientific studies about head-mounted VR-based training simulations in ship maneuvering and navigation outside our research.

2. VR simulation and training system for maritime

The system is developed for practicing different collision avoidance situations at seas. The command bridge, which is implemented as a digital twin to the virtual environment, contains common equipment for ship maneuver and navigation operations such as a radar, ECDIS (i.e., map + route plan), auto pilot, manual steering, and engine power controls. The controls of the bridge are limited, yet their functionality correspond with the real bridge of a large vessel.

Figure 1: Player's hand, radar and cargo in player's field of vision in virtual reality.

The system is used with Varjo VR headset [5] without separate control devices in player's hands (Figure 1). The system exploits eye-tracking feature [6] and hand gesture recognition [7], which allow more natural interactions with the command bridge. Compared to a traditional multi-screen simulation setting in a cave-like room, the main difference is that the physical command bridge with buttons, handles and rags are now virtual (Figure 2).

Figure 2: The important keys of the radar and ECDIS are modeled on top of the keyboard to improve the usability of presses that require finger fine motor skills.

Figure 3: Tiller use implements a larger hand movement than usual and a virtually produced information about the rate of turn and angle.

The virtual environment graphics and physics were built with high-quality in mind: The vessel-size affects its behavior when a certain turn is performed in a specific weather and sea condition. In addition, the command bridge was free to walk (Figure 4), with readable and grabbable objects around. The players could even walk to outside – to check the cargo, look around to the other vessels at sea, or look down – if they dare.

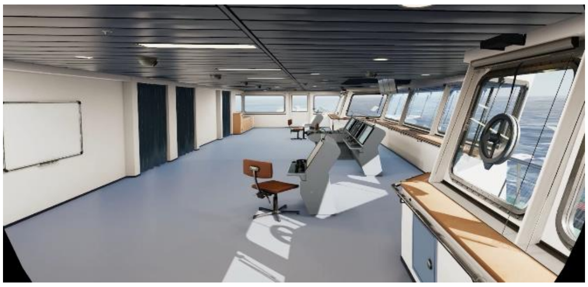

Figure 4: Free moving in the bridge provides necessary views on the sides and back.

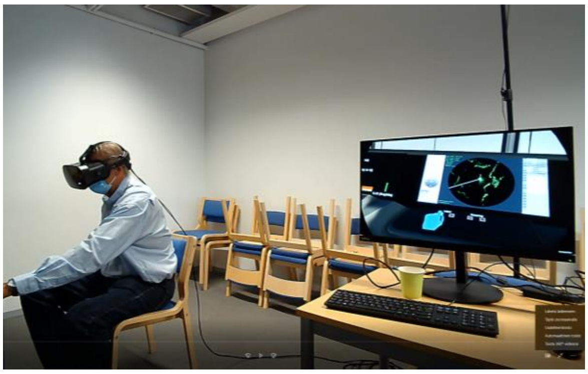

Figure 5: An experienced seafarer testing the bridge controls and ship behavior during the system development.

The system supports behavioral data collection and records all the moves of all ships and all player actions (hand gestures and eye movements with objects) into the database. This allows reconstructing player's path, actions, and the whole performance, whilst training the dedicated neural network for further performance analysis.

In the future, with the help of artificial intelligence, it is possible to give detailed (proactive or reactive) information to the player during or after the play session. For example, the system could proactively guide and highlight to the player the required operations based on the activity patterns it has learned from successful scenarios. Notable is that the order and timing of player actions can vary in successful performances. For debriefing phase, typical to maritime education, the system could automatically recognize actions that are risky (e.g., not following evasive rules, passing distances) and their relative time compared to optimal (e.g., time on task, looking at sea vs. bridge). The development has recognized possibilities for more gamified elements such as use of leaderboards and badges.

Transforming a conventional training to a game-based does not automatically lead to higher learning or motivation in users [8]. Therefore, the system is designed together with maritime training experts and experienced seafarers following user-centered design practices. Expert involvement aimed at increasing narrative quality and realism of the system, which could influence players' views about learning effectiveness in a serious game [9]. The collision scenarios are designed by the experienced teachers and seafarers. Implementations of bridge controls were also frequently tested by one expert (Fig. 5).

3. Methods

Total of 25 international maritime students participated in the tests in four days long test sessions. On average, participants had 93 study credits and 2 to 4 years studies in higher maritime education unit in Finland. The average grade of all their maritime related courses was 3.8/5. They had previously used conventional maritime simulators 10 times (median), and the last use was no longer than two weeks before the test session, and for some participants, even earlier on the same day. Their previous play experiences with any VR device varied between 0 and 2 times.

3.1 Session protocol

In the game play, the player was steering a large, 200-meter long, tanker ship (Figure 6). Before taking the ship into their control, participants went through a tutorial, which introduced the main controls and types of interactions (due to difference to reality).

Participants played two maritime scenarios, first an easy and then a difficult scenario, which varied in length (15 and 30 minutes correspondingly). Both scenarios required skills of basic navigation and collision avoidance that based on the participants' background they possessed. The difficult scenario consisted of more ships on the sea heading or colliding with the player's ship than the easy scenario. Thus, more cognitive load and challenge was expected in the difficult scenario, that in turn was expected to lead to improved learning outcomes [10].

There were no specific tasks given to participants. In the beginning of each scenario, the system showed the target location, required arrival time and weather conditions i.e., common information for all similar maritime simulations. The total number of played scenarios were 40 due to 2 participants quitting after the easy scenario and 8 participants playing only the difficult scenario.

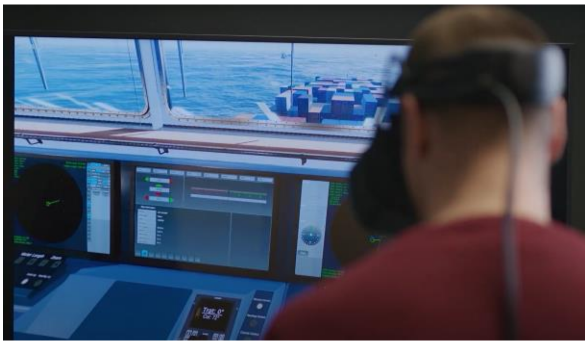

Figure 6: Administrator's view in the test session (reconstructed).

3.2 Data collection

Behavioral data about eye movements and player actions were collected automatically to a database, that was used for training a neural network. For the experience data analyzed in this paper, we used two validated questionnaires UEQ and SUS. As the enjoyment and realism have a significant impact on subjective learning effectiveness in serious games [9], we asked participants' opinion about these, as well as collected their basic demographic data.

Total number of 40 different answers to the short version of User Experience Questionnaire (UEQ) [11]. Short UEQ was answered immediately after the scenario was played. The short UEQ questionnaire evaluates both pragmatic and hedonic quality of the system with 8 different items containing negative and positive extremes (Figure 7). The pragmatic quality scale is like the usability concept in goal-oriented activity, while hedonic quality scale emphasizes user's attraction to technology and its novelty value. Interpretation and analysis of UEQ results followed the original [11]. After the UEQ, participants answered two questions: How easy the scenario was, and how do they grade their own performance in it (scale 1-5 with an open answer).

The SUS questionnaire, which was turned to positive [12] due to supposed cognitive load [13], was answered by 17 participants and only once in the end of the test. The SUS was targeted for the overall system evaluation, not to any specific scenario played.

Negative	Positive	Scale
obstructive	supportive	Pragmatic
complicated	easy	Pragmatic
inefficient	efficient	Pragmatic
confusing	clear	Pragmatic
boring	exciting	Hedonic Quality
not	interesting	Hedonic Quality
conventional	inventive	Hedonic Quality
usual	leading	Hedonic Quality

Figure 7: Short UEQ items and scales [11].

After the SUS, participants were asked if the VR system was 1) more efficient for their learning 2) more realistic and 3) more engaging than other simulators they have used before. These were assessed on scale 1-5, where 1 = strongly disagree... 3= neutral .... 5 = strongly agree. Then became open questions about their feelings and thoughts as well as wishes to the developers. The last question was to assess their previously used simulator with same 8 items of Short UEQ and write the date when last used (for this and other background data, see the beginning of the chapter).

4. Results

The new VR system was evaluated slightly more realistic (3.64/5) and engaging (3.44/5) than other simulators the participants have used before (researcher's own questions 2 and 3 in the previous chapter). This result is in line with the results of UEQ questions. The hedonic quality scored 1.819, which is much higher than with traditional simulators (1.015) in scale – 3 - + 3. On the other hand, the new VR system is not considered more efficient for learning the maritime practices than other simulators the participants have used (researcher's question 1). The average of 25 answers was 2.92/5, which is slightly below the middle. In UEQ, traditional simulators score also slightly higher in pragmatic quality (1.265) than the new system (1.225). Overall experience score for the new system is higher (1.519) than traditional simulators (1.063).

When interpreting the results and benchmarking values to other applications according to historical UEQ data [11], the VR system scores *above average* on pragmatic quality (i.e., 50% of applications result worse). Correspondingly, the score of the new system means that the system is *good* on hedonic quality (i.e., only 10% of applications result better, and

75% result worse). The overall score denotes *good* as well (Figure 8).

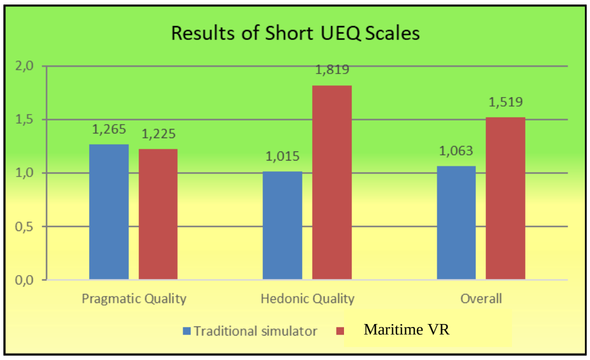

Figure 8: UEQ scores of new VR (red) and traditional systems (blue).

SUS score for the VR system is 66. The score is interpreted as *Ok/Good*, yet slightly below the average, as the SUS score 68 is the average of all applications. That is in line with the mean of pragmatic quality in UEQ results that SUS mainly measures.

The participants agreed (on avg 3.8/5) that the difficult scenario was indeed more complicated than the easy scenario2. Comparing Short UEQ scales between the two scenarios, the difficult scenario was assessed better in both pragmatic (1.132 vs. 1.228) and hedonic quality (1.765 vs. 1.924). Self-assessed performance shows slight improvement (learning) from easy to difficult scenario as the average (school) grade given raised from 4 to 4.38 on average.

5. Discussion

Delightfully, participants evaluate the new VR system high in hedonic quality and more realistic and engaging than the traditional systems they have previously used. Considering realism of VR, users seem to value environmental realism more than realism in their own interactions. All equipment in traditional simulators, radars, tillers, and other tools used with their hands are physically and truly real, while the horizontally viewed environment (sea, weather, vessels, and their subsequent behavior after the interaction) is digitally produced on multiple screens i.e., virtual. In the new VR system, the quality of the environment is much higher: user's field of vision is more solid and integrated, objects in the horizon are visually sharper, sea and ship physics are improved etc. In turn, equipment and interactions are probably the most unrealistic part of the VR system. Although close to a digital twin, the command bridge contains relatively new interaction gestures (grabbing), low number of features (ECDIS and radar had only the main functions) and incompleteness of visual content of controls (e.g., missing map elements). In addition, users had to change their normal behavior due to missing hand recognition when out of vision. For example, many times users tried to turn the ship using the tiller while looking at their effects and estimating the correct turning position in the horizon. However, this natural maneuvering action in VR requires splitting it into several smaller operations where tiller use and looking to the sea need to alternate. Another pragmatic problem observed was the discomfort of wearing the VR headset for long time [16]: to our experience, two scenarios on a row (15+30 mins) was too much. Clearly, these inconsistencies and problems in the command bridge and related controlling tasks of the ship are reflected in pragmatic quality evaluations of SUS and UEQ questions. Luckily, such inconveniences should not affect negatively to users' intention to use and immersion [17].

On the other hand, pragmatic quality was evaluated almost as good as in users' traditional simulators, which gives an indication that completely new interfaces and interactions can be implemented and accepted by users in a virtual setting. While both, XR technology and remote and autonomous ships, are developing rapidly, we need more research on appropriate types of user interactions, interfaces, and gestures that allow one user to control even multiple vessels simultaneously. Practicing these tasks in a serious game-like environment is an advantage.

Although subjective effectiveness of the system was evaluated adequate, we acknowledge that our study design lacks scientific rigor in evaluating the effectiveness of the system and comparing it to traditional systems. For example, our participants were experienced users of traditional simulators and had used these recently, however our intervention lacks these simulators for more rigor comparison. Therefore, this study should be seen as a feasibility study [8] investigating only the feasibility of implementing digital game-based learning in maritime safety

[2] Forthcoming analysis of eye-tracking data [14] shows also increased cognitive load as less targeted and uncertain gaze paths [15].

context and of reaching pragmatic and hedonic goals set to the system. Moreover, the applied short UEQ, and especially its hedonic quality scale, seems to fit well this type of innovative systems and unique experiences causing possibly biased results. VR gaming in general is driven by hedonic values [17] and a part of players' hedonic valuing may be a result of their very first experiences with VR systems.

The development of the system and especially training of neural network is going on. The system is already trained with synthetic ship-movement data (270 computer run training sessions and 100 validating sessions) achieving over 90% accuracy in separating passing and failing performances based on paths and distances between ships.

Since the user tests reported here, the VR system has been developed for multiplayer environment in a metaverse and played by 58 maritime students in Philippines and 43 well-experienced maritime students in Sweden. These data are used for training the neural network to become a standalone and a trusted party in accepting or rejecting training certificates in maritime context.

6. Acknowledgments

We acknowledge the maritime students and experts, and the personnel at Turku Game Lab, who have participated in designing, implementing, and testing this system. This research has been supported by the Business Finland funded project called "Maritime Immersive Safe Oceans Technology (MarISOT)".

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