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RESEARCH ARTICLE

A study on the effects of rapid training method related to ship handling in decision-making skills under stressful situations

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Abstract

Navigational safety is one of the important focuses of Maritime Education and Training (MET), and the quality of MET is the key to cultivating competent officers at sea. This study aims to understand better the effects of a rapid training method on ship handling and navigation in restricted waters, as well as decision-making skills under stressful situations. Tests were carried out in a simulator-based maritime training environment to explore the decision-making skills of maritime students in stressful situations under different training levels and methods. This study compares routine maritime training and task-aimed rapid training in improving manoeuvring and navigational and decision-making skills, and examines the training outcomes. The data used in this study is based on comparing the task performance and stress levels of the two groups of students using simulator-based training results from a designed scenario. The results analyse the training outcomes of decision-making skills and maritime operation performance by applying a specific decision-making model. In addition, the impact of students' stress levels was examined, both subjectively and objectively. The paper concludes with a set of recommendations for the design of future MET. The research helps enhance decision-making skills in maritime training programmes and understanding how learning in simulator-based maritime training environments can be improved.

1. Introduction

The navigation system is basically a 'ship–human–environment' (Inoue, 2000; Xiufeng et al., 2005). Hence, approximately 85% of maritime accidents are accounted for by navigation accidents (i.e. collision and grounding) (Jaeyong et al., 2016) caused by human errors, such as mistakes in ship handling and impropriate decision-making (Wróbel et al., 2017; Wu et al., 2020). In addition, studies found that incompetent officers have frequently contributed to ship accidents (Sankaranarayana, 2022). Therefore, navigational safety is one of the important focuses of Maritime Education and Training (MET), and the quality of MET has drawn more attention from both academics and employers in the shipping industry (Bao et al., 2021). High-quality MET is critical for seafarers to acquire knowledge and skills to manage risks, solve problems and complete operations safely and efficiently, thus ensuring life's safety at sea (Basak, 2017). However, there are challenges involved in MET, such as high investment and high running costs (Markopoulos et al., 2019), as well as being time-consuming. A significant challenge facing MET is training a skill level efficiently and cost-effectively in a safe environment (Oh et al., 2016).

Using simulator-based maritime training has a long history in MET (Kim et al., 2021). Simulators provide a non-risk environment for trainees to practise what they have learned in the classroom. Simulator-based training is an effective way to reproduce scenarios that may occur on board so that trainees can obtain practical experience and become capable of handling unexpected scenarios in future offshore work. Throughout the specific simulation exercises, trainees acquire technical, procedural, and operational skills, and, therefore, their capabilities can be improved. After training, trainees can better understand the required decision-making process and how different actions affect a situation (Markopoulos et al., 2019); thus, they learn how to prioritise actions in challenging traffic and emergency operations and conditions.

In navigation tasks, decision-making skills are the key to safe sailing (Norros and Hukki, 2003). For instance, in collision avoidance, the navigator must decide which means are appropriate (i.e. radar, visual means, automatic identification system) in the situation. Afterwards, the navigator must determine (decide) whether the risk of collision exists and which action should be taken (Allen, 2004, p. 217). Environmental stress is also one of the dominant factors that cause accidents at sea (Sampson and Thomas, 2003; Hetherington et al., 2006; Gug et al., 2022). Working at sea is inherently stressful (Carotenuto et al., 2013; Hystad and Eid, 2016; Jensen and Oldenburg, 2021), especially when the situation is rife with changes and many decisions must be made under pressure (Størkersen et al., 2018). In addition, many decision-making situations themselves can trigger stress responses. Therefore, stress can affect decision-making under varying degrees of uncertainty while adapting the underlying decision-making mechanism (Starcke and Brand, 2012). As a result, high stress levels undoubtedly cause decision-making faults, which can be dangerous at sea.

Training in decision-making skills is challenging due, for example, to ill-structured environments (Klein, 1997) characterised by uncertainty, unpredictability and a high degree of variability, requiring individuals to employ critical thinking, problem-solving skills, and creativity to address the issues they encounter (Eilam and Poyas, 2006; Albers, 2022). The maritime field can be described as an environment where the problems or tasks do not have clear-cut solutions or predefined paths to success. This leads to MET being a challenging field of education in general. The environment at sea can change rapidly, not always leaving decision-makers in a familiar and predictable situation. Therefore, developing skills in decision-making is an essential subject in MET. The present study's objective is to better understand the effect of training in decision-making skills in a simulator-based MET environment and to explore the decision-making skills of maritime students in stressful situations under different training levels and methods.

MET is costly (Sampson, 2004); hence, ensuring it is effective and efficient is important. In addition to the expensive training equipment (simulators), other factors, such as devices and laboratories for maritime practice, teaching costs, wages, academic staff costs, and administration and support staff costs, account for a large part of the budget (Cicek and Er, 2008). Therefore, it is necessary to continuously update and upgrade the contents of MET education (Čampara et al., 2017). For instance, reducing the training time without compromising training effectiveness or learning more skills during the same MET period effectively reduces MET costs. From skill acquisition theory (DeKeyser, 2020), we know that learning ship handling and navigation skills involves learning habits and skills. This kind of learning is always slow because it requires practice and overcoming mistakes through practice. However, it is possible to speed up this kind of learning if we provide a psychologically safe coaching environment where students feel comfortable expressing their thoughts, ideas and emotions without fear of negative consequences and where they are allowed to make mistakes during the learning process (Graen et al., 2020). In learning skills, when errors occur, the learner will feel uncomfortable with the temporary incompetence. If learners do not make the same mistake again, they are rewarded. Once learners get consistent rewards for correct responses, the learning progress speeds up, and the learning is reliable (Schein, 1992). Therefore, it is possible to have rapid training methods for trainees to acquire skills. However, these methods are not widely used in maritime training, as thorough training is required.

Based on the literature mentioned earlier, conducting studies on the training process is necessary. The innovation of this paper is that we first apply the decision-making model (NMD) to different situations to analyse the decisions made by the students. Secondly, a concept of 'project-aimed rapid training' (see the definition in the following paragraph) is introduced in the MET to provide targeted and accelerated skill development tailored to specific learning objectives and project requirements. Lastly,

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using simulators in MET, a case study is presented to document the development of decision-making skills. In this context, workload and stress levels were assessed by studying the interaction between subjective workload, stress level and decision-making quality.

This study attempts to formulate answers to the two questions: (1) Can project-aimed rapid training provide equivalent quality decisions in stressful and critical situations compared to regular training? and (2) Can the training method affect the decision-making model applied by the participants? In this study, the concept of 'project-aimed rapid training' was derived from 'project-based learning (PBL)' (Kokotsaki et al., 2016) and studies which proved the effectiveness of PBL (Balemen and Keskin, 2018; Cahyani, 2021). The context of 'project-aimed rapid training' refers to a training approach within maritime education and training programs that is specifically designed to quickly and effectively develop the skills and competencies needed for a particular project or task. This training method focuses on delivering targeted instruction and practical experience to enable participants to quickly acquire the necessary knowledge and abilities to fulfil project requirements. It emphasises a rapid learning process tailored to meet the project's immediate needs, ensuring that participants are adequately prepared to contribute effectively and efficiently to project objectives. Several key criteria define the term 'quality decision' applied in the study. Firstly, safety is prioritised, ensuring the solution leads to safety, such as no collisions. Compliance with maritime regulations and conventions is also essential, reflecting adherence to established standards and best practices. Timeliness is another crucial factor, with decisions made promptly and effectively to address evolving situations. Efficient decisions also involve effective risk management, mitigating potential hazards and ensuring operational safety. In addition, alignment with overarching goals and adaptability to changing conditions further characterises quality decision-making in MET.

The paper is presented as follows: The following section briefly introduces the theoretical basis, including the decision-making model and simulator-based MET. Section 3 presents the designed training scenario, and a customer decision quality rating scale is proposed for evaluating the impact of the MET programme on decision-making. Section 4 presents the results of the training scenario, including the workload assessment, the stress level and the quality of the decision-making. Section 5 discusses the results. The final section presents conclusions from the study and future work.

2. Theoretical basis

Decision-making plays a vital role in maritime operations (Allen, 2004, p. 217) and constitutes the foundation of the present study. At every stage in maritime activities, seafarers make decisions by accessing information, understanding the situation and assessing risks to ensure that conditions are safe and activities are performed effectively. Here, the term 'risk' represents a combination of the probability of an unwanted incident and the consequences of the incident. These decisions are critical for the ship's continued safety and have major implications for the environment and the economy. Therefore, training in decision-making skills is essential in MET.

Decision models can be used to describe how people make choices in realistic settings. There is no unified decision theory, but researchers have proposed different models in different settings (Klein et al., 1993, p. 103). One such model is naturalistic decision-making (NDM) (Klein et al., 1993, p. 9). During maritime activities in a high-risk environment, decisions must be made under time pressure, where the information might be insufficient and the goals not clearly defined. Therefore, it is impossible for decision-makers to assess all the possible options and the consequences. Hence, making rational and optimal decisions under time constraints is difficult. NDM does not require the decision-makers to possess the rationality, knowledge and information-processing capacity to make the decisions. NDM is suitable for situations with limited time, changing contexts and unstable conditions involving persons with different experience levels.

Under the NDM framework, decisions need not be the best possible option; the solution should be satisfactory but not the ultimate solution since time is of the essence. In MET, students are given classical decision-making training, such as situation awareness training for collision avoidance. However,

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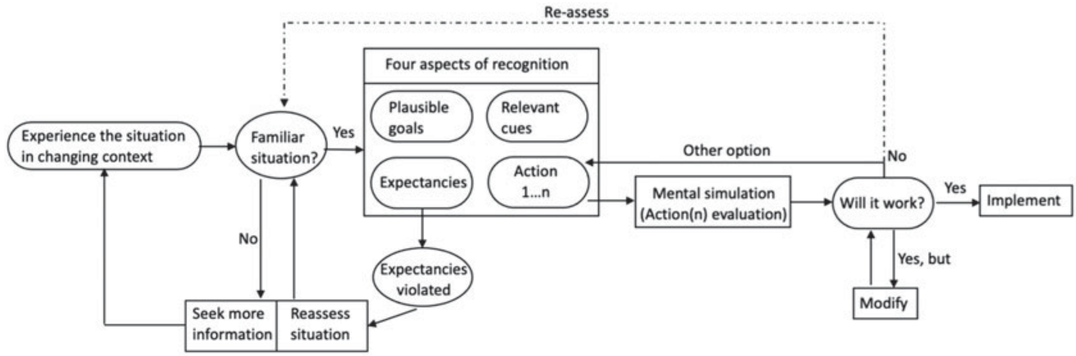

Figure 1. *RPD mode in a complex situation is re-illustrated based on Klein (1993).*

the decisions made in the real world are often spontaneous, more in line with NDM models than classical decision-making models (Orasanu and Connolly, 1993; Canon-Bowers and Bell, 1997), where individuals can take the time to analyse everything, evaluating each option by weighting the associated costs and benefits (Klein et al., 1993). NDM poses a more significant challenge. NDM does not rely on decision theory or other formal models but is rooted in intuition. To make acceptable decisions, many experiences formed in patterns provide tacit knowledge (Cohen et al., 1998). Specific training programmes can speed up the process of obtaining these experiences.

From the NDM framework, the primary protocol is the recognition-primed decision-making (RPD) mode. This mode describes how people use their experience to make quick and effective decisions in complex situations. It relies on the decision-maker's mental simulation, wherein the decision-maker examines their memory for the situational cues from previous learning situations to match the current events. The RPD mode shows how to implement decisions from four aspects of recognition (plausible goals, relevant cues, expectancies and a series of actions) to generate a plausible course of action (COA) and use mental simulation to evaluate the COA during a challenging situation (Klein, 1993) (Figure 1). With the RPD mode, the decision-makers must identify a reasonable COA as rapidly as possible. The quality of the decisions is highly dependent on their knowledge, experience and training.

3. Materials and methods

3.1. Participants

A total of 22 (mean age = 22 · 4 years, standard deviation = 2 · 04, 5 females and 17 males) undergraduate students in nautical science at the Arctic University of Norway (UiT) voluntarily participated in a simulator-based experiment. The participants numbered 14 from the first-year and eight from the second-year courses. Some of them have practical experience at sea through part-time jobs. Note that the assessment of the skills was done before the experiment, and it was based on the learning outcomes of students of different grades. The assessment results of participants' skill levels can be found in Appendix A. Moreover, according to the participants, they were mentally and physically healthy at the time of the experiment.

3.2. Materials and apparatus

The experiment was conducted on two simulator bridges, both with 240° views and equipped with the K-sim navigation software from Kongsberg Digital. A standard instructor station was assigned to both simulator bridges for acting the multiple roles, such as machine, deck, and crew on the towing object. Two types of vessel models were used in the experiment. The vessel model of the towing object was a small bulk carrier, *Hagland Saga* (HS), with a length between perpendiculars of 90 m. The three vessel models used in the experiment were two similar tugs (named *SMIT Panama*) and the vessel being towed.

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Table 1. *Detailed information on the vessel models used in the experiment.*

Vessel	Length (m)	Beam (m)	Draught fore (m)	Draught aft (m)	No. of propellers	No. of rudders
Tug vessels	41 · 80	11 · 40	3 · 67	4 · 22	2	2
Vessel being towed	89 · 99	14 · 00	5 · 47	5 · 45	1	1

Detailed information on the vessel models is given in Table 1. The tow was arranged with one tug behind the object vessel and one tug in front. A single line connected the bow of the aft tug and the stern of the object vessel. Another single line was connected between the bow of the vessel and the stern of the front tug. Each of the lines had a total length of 200 m. The hydrographic conditions in the area were a moderate current situation, approximately 0 · 5 knots towards the southwest. The wind speed was 6 knots, coming from a northeasterly direction.

3.3. Experiment design

This study's experiment scenario was based on a towing operation as a within-subject factorial. In the experiment, students from each year's class were randomly divided into groups of two; there were seven groups from the first year and four groups from the second year. Based on the different training methods, the second-year students were assigned to the control group, and the first-year students were assigned to the experiment group. The experiment can be considered a quasi-experiment, as the students were not randomly assigned to the experiment and control groups. Although the absence of random assignment casts some doubt on internal validity, the results of such studies are still compelling because they are not artificial interventions in social life and because their ecological validity appears strong (Bryman, 2012, p. 50).

Furthermore, in each group, every two participants were assigned as a team (i.e. one participant was randomly assigned to one tug), and, therefore, two people were involved in handling the two tugs during the towing operation. In Appendix B, Figure B1 illustrates how the tugs were arranged and how the towing operation was conducted. During the experiment, participants only took part in one of the towing exercises and did not switch roles throughout the sessions. The experiment also included several dependent variables for analysing the results: training methods, cognitive workload, stress level and decision-making.

The towing operation was chosen because it is not only a basic operation in the maritime domain but also provides the environmental conditions that determine the level of ship-handling difficulty, which is an essential factor affecting the likelihood of accidents. Beforehand, every participant signed a consent form to participate in the experiment.

3.3.1. Scenario

The participants were asked to tow an object (a small bulk carrier, *Hagland Saga*) near the Ryøya island area (south of Tromsø) towards Tromsø (a city in Norway). The intended route for the operation was to continue towards Tromsø, changing course north after passing the narrow strait 'Rystraumen'. The map of the area is shown in Appendix C, Figure C1. Each participant sailed a tug. Tug Bravo was in front of the object to lead the way, and tug Charlie was at the back of the object. Participants could communicate with each other via maritime VHF (very-high frequency) radiocommunication; they could also communicate with the instructor station by using UHF (ultra-high frequency) radiocommunication so that the other tug would not hear their conversation.

Good weather was chosen for the scenario. The weather conditions are detailed in Table 2. During the towing operation, failure of both engines of the forward tug would be induced when the tugs were in a critical location where they would pass Ryøya island, located south of Kvaløya, southwest of Tromsø.

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Table 2. *Weather condition applied in the scenario.*

	Speed	Direction
Wind	6 knots	From 040°
Current	$0 \cdot 5$ knots	270° (going west)

Table 3. *Geographical location of the start point, and failure induce location (based on HS).*

	Start point	First failure induced	Second failure induced
Latitude	$69°32 \cdot 948'$N	Depends on the current location	Depends on the current location
Longitude	$18°38 \cdot 026'$E	18°43E	$18°43 \cdot 5$E

Geographical locations are listed in Table 3, and the 3D view in two different directions of vision can be found in Figure B1 in Appendix B. With a suggested sailing speed of 6 knots, tug Bravo would receive the first failure information from the machine department around 20 min after they started. After an approximately 30 s to 1 min time gap, tug Bravo would receive the second failure information and would lose all the power to continue sailing.

3.3.2. Training methods

In this study, the training programme was conducted on the bridge simulators. The reasons for using simulator-based training and the description of the training programme are presented below.

- Why use simulator training?

The use of simulators is a key part of modern maritime training and education. The training of maritime students is based on the regulations found in the *International Convention on Standards of Training, Certification, and Watchkeeping for Seafarers* (IMO, 2018). This regulatory framework (STCW-code, tables A-2/1 and A-2/2) describes the minimum requirements for the students regarding competence, knowledge, understanding and proficiency. The tables mentioned describe methods for demonstrating competence. For several of the modules described in the code, the available methods for demonstrating competence are a vessel or simulator. For practical and economic reasons, simulators are the preferred method.

Although the training and education programmes might differ in organisation and content (Nazir et al., 2019), simulators are still a key part of the training. Studies also describe how using simulators in the training process can reduce the risk of maritime accidents (Hanzu-Pazara et al., 2008). Maritime simulators can be used for training in a broad spectrum of situations, such as complex tasks (Hjelmervik et al., 2018). It has also been used for training on towing operations as specific tasks (Gudmestad et al., 1995).

- Description of the training programme

The students participating in the experiment are all part of the bachelor programme in nautical science at UiT. During the three-year programme, the students will have, in total, 32 simulator exercises with an instructor present, or 96 h of simulator training for each student. The simulator is also available for self-study exercises, and most students will have achieved a significantly higher number of hours in the simulator by the end of their studies. The students participating in the experiment were in the first or second year of their studies. The first-year students had fulfilled half of the simulator exercises (16 exercises or 48 h, including two examinations with external evaluation), and the second-year students had fulfilled all the simulator exercises (32 exercises or 96 h, including two examinations with external evaluation).

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After the first-year course study, the expected learning outcomes of the courses for the first year and second year of the nautical bachelor program, the students should be able to critically analyse and communicate the interplay between regulations, technology and human factors and their significance for the safety of life, the environment and property at sea. Through the simulator exercise, students have experience using electronic systems. They can use and interpret information from on-board meteorological instruments, radar and automatic radar plotting aids (ARPAs) and use this information to make decisions for the safety of sailing. They can carry out safe watchkeeping by demonstrating the ability to handle resources, communicate, have leadership skills and have situational awareness.

After the second-year course study and based on the expected learning objectives, students should be able to carry out an independent analysis and communicate how navigation procedures and technical equipment in combination affect maritime safety, as well as identify weaknesses and limitations in the system and find solutions. Students can decide, implement and communicate an optimal use of technical and human resources on board to plan and carry out safe, efficient and environmentally friendly maritime transport. Through the set of simulation exercises, students are trained to handle emergencies. The students must choose the route themselves and learn to deal with other traffic in the area and the other simulator ships, in addition to other traffic. Anchoring and towing operations are learned and practised in several simulation training exercises during the second semester of the second-year study. Situation awareness, decision-making skills and communication skills are improved during their second-year studies.

For first-year students, an extra towing operation training course (project-specific rapid content training) was conducted rapidly to obtain the skills needed to fulfil the task. The content of towing operation training was the same as that for the second-year students. Key points, such as towing theory, methods and dealing with emergencies, were covered in a 20-minute video lecture. One-hour hands-on training and practice on the simulator were carried out before the experiment was conducted. After this rapid training, the first-year participants gained the ability to complete the towing operation.

3.3.3. Workload assessment

In this study, a reliable assessment tool, the NASA Task Load Index (NASA-TLX) (Hart and Staveland, 1988; Sharek, 2011), was employed to access the workload. Six categories, including Mental Demand, Physical Demand, Temporal Demand, Performance, Effort and Frustration Level, were rated by the participants after the experiment. For each category, the rating was transferred to a ten-point Likert-type scale from low to high levels, where 0 is low and 10 is high.

3.3.4. Stress level assessment

The stress level was assessed in both subjective and objective ways. The State-Trait Anxiety Inventory (STAI) Form Y-1 (Spielberger, 1983) was used to assess the self-assessment of the stress level. Each participant filled in the STAI Y-1 form immediately after leaving the simulator bridge. The STAI Y-1 form has a brief self-rating scale for assessing state and trait anxiety. It consists of 20 questions that evaluate the participant's feelings. STAI scores can be up to 80 and are commonly classified on three levels: 'no or low anxiety' (20–37), 'moderate anxiety' (38–44), and 'high anxiety' (45–80) (Fountoulakis et al., 2006).

The objective stress level can be reflected by changes in the heart rate (HR). The HR increases when people are stressed (Vrijkotte et al., 2000). The reason is that the stress state of the body triggers the release of the hormones cortisol and adrenaline, which raises the body's blood pressure and causes the HR to increase. In this study, a medical-grade wearable biosignal data acquisition device, E4 Wristband, was used to measure the HR data of the participants. A photoplethysmogram (PPG) sensor equipped with an E4 wristband measured blood volume pulse (BVP), from which heart rate variability could be derived. Before participants entered the simulator, they were asked to sit and relax for 10 min so that the baseline of biosignal data could be collected. Ten minutes was sufficient relaxing time, based on comparable studies (Grewen et al., 2005; Ciabattoni et al., 2017).

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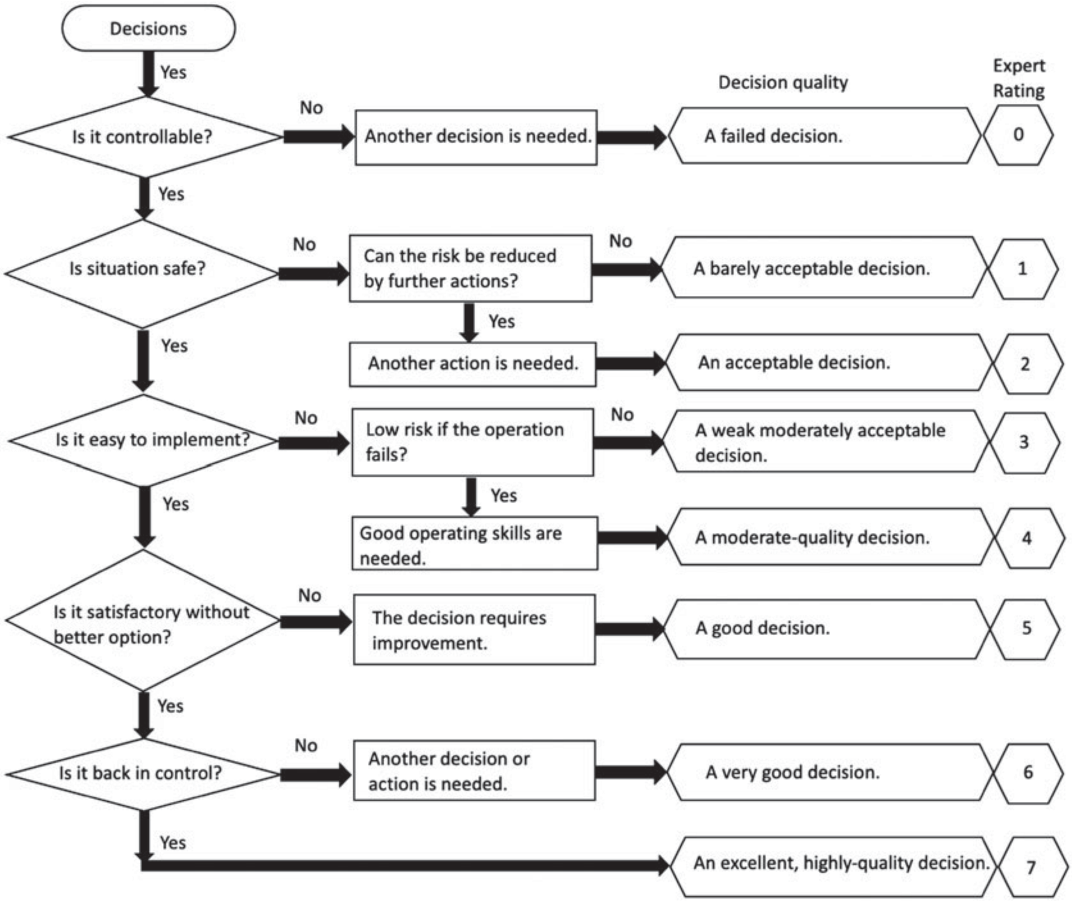

Figure 2. *Proposed customer decision quality rating scale.*

3.3.5. Decision-making (learning objectives, performance criteria and a proposed customer decision-quality rating scale)

The towing operation is a complex task that requires knowledge, experience and cooperation. The towing performance, communication skills, decision-making skills and reaction time after the emergency occurred were evaluated during the case study. During the experiment, two experts/instructors commented on the participants' performance during the task. For decision-making, we only examined the decisions taken after the emergency was induced.

When an emergency happens during the towing operation, the most important thing for the decision-makers is to decide a safe and reasonable action as soon as possible. The quality of the decisions is not the most critical aspect in this case; efficiency is considered the priority. This is what the RPD mode requires. However, the quality of the decision can still be evaluated afterwards. In this study, an expert rating system inspired by the Cooper-Harper Handling Qualities Rating Scale (Cooper and Harper, 1969) is proposed for the assessment (see Figure 2). From the rating of the decision, we can analyse the impact of the knowledge, experience and training method on the decision-making. In addition, the rating scale was consistent because it was from the same expert who did the assessment. This means the experts are trained in this assessment, and the students are used to it.

In this proposed expert rating scale, there are five levels of requirements reflecting navigational safety. These requirements are presented in the form of questions, and status is judged based on the actual situation after a decision has been made. To obtain an accurate rating score, it is essential to define the decisions correctly based on the situation. Regarding these requirements, the first level is whether the

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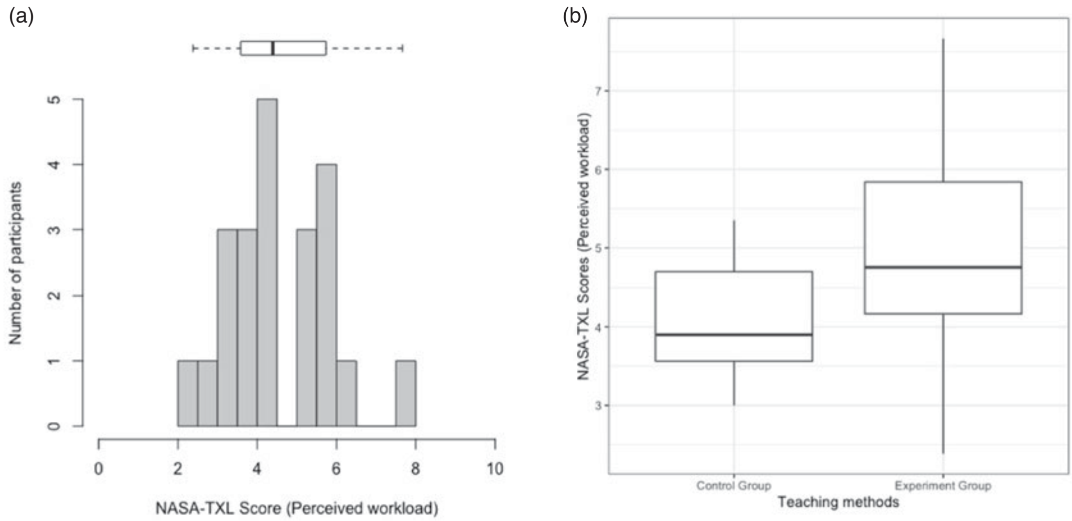

Figure 3. *Perceived workload measured using NASA-TXL: (a) the summary statistics (distribution and median) of the NASA-TXL score by all the participants; (b) the summary of the minimum, first quartile, median, third quartile and maximum of NASA-TXL scores in groups.*

decision is 'controllable'. It is necessary to know that all the vessels involved should be under control, which means that participants will know what to expect after making a decision. For example, neither the towed object nor the tugboats should drift. Otherwise, another decision is required, and the first decision will be considered a failed decision. The second level, 'safe situation', means that there will not be any incident or accident after the decision-making. For instance, if there is a possibility or tendency to collide, it is considered unsafe. The next level of the requirement is the ship handling skills involved. 'Easy to implement' means it does not require a high standard of ship handling skills to complete the operation. For instance, after the decision is made, the situation is expected to be under control and safe. However, if the navigator does not have sufficient skills to handle the operation, and the situation is not a controllable and safe situation, then if the operation fails and the situation is in the low-risk category, the rating score for this decision will be higher (a score of 4 in expert rating) than if the situation is in the high-risk category, which gives a score of 3. Next, we consider whether the decision is 'satisfactory'. If there is no better option for the decision, we move to the last stage to check whether the situation is 'back in control'. In this case, the problem is solved, and the emergency is lifted.

4. Results

4.1. Workload

A one-way analysis of variance (ANOVA) method was used to find the effects of the different tugboats and groups on the perceived workload. Results show that there was no statistically significant difference ($F(1,20) = 0 \cdot 114$, $p > 0 \cdot 05$) in the perceived workload on the different tugboats during the experiment. (Note that, commonly, if the p-value is higher than $0 \cdot 05$, we say there is no statistically significant difference between the groups.) In other words, during the experimental task, the participants rated the workload of sailing on the front tugboat and the back tugboat as similar. In addition, participants in the experiment group perceived a higher workload ($M = 4 \cdot 85$, $SD = 1 \cdot 44$) than those in the control group ($M = 4 \cdot 13$, $SD = 0 \cdot 85$). However, the result of the one-way ANOVA also shows that there was no statistically significant difference ($F(1,20) = 1 \cdot 65$, $p > 0 \cdot 05$) in perceived workload as an effect of teaching methods. The overall perceived workload is $4 \cdot 59$ out of 10 with a standard deviation of $1 \cdot 28$. The summary statistics are depicted in Figure 3.

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Table 4. *Results of the reaction time and decision quality for the two groups.*

Teaching methods (Groups)	Back tugboat cut line time (average in minutes)	Decision quality rating (full score is 7)
Control group	$M = 0 \cdot 87$ min, $SD = 0 \cdot 33$	$M = 5 \cdot 0$, $SD = 0$
Experiment group	$M = 3 \cdot 59$ min, $SD = 1 \cdot 47$	$M = 3 \cdot 3$, $SD = 1 \cdot 64$

Note: SD: standard deviation.

4.2. Stress level

STAI Form Y-1 measured the subjective stress level. Like the workload, one-way ANOVA was employed to analyse the effect of teaching methods and tugboats on the perceived stress. The results show that participants in the control group perceived higher stress ($M = 46 \cdot 5$, $SD = 3 \cdot 78$) than in the experiment group ($M = 41 \cdot 0$, $SD = 6 \cdot 85$), with a statistically significant difference ($F\ (1,20) = 4 \cdot 34$, $p = 0 \cdot 05$). Sailing on different tugboats had no effect on the perceived stress ($F\ (1,20) = 0 \cdot 347$, $p > 0 \cdot 05$). Based on the classification, the control group is considered to have a high anxiety stress level, and the experiment group is considered to experience a moderate anxiety stress level (Fountoulakis et al., 2006).

The HR of the participants measured the objective stress level. The data shows that HR increased significantly when the participants were towing (mean HR = $84 \cdot 9$, standard deviation = $8 \cdot 13$) compared to the situation during the relaxing time (mean HR = $76 \cdot 6$, standard deviation = $5 \cdot 93$). A paired *t*-test was employed to analyse the comparison. The results show a significant increase in HR when participants were performing the towing operation, $t\ (21) = 5 \cdot 885$, $p < 0 \cdot 001$. The HR data shows that participants were stressed under the towing operation, which aligns with the STAI Form Y-1 results.

4.3. Decision-making and performance

Navigating and towing operations require frequent decision-making. Evaluating each decision along the way is more complicated than you might think because of the information available, the number of outcomes, uncertainty in outcomes, and risk involvement. Therefore, any decision is acceptable as long as the sailing is safe. In this study, we only looked at one critical situation and decision-making related to this situation where the emergency occurred. A nautical expert made a qualitative assessment regarding the decisions made by the students based on the model presented in Figure 2. The nautical expert had a background as a simulator instructor, and making qualitative assessments of situations like this, being a routine towing operation, was a situation where the expert must be considered experienced. To examine the participants' ability to respond to emergencies, a chain of failures occurred in a short time. After the failures were induced, the quality of the decision-making was analysed using the proposed custom decision-quality rating scale. For example, one of the towing teams did nothing after being informed that the front tugboat had engine failure. After a while, they decided to drop anchors in the middle of the sea channel (Figure B1), one after another, without communication. The situation is uncontrollable since it could be dangerous to all vessels, and the decision was rated as a failed decision. Moreover, the average time of the back tugboat cutting the line was a critical factor in the evaluation. The results are presented in Table 4.

The scenario was the same for all the participants during the experiment. However, participants with different training backgrounds make different decisions based on the speed and location when the failure occurred. For instance, when the emergency occurred, the front tugboat informed the back tugboat after some time that it had lost engine power. However, each team made very different decisions regarding what to do next. Some of the decisions and consequences are listed in Table 5. Even if participants make the same decision, the result may vary based on the current situation and other factors such as the participant's ship operating skills, experience and previous training. Figure 4 shows an example of risky decision-making.

Table 5. *Different options for decision and the consequences of the decisions.*

Decision-maker	Options for decision (after the second engine failure is induced):	Consequences of decisions
Control group	Front tugboat staff cuts the line immediately, while the back tugboat staff needs to cut the line and sail to the front.	The towing object may be lost, it starts drifting.
Experiment group	Front tugboat staff do not cut the line and want to be tugged together with the other tugboat.	Pulling both the towing object and the other tug is higher risk than tugging only one vessel.
Experiment group and control group	Front tugboat changes direction after the engine failure.	Avoiding being hit by the towed ship and giving a way for the back tugboat to go to the front.
Experiment group	Front tugboat staff decides to launch anchor.	No consequences if it is detached from the towed ship. If it is still connected to the towed ship, it creates an unstable situation.
Experiment group	Back tugboat reduces the speed and tries to stop the towed ship.	Avoid collision.
Experiment group	Back tugboat sails backwards.	Difficult to maintain safety when manoeuvring backwards.
Control group	Back tugboat staff cuts the line without reducing the speed and sail to the front.	Good ship handling skill is demanded, and an unstable situation is created.
Experiment group	Back tugboat sails between the towing object and the front tugboat.	This represents a short cut, but there is a high risk of collision. Good skill is required.

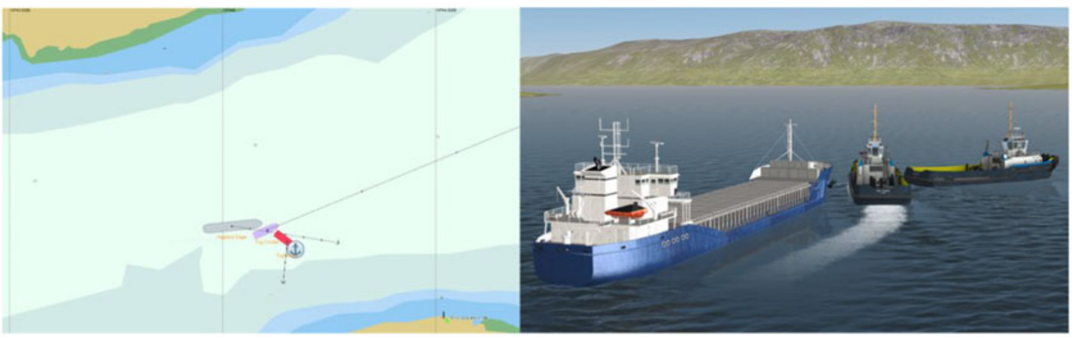

Figure 4. *An example of a risky decision and its corresponding 3D view are shown on the map. One of the participants decided to cross the narrow passage between the tugboat and the disabled ship, an action which requires considerable ship-handling skills.*

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Table 6. *Correlations between variables; results presented are the Pearson correlation coefficient, r.*

		1. Teaching methods	2. NASA-TXL Total	3. Stress level	4. Decision quality rating
1.	Teaching methods (Groups)	–			
2.	NASA-TXL Total	–0 · 28	–		
3.	Stress level (STAI Form Y-1)	0 · 42*	–0 · 04	–	
4.	Decision quality rating	0 · 55*	–0 · 29	0 · 11	–

Note: For numbers marked *, then $p \leq 0 \cdot 05$ and we have strong correlation. The matrix is presented in such a way that it is symmetrical.

4.4. Correlation

Correlation analyses were performed to determine the interaction between workload, stress, and quality of decisions as factors dependent on the teaching methods. The correlations between these variables are listed in Table 6. To calculate the correlation, we set the experiment groups who had undergone a rapid training course as index 1 and the control groups who had received conventional training as index 2. The results show that a higher stress level is associated with the period of the participants' study ($r = 0 \cdot 42$, $p = 0 \cdot 05$). In addition, the quality rating of the decision is also correlated with the length of time the participants have been studying ($r = 0 \cdot 55$, $p = 0 \cdot 008$) and a 95% confidence interval for the correlation coefficient r is found to be $[0 \cdot 1643784, 0 \cdot 7876370]$.

5. Discussion

In this study, teaching methods were examined and evaluated using decision-making performance in a towing task. The aim was to understand better the effect of training decision-making skills in a simulator-based maritime MET environment. By utilising the simulator at the university and inviting different groups of participants with varying training backgrounds, this study investigated the impact of routine maritime training on improving decision-making skills and how individual decisions are reflected in ship handling skills. In addition, perceived workload and stress levels were compared to test the sensitivity.

The utilisation of the NASA-TXL rating as a subjective measurement of the towing workload revealed that all participants perceived a similar workload and that there was no significant difference between those working on the front and back towing tugs. This reflects that the teaching methods did not result in different perceived workloads. Furthermore, the towing operation simulated represents a collective operation with two persons working as a pair, and hence, it is difficult to distinguish the workloads of working on different tugboats.

A towing operation is a stressful task. From the results of the stress level self-assessment, the control group participants (being in their second year of study) perceived more stress than those in the experiment groups (with limited training in using the simulator). The HR data also shows that all the participants experienced a significant increase in heartbeats per minute while performing the towing task. However, there was no significant difference in heart rate increases among participants who received different training methods. This reflects the limitation of HR as an objective stress measurement in discriminating between the various stress levels.

From the decision-making results, the control group is found to have made more homogeneous decisions than the experiment group. This can be explained by the assumption that the participants in the control group had a more profound theoretical knowledge regarding towing operations than the participants from the experiment group. The experiment group underwent a project-specific rapid content training (crash course) consisting of a 20-minute video lecture and a one-hour simulator session, with seven participants participating in each session. The control group underwent several simulator exercises, including three towing operation tasks and lectures over a certain amount of time. The results imply that teaching students how to handle a tug through such a rapid course is possible. Still, obtaining the same level of knowledge, skills and understanding of the situation is challenging compared to regular teaching over a more extended period.

The results from the analysis of the participants' decision-making show that the model of naturalistic decision-making is suitable for this kind of analysis. Many of the characteristics of NDM, such as high stakes, time stress and uncertain dynamic environments (Orasanu and Connolly, 1993), are present in this exercise. For example, the participants can experience high stakes and a certain amount of time pressure during the experiment; meanwhile, the surrounding conditions change, caused or not, due to the decision made by participants as time passes. The decisions can also be considered a chain of events, as one decision will affect the next decision. An example could be cutting the line between the functional tug and the towed object. This decision will change the number of options, increase the time pressures and certainly affect the participants' next decision.

From the results, it seems that the use of the RPD mode can explain the decisions made by the control group because the participants in the control group had undergone three towing operation exercises at different levels during their routine training and one more year of study with several simulator-based training exercises than the participants in the experiment group. Therefore, the scenario was familiar to them, and they used their experience from previous simulator-based exercises and lectures as input for making their decisions. Since all the control group participants had been through the same exercises and lectures, that could be why they made relatively homogenous decisions when the RPD mode is applied. Moreover, the reason for the participants in the control group experiencing a higher level of stress could be their awareness that they should know this task and be able to handle this situation based on their previous exercises and lectures. They might expect to perform better than before. However, the participants in the experiment group might think that their performance is not as important, as they have only been through a short and rapid training course. Therefore, their perceived stress level is lower. In addition, the participants in the experiment group also have limited experience, so they might not realise the severity of the situation and what could go wrong.

When it comes to the decisions of the participants in the experiment group, it can be assumed that they also initially tried to follow the RPD mode; however, their level of experience is not high enough to apply this mode effectively, which means that they are not able to find relevant input from the crash course or other simulator-based exercises to assist them in making their decision. This hypothesis is strengthened, for instance, by the data from the time elapsing before they decide to cut off the line. It is significantly longer for the experiment group, meaning they took more time to assess the situation, search for previous experience that could guide them to their decisions and wait for more information. As the time pressure increases, many of them would start exploring the field of creative decisions rather than recognition-primed decisions. The high number of different solutions from this group strengthens this hypothesis. As the various solutions are analysed, solutions that are not in line with either the theory from the crash course or other simulator-based exercises can be found. These solutions might be effective, as in the example mentioned where the participant decided to pass between the front tug and the object being towed. However, the solution is connected to high risk and could lead to increased complexity for the next set of decisions that must be made.

To summarise, the participants who have been through conventional teaching over a more extended period can apply their knowledge and skills deeper when exposed to unfamiliar and critical situations, compared to participants who have been through project-aimed rapid training.

5.1. Implications of the study

This study provides an approach to the efficiency and effectiveness of maritime training programs through project-aimed rapid training methods. In this experiment, the participants had very compressed training content, involving many participants simultaneously present in the simulator-based practice. Project-focused rapid training design can produce efficient training results by integrating theoretical teaching with simulation exercises. For example, at UiT, the MET program requires students to complete eight simulated training exercises per semester during the first two years of study, for 32 exercises. The duration of these simulations varies from $0 \cdot 5$ to 4 h, depending on their complexity. Well-designed project-aimed rapid training enables trainees to accomplish training tasks effectively, leading to improved learning outcomes and enhanced decision-making skills, especially in emergencies.

Based on the findings, it is recommended that project-aimed rapid training, with some increases in training duration, should be considered while reducing the number of simultaneous participants engaged in the simulator-based practice, as this has been shown in this paper to enhance learning outcomes effectively. Moreover, the results underscore the importance of traditional teaching methods over an extended period to establish a solid foundation. Such fundamentals are essential for developing creative solutions to unfamiliar situations, particularly emergencies. Proficiency in handling emergencies safely and effectively necessitates a blend of experience and knowledge. Notably, the frequency of simulator-based exercises can significantly influence the success rate of specific tasks, even if the exercises are not task-specific. Increased exposure to simulator-based training correlates positively with enhanced decision-making skills.

This approach can potentially improve learning outcomes and equip navigators with the requisite skills to cope with the complexities of the maritime industry, ultimately enhancing safety standards and optimising training effectiveness.

5.2. Limitations of the study

In this study, we acknowledge the limitations associated with the validity of the decision-quality scale. Results may be influenced by biases inherent in the decision quality scale itself. Although developing decision quality rating scales is intended to serve an objective purpose, the ratings may be subject to the expert rater's subjective judgement. Consequently, the results of the correlation analysis may be influenced by these ratings. Consistency was maintained in the rating scale to mitigate subjective bias, with assessments conducted by the same expert throughout. This ensures uniformity in the assessment process, similar to regular simulator training sessions. Both experts and students are accustomed to this standardised assessment approach. Further validation studies are warranted in future research endeavours to address this limitation comprehensively.

It can be noted that there was an absence of post-experiment interviews or debriefing sessions with participants. While such qualitative data could have provided valuable insights into participants' experiences and decision-making processes, practical constraints prevented their inclusion. One primary concern was the potential disruption to the teaching program and participants' training schedules. As the simulation training sessions were already tightly scheduled, introducing additional activities, such as interviews, could have detracted the students from the effectiveness of the training and impacted the overall learning experience. Furthermore, given the importance of maintaining the participants' anonymity and confidentiality, conducting interviews immediately after the experiment could have posed privacy concerns. To address this limitation, future research endeavours could explore alternative methods for gathering qualitative data, such as conducting follow-up interviews later or incorporating participant feedback forms. Despite this limitation, the quantitative data collected in this study still provides valuable insights into the effectiveness of the training methods and the decision-making models applied by participants.

6. Conclusions and future work

Consequently, this study tried to answer two questions: (1) Project-aimed rapid training can give sufficient knowledge for participants to fulfil the task; however, in stressful and critical situations, their decision qualities are lower than students with regular training. (2) Different training methods can influence the decision-making models manifested by participants, which are discerned through research analysis and aligned with relevant theories. This research finds that the participants who have been through conventional teaching over a more extended period can apply their knowledge and skills at a deeper level when exposed to unfamiliar and critical situations than participants who have been through project-aimed rapid training. Participants with only rapid training did not have enough experience to apply the RPD mode; however, most of them used creative decisions to solve the problems.

For future work, we intend to implement project-aimed rapid training in other parts of training and education to make the routine/regular education programme more efficient. Another option is to execute extended project-aimed rapid training with increased training time to measure the effect of the length of the training.

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Ethics approval. The project was approved by NSD Norsk Senter for Forskningsdata (Norwegian Centre for Research Data).

Competing interest. The authors declare no competing interests.

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A. Appendix A. Assessment of participants' skill levels

Groups	Number of participants	Skills on average	Simulator-based training time
Control group	8	Good navigation skills, good ship handling skills, reasonably good communication skills, some emergency handling skills.	32 exercises or 96 h of training
Experiment group	14	Good navigation skills, moderate ship handling skills, less efficient communication skills, no emergency handling skills.	16 exercises or 48 h of training

Note: The project-aimed rapid training aimed to minimise the skills gap between the two groups. Additionally, the assessment of the skills was made prior to the experiment:

(1) Good navigation skills are defined as skills the students have obtained to be familiar with all basic tools and methods for navigation. There should be no difference in skills and knowledge between the two groups, although the control group will have somewhat more experience from the simulator.
(2) Good ship handling skills are defined as skills the students have obtained by becoming familiar with theory regarding ship handling and completing simulator training specifically aimed at learning ship handling.
(3) Moderate ship handling skills are defined as basic skills the students have acquired in the simulator necessary to manoeuvre a ship as a part of regular simulator exercises where the main focus is navigation, but they have not been through the theoretical training and simulator training specifically aimed at ship handling.
(4) Reasonably good communication skills are defined as skills the students have obtained through some internal and/or external communication from simulator exercises, but they have not yet been through specific communication training.
(5) Less-efficient communication is defined as a skill that students have acquired with minimal training in the simulator, primarily through exercises where communication is not emphasised.
(6) Some degree of emergency handling skills is defined as skills the students have obtained by being through simulator exercises where emergency handling was part of the scenario, but they have not been through specific training in emergency handling.
(7) Students lacking emergency handling skills imply that they have not undergone training in either theory or simulator exercises related to emergency handling.

B. Appendix B. Views from the simulator

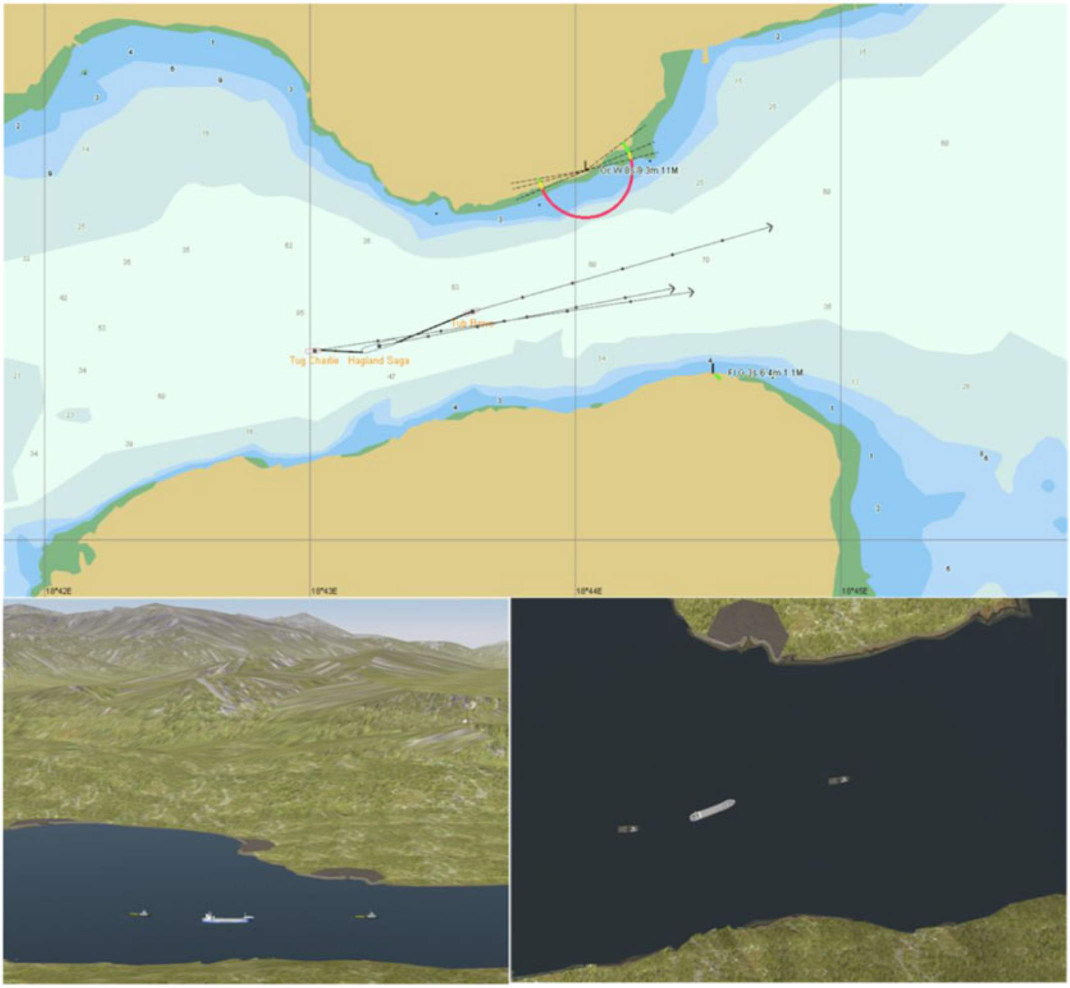

Figure B1. View from the simulator at UiT, The Arctic University of Norway. The location where the critical situation took place is shown on the map and its corresponding 3D views in two different directions of vision.

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C. Appendix C. Experiment area shown on the navigation map

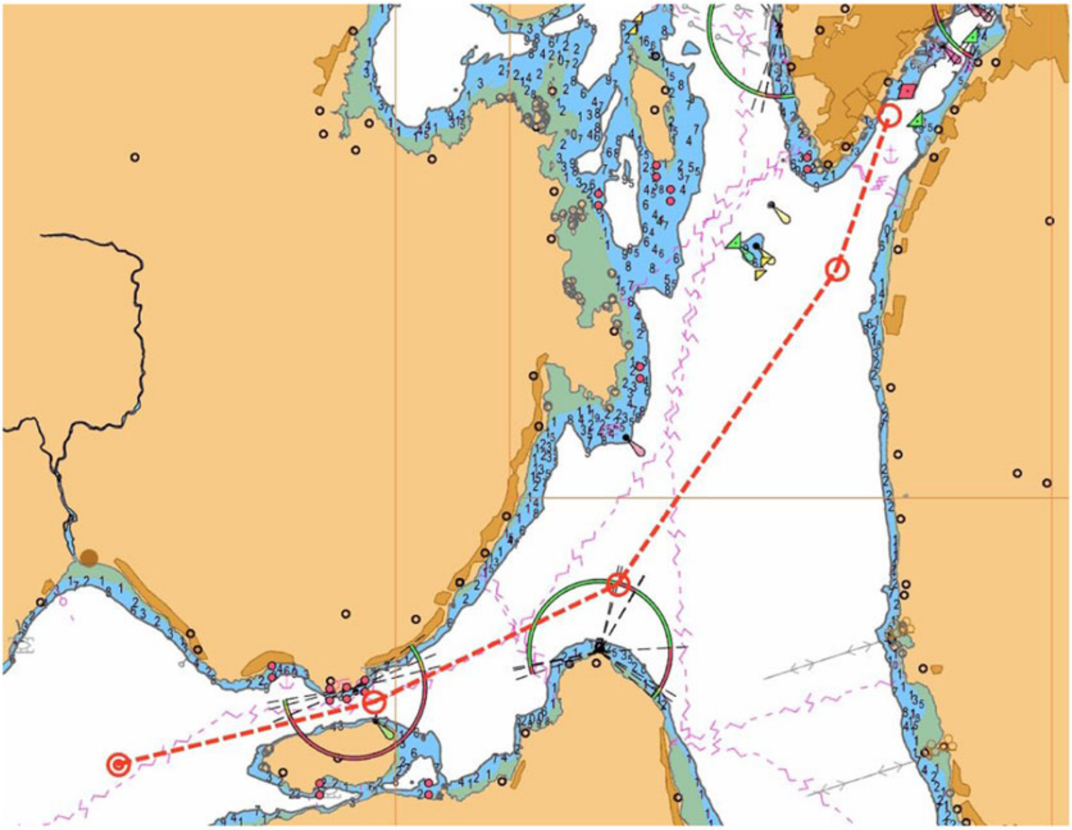

Figure C1. *The experiment area is shown on the navigation map. The red arrows on the map show the planning route. Tromsø is seen at the upper-right of the figure.*

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