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Virtual reality enhances safety training in the maritime industry: An organizational training experiment with a non-WEIRD sample

Guido Makransky | Sara Klingenberg

Abstract

Objective: Many industries struggle with training dynamic risk assessment, and how to bridge the gap between safety training and behavior in real life scenarios. In this article, we focus on dynamic risk assessment during a mooring operation and investigate the potential value of using immersive virtual reality (VR) simulations compared to standard training procedures in an international maritime training organization.

Methods: In a pilot study, we compared two ways of implementing a VR simulation (stand-alone or with post-simulation reflection) to a manual and a personal trainer condition in a between-subjects design with 86 students in a maritime school. Based on the results we compared the stand-alone VR simulation to the personal trainer condition in a between-subjects design in a non-Western, Educated, Industrialized, Rich, and Democratic (WEIRD) sample of 28 seafarers from the Kiribati Islands at an international maritime training organization.

Results: The VR simulation group reported significantly higher perceived enjoyment ($d = 1.28$), intrinsic motivation ($d = 0.96$), perceived learning ($d = 0.90$), and behavioral change ($d = 0.88$), and significantly lower extraneous cognitive load ($d = 0.82$) compared to the personal trainer group, but the differences in self-efficacy, and safety attitudes were not significant.

Discussion: The results support the value of using VR to train procedures that are difficult to train in the real world and suggest that VR technologies can be useful for providing just in time training anywhere, anytime, in a global market where employees are increasingly cross-cultural and dislocated.

KEYWORDS
non-WEIRD sample, safety training, simulation, virtual learning, virtual reality

1 | INTRODUCTION

Confronting a vast array of economic, global, technological, and labour market issues, today’s organizations are tasked with a difficult mission to develop effective, yet efficient training programmes to educate, inspire and retain their workforce. At the same time, they face the daunting challenge of maintaining high engagement and motivation of a new generation of employees, who are increasingly...
et al., 2021). Thus, companies are challenged with the task of administering standardized training, across a broad range of geographic locations, with an increasingly global and diverse group of trainees (O’Leary & Cummings, 2007). A standard solution to have trainers/trainees travel to conduct/receive training is not sustainable due to the high cost, both in terms of economy and energy (O’Brien & Aliabadi, 2020). Market analysis show that in 2019 the total training expenditures in the United States alone reached $83 billions of which $23 billions was spent on travel costs, and similar expenditures have been reported for 2020 (Statista, 2020). Furthermore, the COVID-19 pandemic has brought about an abrupt and critical need to create flexible learning and work environments that rethink the way we communicate by using fluid pedagogical practices and incorporating technology (Bailenson, 2021; Greenhow & Lewin, 2021). While the pandemic has accelerated the need to rely on digital solutions for training, a vast array of benefits including, but not limited to, reduced cost of training (O’Brien & Aliabadi, 2020), higher flexibility and standardization (Hertel et al., 2017), just-in-time training (Ahmad et al., 2020), employee centred training (Berkley & Kaplan, 2019), and reduced negative environmental impact (O’Brien & Aliabadi, 2020) suggest that the digitalization of organizational training is here to stay.

Although digital solutions provide numerous advantages, a challenge with many online meeting forums such as Zoom, which are increasingly used as training platforms, is that the social and environmental presence that trainees experience through real world interactions is difficult to replicate (Bailenson, 2021). Immersive virtual reality (VR) on the other hand has the unique affordance of virtually transporting trainees to a specific world or scenario that has a high level of psychological fidelity (Bailenson, 2018), that is, ‘an environment in which the sensory information is compelling enough to create perceptions of being physically present in the environment’ (Ryan et al., 2019, p. 18). This allows for interactive and experiential training, where trainees can rehearse specific sequences with high resemblance to their real-world counterparts and learn from their mistakes by receiving immediate feedback (Feng et al., 2018). Furthermore, it removes traditional time and location constraints, making learning possible to anyone, anywhere, anytime (Ryan et al., 2019). However, although research related to the effectiveness of VR training in general and safety training, specifically, is rapidly increasing, little is known about how such programmes would work with employees from non-Western, Educated, Industrialized, Rich, and Democratic (WEIRD) populations (Henrich et al., 2010). Studies with non-WEIRD samples in realistic training settings are thus needed to ensure that the value of VR-based educational and training experiences is investigated to ensure that VR is accessible to diverse populations (Mado et al., 2021; Stanney et al., 2020).

In this article, we explore a growing paradigm in organizational training and development by investigating the value of a VR-based safety training by comparing it to standard training solutions in the maritime industry. Specifically, we investigate the function of such training programmes with seafarers from the Kiribati Islands, which is among the 47 least developed countries in the world according to the United Nations (United Nations, 2020). We have chosen to focus on employee safety training within the maritime industry, because the maritime industry has the fundamental challenge of having geographically dispersed employees with diverse cultural backgrounds, while at the same time it is responsible for ensuring that safety knowledge and skills on board all vessels live up to international standards. Thus, just-in-time safety training with realistic environments is relevant in this industry.

Taking this as a point of departure, the main research question investigated in this article is:

Research question 1: Is VR-based safety training superior to standard safety training for a non-WEIRD sample of professional seafarers?

There is mounting evidence that the efficiency of VR-based learning and training interventions is related to the method by which VR simulations are implemented (e.g., Klingenberg et al., 2020; Makransky, Andreasen, et al., 2020; Meyer et al., 2019; Petersen et al., 2020). More specifically, studies suggest that combining VR with a generative learning strategy that allows students to reflect over the material after the lesson can increase learning outcomes (e.g., Klingenberg et al., 2020; Makransky, Andreasen, et al., 2020; Parong & Mayer, 2018). Furthermore, a criticism of VR-based cross media experiments is that conclusions greatly depend on the media which is selected as the control condition.

To address these concerns, we conducted a pilot study with maritime students prior to conducting the main study with the non-WEIRD sample of seafarers to investigate the following research questions:

- Research question 2a: Are there significant differences between a stand-alone VR safety simulation and the same VR simulation followed by a reflection activity?
- Research question 2b: Are there significant differences between a safety training administered through a personal trainer or a manual?

2 | LITERATURE REVIEW

In the following sections, we will describe challenges related to safety training in the maritime industry. We then elaborate on the rationale for employing VR-based safety training and why assessing the value of such training experiences with non-WEIRD samples is particularly important in this field. Based on these considerations, we finally present theoretical frameworks that have informed our choice of instructional design in the VR simulation, and highlight ways in which this addresses current challenges in maritime safety training.

2.1 | Safety training in the maritime industry

Since 1945, international trade has experienced an explosive growth. About 11 billion tons of goods are transported by ship each year and in
2019, the annual world shipping trade exceeded a total value of 14 trillion US Dollars (International Chamber of Shipping, 2021). This has made international shipping responsible for transporting approximately 90% of world trade (Dobie, 2020). Nonetheless, while the growth is predicted to continue in the forthcoming years, a general decrease in the number of crew members on-board vessels has been observed (Turan et al., 2016). This places extra demands on the individual crew member and can potentially lead to situations prone to human error, which is estimated to be a contributing factor in 75%–95% of marine incidents (Dobie, 2020). Therefore, it is no surprise that in a recent report, the Maritime Training Insights Database (2020) considers ‘reducing accidents’ and ‘improving safety performance’ as two main drivers of maritime training.

From an employee perspective, seafarers perceive the quality of their training onboard to be significantly less than optimal (Maritime Training Insights Database, 2020). This draws attention to a transfer problem, that is, that participating in safety training by no means guarantees that it is effective in improving safety (Krauss et al., 2014). One explanation is that, currently, safety training is often delivered through standard training courses which use one-size-fits-all methods, without assessing individual needs or providing the opportunity for users to experience the immediate relevance of the training material (Ricci et al., 2016). Another is that traditional training methods have a low level of physical and psychological fidelity, which contributes further to the creation of a transfer gap (Makransky, Borre-Gude, & Mayer, 2019). This may advance the compartmentalization of safety, that is, that safety is viewed as separate from the operation and not related to daily work procedures, which can lead to diffusion of responsibility for safety (Turan et al., 2016). Furthermore, a majority of operators rely on in-person and work-based training assessment and 21% of the responding operators do not assess training outcomes at all (Maritime Training Insights Database, 2020). We address these concerns by assessing the effect of a user-centred VR maritime safety simulation on the topic dynamic risk assessment during a mooring operation on board a vessel and compare it to standard training methods.

### 2.2 The relevance of VR in safety training

Krauss et al. (2014) highlight several features that can positively affect safety training outcomes including employee characteristics (e.g., motivation, self-efficacy, beliefs, values), instructional design characteristics (e.g., interactive and experiential training), commitment of the management and opportunities to apply the learned material immediately following training. This is supported by a meta-analysis by Burke et al. (2006), which found that engaging training was roughly three times more effective in fostering safety training knowledge and skill acquisition compared to non-engaging training. In effect, more engaging training methods are expected to improve knowledge acquisition and transfer as well as the development of anticipatory thinking (Burke & Sockbeson, 2015).

VR-based simulations are highly engaging because they promote a high level of the psychological presence (the feeling of ‘being there’ in the virtual environment; Lee, 2004) and agency (experience of controlling one’s own actions, Makransky & Petersen, 2021). Through a head-mounted display (HMD) that renders the virtual environment stereoscopically, it is possible to create highly complex and realistic representations of real-world scenarios that are too difficult, expensive, or dangerous to produce in real life (Dalarno & Lee, 2010). This can provide familiarity with the associated real-world environment and eliminate potentially distracting variables (Renganayagalu et al., 2021).

Within recent years, an increasing number of large companies have begun to explore the vast number of opportunities offered by VR for corporate training, for example, Wallmart, Verizon (Bailenson, 2020), and VR simulations are increasingly used in different areas of safety training, including construction safety training (e.g., Li et al., 2018), medical training (e.g., Andreatta et al., 2010), fire and rescue training (e.g., Cohen-Hatton & Honey, 2015; Saghafian et al., 2020) and maritime safety training (e.g., Markopoulos et al., 2019; Markopoulos et al., 2020; Markopoulos & Luimula, 2020). Thus, recent systematic reviews of VR for professional training conclude that VR is particularly useful for safety training because it provides the opportunity for trainees to practice procedures immediately and in a safe environment (Grassin & Laumann, 2020; Naranjo et al., 2020), and it provides meaningful, contextual, and situated learning experiences that increase learning engagement and motivation (Renganayagalu et al., 2021; two factors important for safety training according to Burke et al. (2006). Furthermore, empirical studies and reviews on VR training suggest that the affordances of the medium can increase engagement (Buttussi & Chittaro, 2021; Di Natale et al., 2020; Makransky, Petersen, & Klingenberg, 2020), knowledge retention (Bacevic-Lopez-Cordoba, Wismer, et al., 2021; Buttussi & Chittaro, 2021; Chittaro & Buttussi, 2015), safety behaviour (Makransky, Borre-Gude, & Mayer, 2019) and transfer (Buttussi & Chittaro, 2021; Checa & Bustillo, 2020; Stevens & Kincaid, 2015). In this way, VR encompasses several affordances that enhance safety training outcomes according to Krauss et al. (2014).

### 2.3 The importance of non-WEIRD samples

Data in the behavioural sciences are dominated by samples drawn from WEIRD populations. In fact, Henrich et al. (2010) report that 96% of psychological samples come from countries representing only 12% of the world’s population. Not only are these samples not representative of the worlds’ population, according to Henrich et al. (2010) ‘WEIRD subjects are particularly unusual compared with the rest of the species’ (p. 61). More recent examinations suggest that these empirical patterns persist (Apicella et al., 2020), which once again actualizes questions regarding the generalizability of previous research findings and accentuate the need for studies with diverse non-WEIRD populations (Henrich et al., 2010).

This is particularly relevant within the area of organizational training, where employees in a global sector such as the maritime industry are cross-cultural, and crews are on board vessels in different parts of the world. According to the International Chamber of Shipping (2022), ‘The world fleet is registered in over 150 nations, and manned by over
a million seafarers of virtually every nationality’. With the five largest supply countries for all seafarers being China, the Philippines, Indonesia, the Russian Federation and Ukraine, it is important that studies investigating safety training in this industry do so with non-WEIRD samples.

Apart from being relevant in the maritime industry, this is of high importance in the field of technology. Linxen et al. (2021) describe how computer technology is often designed in technology hubs in Western countries, invariably making it WEIRD. In their review of papers published in the proceedings of the 2021 CHI Conference on Human Factors in Computing Systems they find that 73% were based on Western participant samples. Looking at a recent review on industrial VR training by Naranjo et al. (2020), we found that 54% of the included papers consisted of purely technological contributions, without testing a human sample. Of the 20 papers that did include human testing, most of them focused on usability testing and well-explored samples such as students from Western societies. Furthermore, only a handful of the 20 papers included testing in a high-ecology experimental setting, such as integrated training connected to the workplace (Naranjo et al., 2020). This highlights the importance of using non-WEIRD samples within actual organizational contexts when investigating the value of VR-based training.

2.4 | Designing effective training in VR

There is increasing evidence that the efficiency of VR-based learning and training interventions is related to how the VR simulations are designed (e.g., Bacevic et al., 2021; Bower & Jong, 2020; Cavalcanti et al., 2021; Makransky, Borre-Gude, & Mayer, 2019; Makransky & Petersen, 2021; Parong & Mayer, 2018; Petersen et al., 2020, 2022). Therefore, we developed the VR-based safety training simulation using best practice instructional design principles from multimedia learning (Mayer, 2014), and immersive media (Makransky & Petersen, 2021). In addition, we used Burke and Sockbeson’s (2015) worker characteristic-work criteria-work context framework for safety training, which highlights dependent variable categories that affect safety training interventions.

The Cognitive Affective Model of Immersive Learning (CAMIL) offers an evidence-based framework for creating VR learning experiences (Makransky & Petersen, 2021). According to CAMIL learning in VR can be enhanced if effective instructional methods take advantage of the technological affordances of the medium. CAMIL identifies two general psychological affordances of VR: presence and agency which are positively influenced by technological factors such as immersion, control factors and representational fidelity (Makransky & Petersen, 2021). Furthermore, presence and agency can influence learning, behavioural change, and performance through a number of cognitive and affective factors such as interest, intrinsic motivation, embodiment, and cognitive load (Makransky & Petersen, 2021). Therefore, CAMIL predicts that a higher level of presence and agency allows VR training simulations to closely mimic realistic training scenarios, thereby allowing trainees to construct knowledge based on realistic interactions with the environment.

While CAMIL provides a theoretical perspective for understanding and assessing the benefits of technology-based training, other theoretical models are related specifically to safety training. According to Burke and Sockbeson’s (2015) framework, safety performance that workers engage in, that is, the work criteria, can be viewed with respect to safety compliance, which refers to the expected safety behaviours; safety participation, which refers to actions of a more discretionary nature and safety outcomes, which refers to consequences of unsafe work such as accidents, injuries etc. Safety training interventions can furthermore be directed at different worker characteristics. These can be broadly classified as either safety knowledge, understood as the factual, declarative, and procedural knowledge that the training is aimed at, or safety motivation, referring to interventions aimed at modifying the effort workers are exerting to engage in safe work behaviour, such as self-efficacy and confidence. Situational characteristics that might moderate the effects of safety training is suggested to be safety climate, workplace hazards and cultural characteristics.

We designed the VR training content based on these models which are described in more detail in the Methods section. Furthermore, we used these models to assess important training process and outcome variables including enjoyment, intrinsic motivation, self-efficacy, extraneous cognitive load, reflection, perceived learning, safety attitudes and expected behavioural change in this study, which we will elaborate on in the following:

Research on learning in VR suggests that the increased opportunities to practice in VR, can enhance learning transfer (e.g., Schank, 2005; Zwaan, 2005) and Burke and Sockbeson (2015) found that different worker characteristics including safety knowledge and safety motivation are key factors for the transfer of training (Grossman & Salas, 2011). To address transfer, we measured behavioural change, which in this study can be defined at the trainee’s intentions to change safety behaviour. Furthermore, we measured motivational and affective factors, including safety attitudes, enjoyment, motivation, and self-efficacy, which have been shown to be important for transfer of training (Blume et al., 2010; Burke & Hutchins, 2007; Burke & Sockbeson, 2015; Krauss et al., 2014). Safety attitudes are known to affect transfer of learning (Gegenfurtner et al., 2009) and behaviour (Ajzen, 1991). Enjoyment and intrinsic motivation are also factors important for learning (Pekrun, 2006) and empirical research comparing learning through VR to learning through less immersive media have found lessons in VR can lead to higher levels of enjoyment and intrinsic motivation (e.g., Makransky & Lilleholt, 2018; Meyer et al., 2019). Similarly, a range of empirical studies have demonstrated that self-efficacy, defined as one’s perceived capabilities for learning or performing certain actions (Bandura, 1977), can be increased through VR-based lessons because learners are given immediate feedback to realistic training scenarios (e.g., Buttussi & Chittaro, 2018; Klingenberg et al., 2020; Makransky, Andreassen, et al., 2020). This is also supported by studies on safety training, which compare VR with a less immersive media (e.g., Lovreglio et al., 2020; Nykänen et al., 2020). Additionally, we measured extraneous cognitive load, which is influenced by the instructional design and therefore, has been identified as a factor particularly important for learning in VR, where both the learning content and the media might be novel (Makransky & Petersen, 2021).
3 | PILOT STUDY

A pilot study was used to investigate research questions 2a and 2b with the objective of identifying the best virtual and standard training method. In the pilot study, we randomly assigned trainees to one of four conditions: (1) A training manual, (2) Personal trainer instruction, (3) A stand-alone VR simulation (VR), and (4) A VR simulation followed by reflection with a personal trainer (VR Reflection).

3.1 | Participants

The sample in the pilot study consisted of 86 students (18 female, 67 male, 1 non-binary). They were from a vocational school (n = 18) or first year students at Svendborg International Maritime Academy (SIMAC) which is Denmark’s largest maritime education centre (n = 68). Most of the students ranged in age from 16 to 34, while three were above 40 (Mdn = 22). A total of 42 (48.8%) responded that they had never experienced using a VR headset, 35 (40.7%) reporting using VR for less than 2 h, and 9 (10.5%) had used VR for more than 2 h.

3.2 | Procedure

The experiment was implemented as part of students’ safety training in dynamic risk assessment on board a vessel on the topic of safety during a mooring operation. It took place over the course of 2 days with participants entering in groups of eight students at a time. The procedure for all groups followed the same set up and took approximately 1 h to complete. An overview of the experimental procedure and the four conditions is provided in Figure 1.

Initially, participants received a common oral introduction. They were informed that they would be learning about dynamic risk assessment as part of a research study and therefore were expected to respond to several surveys during the lesson. They were then asked to sign a consent form which made it clear that their data was gathered anonymously and that they could withdraw from the experiment at any time. Students were then given a random ID-number, which blindly assigned them to one of the four experimental conditions: training manual (n = 17), personal trainer instruction (n = 21), VR (n = 23), or VR followed by a reflection exercise (n = 25). Then, they were given the link to the pre-test, which they completed on their own laptops. For the main part of the experiment, participants were separated into four different rooms (one for each condition) to avoid distractions and to ensure that they were blind to the other conditions. Specific precautions regarding the COVID-19 pandemic including wearing face masks and disinfecting the HMDs with CLEANBOX technology were taken.

3.3 | The four conditions

The training material consisted of four versions of a dynamic risk assessment training on the topic of safety in a mooring activity on board a vessel (manual, personal trainer, VR, and VR Reflection). Extreme care was taken to ensure that the training material included identical information.

3.3.1 | Manual condition

Participants in the manual condition were asked to study a safety training manual individually. The manual was composed of screen shots from the VR simulation with explanations of the content. It consisted of the same information as the VR simulation in order to maintain consistency across conditions. This condition mimicked a scenario that is currently the most common training method in the industry, where trainees are provided with manuals related to risk assessment and training and are asked to learn the material on their own.

3.3.2 | Personal trainer condition

In this condition, a trainer well-known to the students presented a power point slide show with the same pictures and information used in the manual to ensure consistency across conditions. Students were given the personal training two to four trainees at a time. During the training lesson, they were able to ask questions and discuss the topics in more detail. This was designed to mimic a personal training situation where an expert could introduce trainees to the topic in detail.

3.3.3 | VR condition

In this condition, participants engaged in the VR simulation described below. This condition was designed to mimic a scenario where trainees had access to a stand-alone VR training simulation, without access to assistance or help from a professional trainer, which is a scenario that would be practical on-board vessels in the maritime industry. It reflects a situation in which HMDs could be readily available making just-in-time training possible anywhere, anytime.

3.3.4 | VR Reflection condition

Trainees engaged in the VR simulation as described in the previous condition. However, in addition they were able to reflect over the training material in a semi-structured session with a teacher from the school. It was structured around four slides with screen shots from the simulation identifying the safety hazards that the trainees had encountered in the simulation. The reflection activity gave trainees an opportunity to discuss the dynamic risk situations: how they dealt with them in the simulation and how they would deal with them in a realistic scenario. This condition was designed to mimic a scenario where trainees could access professional help after having engaged in the VR simulation. An example would be on board a vessel where a
captain or another responsible person could provide additional support following the training, for example by acting as an instructor who helps the trainee reflect over the content of the simulation.

3.4 | The simulation

The VR simulation was administered on Oculus Quest HMDs and developed in Unity 2020. Interactivity in the simulation occurred through movements of the head and use of controllers. The simulation was designed as a collaboration between the experts from a VR development company, an international shipping company, a maritime education academy and the research team from a large European University to ensure that important work criteria were considered. The simulation was targeted individual dynamic risk assessment during a mooring operation, that is, when the vessel is secured to a permanent structure such as a quay or a pier on the shore.

The simulation was designed based on multimedia design principles (Makransky, 2021; Mayer & Fiorella, 2021), and to mirror the recent change in safety training focus from what can go wrong to making sure things go right. Therefore, it was structured around abilities which can be considered the functional cornerstones of resilience (Hollnagel, 2011). This includes being able to anticipate (events beyond the current operation) monitor (know what to focus on and perceive changes in performance and environment), react (successfully detecting, recognizing, and assessing events in time) and learn (promote, facilitate, and enhance learning from experience). The learning goals of the safety training simulation were therefore being aware of potential dangers, recognizing signs of dangers in varying conditions, responding to dangerous situations, and learning from the outcome of actions during a mooring operation.

Participants experienced the simulation from a first-person perspective. Upon entering the virtual environment, they found themselves in a classroom setting. Here, they received general instructions explaining the purpose of the training as well as practical information regarding the forthcoming exercise from a virtual instructor. They were also introduced to the equipment that they would use in the scenario (see left panel of Figure 2 for a screen shot from the initial training phase). This included how to use a radio to communicate, how to operate a winch, which is used to control the tension on the mooring line by pulling the controller forwards or backwards, and how to use a hand signal to indicate danger and alert other crew members.
In the main scenario, participants were placed on a deck from where they had to lead the mooring operation. During this part of the simulation, they had to follow the operation and make sure procedures were carried out correctly and safely as they were responsible for directing other crew members on board the vessel. First, participants were instructed by the captain to observe conditions and surroundings to react in time through radio communication and communication with colleagues on deck (see middle panel of Figure 2) and on the quay. For instance, they had to notice changing weather conditions such as increasing wind to predict that this could result in an increased tension of ropes that could potentially burst. A bursting rope is a safety threat, and the responsible person must therefore adjust the ropes to keep them from bursting. At the same time, he or she must make sure their employees are out of the way to keep them from being hit if the ropes burst. Thus, the simulation was designed to make participants anticipate, monitor, and react to specific dangers such as crew members not wearing appropriate personal protective equipment (PPE), watch out for bights, and ensure that crew members are not in the snap back zone (see right panel of Figure 2 for a screenshot of a crew member being injured because they were in the snap back zone during a rope burst). The participants had to monitor these different safety risks while being responsible for sending in the lines. If failing to do these things, participants would experience the consequences of poor safety performance. Ultimately, severe failures resulted in fatal consequences and the simulation would end. However, if participants successfully managed to anticipate, monitor, react and learn the required safety procedures, they would finally return to the virtual classroom setting, where an instructor summarized key concepts from the safety training lesson and participants were able to reflect on their performance.

3.5 | Pre- and post-test measures

The pre-test questionnaire measured demographic characteristics (age, gender, degree programme and educational level), experience using VR, and prior knowledge. The post-test consisted of scales measuring enjoyment (Tokel & Islar, 2015); intrinsic motivation (Deci et al., 1994); self-efficacy (Pintrich et al., 1993); extraneous cognitive load (Andersen & Makransky, 2020), safety attitudes (Lu & Tsai, 2008), perceived learning (Lee et al., 2010), and behavioural change (Baceviciute, Lopez-Cordoba, Wismer, et al., 2021). A complete list of items is available in the Appendix S1. All items were on 5-point Likert scales ranging from (1) strongly disagree to (5) strongly agree.

3.6 | Pilot study results

One-way ANOVAs indicated that the groups did not differ significantly on age, $p = 0.784$; prior knowledge, $p = 0.525$; or experience with VR, $p = 0.278$. Furthermore, a chi square test indicated that the groups did not differ significantly on gender, $p = 0.676$.

3.6.1 | Research question 2a: Comparing VR and VR reflection conditions

The left columns of Table 1 provide the means and standard deviations for VR and VR reflection conditions on all outcome variables used in the study. Non directional independent samples t-test indicated that students in the VR condition reported significantly higher intrinsic motivation $t_{(46)} = 2.667$, $p = 0.011$, $d = 0.79$, and self-efficacy $t_{(46)} = 2.312$, $p = 0.025$, $d = 0.67$, compared to the VR reflection condition. The differences between the groups on the other five outcome variables were not significant (see Table 1). The VR condition without reflection will therefore be used in the main study to investigate research question 1.

3.6.2 | Research question 2b: Comparing manual and personal trainer conditions

The right columns of Table 1 provide the means and standard deviations for manual and personal trainer conditions on all outcome variables used in the study. Non-directional independent samples t-test indicated that students in the personal trainer condition reported significantly higher...
TABLE 1  Pilot study means, standard deviations, two tailed p-values, and effect sizes for the outcome variables included in the study

<table>
<thead>
<tr>
<th>Outcome</th>
<th>Virtual training comparisons</th>
<th>Standard training comparisons</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>VR</td>
<td>VR reflection</td>
</tr>
<tr>
<td>Enjoyment</td>
<td>4.36 (0.70)</td>
<td>4.07 (0.59)</td>
</tr>
<tr>
<td>Intrinsic motivation</td>
<td>4.17 (0.53)</td>
<td>3.67 (0.73)</td>
</tr>
<tr>
<td>Self-efficacy</td>
<td>3.99 (0.63)</td>
<td>3.55 (0.68)</td>
</tr>
<tr>
<td>Cognitive load</td>
<td>2.10 (0.92)</td>
<td>2.36 (0.90)</td>
</tr>
<tr>
<td>Safety attitudes</td>
<td>4.20 (0.64)</td>
<td>3.96 (0.72)</td>
</tr>
<tr>
<td>Perceived learning</td>
<td>4.14 (0.72)</td>
<td>4.04 (0.63)</td>
</tr>
<tr>
<td>Behavioural change</td>
<td>3.96 (0.79)</td>
<td>3.88 (0.63)</td>
</tr>
</tbody>
</table>

Bold values represent significant differences (alpha = .05).
Abbreviation: VR, virtual reality.

FIGURE 3  Illustration of main study research design

enjoyment, $t_{36} = 2.123$, $p = 0.041$, $d = 0.68$; self-efficacy, $t_{36} = 2.198$, $p = 0.034$, $d = 0.72$; safety attitudes, $t_{36} = 2.424$, $p = 0.021$, $d = 0.78$; perceived learning, $t_{36} = 2.139$, $p = 0.039$, $d = 0.69$; behavioural change intentions, $t_{36} = 2.905$, $p = 0.006$, $d = 0.95$; and significantly lower extraneous cognitive load, $t_{36} = -2.609$, $p = 0.013$, $d = 0.84$, compared to the manual condition. The differences between the groups on intrinsic motivation was not significant. The personal trainer condition will therefore be used in the main study to investigate research question 1.

4 | MAIN STUDY

The main study was used to investigate research question 1 by comparing the VR-based safety training to the personal training condition in a non-WEIRD sample of professional seafarers.

4.1 | Participants

The sample consisted of 28 male participants, who were all crew members with several years’ experience working on a vessel (20 had over 5 years, four had between two and 5 years, and four had between 1 and 2 years of experience). All had previously participated in a mooring activity; eight in the role of the responsible person and 20 as crewmembers. Participants were between the ages of 24 and 65 years ($Mdn = 35$). All crewmembers were from the Kiribati Islands, and the training took place as part of a formal training at the headquarters of an international maritime training organization. None of them reported having used VR for more than 2 h, 6 (21%) reported having used it but for less than 2 h, and 22 (79%) reported never having used VR before. The technological readiness of the sample was generally low. This was exemplified in trainees needing technical support to turn on and use the tablets that were used for the surveys.
4.2 | Procedure

Overall, the experimental procedure resembled the procedure in the pilot study. However, only two experimental conditions were implemented: VR (n = 15) in which participants engaged in the VR safety simulation, and personal trainer instruction (n = 13) in which participants were trained in groups of 2-4 by an experienced trainer from the international training organization (see Figure 3). The surveys were administered on iPads supplied by the organization.

The experiment was conducted over the course of 1 day with participants entering in groups of up to eight at a time. The procedure for all groups followed the same set up as in the pilot study (see Figure 3 for an overview). Following an oral introduction, participants completed an online pre-test. Based on their random assignment to one of the two experimental conditions, they were led to different rooms, where they engaged in the safety training. Then, participants were asked to complete an online post-test. Specific precautions regarding the COVID-19 pandemic were taken during the entire experiment. The entire procedure took approximately 1 h.

4.3 | Materials

The VR safety simulation used in the main study was identical to the one used in the pilot study (see above for a description). The pre-test questionnaire measured demographic characteristics (age and gender), experience working on a vessel, experience with mooring operations, and experience using VR. The post-test included the same items as in the pilot study (see list of items in Appendix S1).

4.4 | Main study results

Independent samples t-tests indicated that the groups did not differ significantly on age, \( p = 0.053 \); prior knowledge, \( p = 0.848 \); or experience with VR, \( p = 0.291 \). Table 2 provides the means and standard deviations for the VR and personal trainer conditions for all outcome variables used in the study. Independent samples t-tests indicated that the VR group (\( M = 4.58, SD = 0.54 \)) reported enjoying the training significantly more than the personal trainer group (\( M = 3.85, SD = 0.60 \)), \( t_{(26)} = 3.384, p = 0.002, d = 1.28 \). Similarly, the VR group (\( M = 4.47, SD = 0.58 \)) reported significantly higher intrinsic motivation related to safety training than the personal trainer group (\( M = 3.83, SD = 0.76 \)), \( t_{(26)} = 2.508, p = 0.019, d = 0.96 \). The difference between the two groups on self-efficacy was not significant \( t_{(26)} = 1.600, p = 0.112, d = 0.61 \). Moving to Extraneous cognitive load, the VR group (\( M = 2.09, SD = 0.82 \)) reported significantly lower extraneous cognitive load compared to the personal trainer group (\( M = 2.64, SD = 0.52 \)), \( t_{(26)} = -2.089, p = 0.047, d = 0.82 \). However, the difference between the two groups was not significant for safety attitudes, \( t_{(26)} = 1.788, p = 0.085, d = 0.66 \). The difference did reach statistical significance, with the VR group reporting significantly higher perceived learning (\( M = 4.53, SD = 0.52 \)) than the personal trainer group (\( M = 4.15, SD = 0.32 \)), \( t_{(26)} = 2.288, p = 0.031, d = 0.90 \). Finally, the VR group scored significantly higher (\( M = 4.42, SD = 0.47 \)) than the personal trainer group (\( M = 3.92, SD = 0.66 \)), \( t_{(26)} = 2.294, p = 0.030, d = 0.88 \) on behavioural change.

5 | DISCUSSION

The aim with this study was twofold: to investigate the value of using VR-based training compared to standard training with a non-WEIRD sample (Research question 1), and to investigate ways in which such a training intervention is most effectively implemented based on seven variables of interest (Research question 2a and 2b).

Regarding our first research question, we found that employing a VR safety simulation among a non-WEIRD sample of professional seafarers resulted in significantly higher levels of enjoyment, motivation, perceived learning and behavioural change, and significantly lower cognitive load compared to a personal training procedure but the difference in self-efficacy between groups was not significant. Many of these findings are consistent with results from previous research studies with WEIRD samples that have compared learning in VR to standard procedures. Thus, our findings contribute to a growing pool of evidence suggesting that immersive VR simulations can lead to significantly higher enjoyment (e.g., Cavalcanti et al., 2021; Makransky & Lilholt, 2018; Meyer et al., 2019); intrinsic motivation (Dalgarno & Lee, 2010; Makransky, Borregude, & Mayer, 2019; Sanchez-Sepulveda, Fonseca, et al., 2019),...
behavioural change (Makransky, Borre-Gude, & Mayer, 2019; Mottelson et al., 2021; Vandeweerdt et al., 2022) and perceived learning (e.g., Hamilton et al., 2021; Makransky & Lilleholt, 2018; Wu et al., 2020) compared to training methods using less immersive media. Importantly, the results suggest that the positive outcomes of learning with VR simulations, identified in the studies referred to above as well as recent meta-analyses (e.g., Luo et al., 2021; Wu et al., 2020), are not limited to WEIRD samples.

Not all research points to the positive outcomes of VR-based interventions. For instance, a recent review on VR serious games reports that only 30% of the included studies find that VR enhances interventions (Checa & Bustillo, 2020) and a study by Leder et al. (2019) specifically related to safety training found that VR-based safety training was less effective than a PowerPoint lesson (Leder et al., 2019). Thus, our results specifically highlight the importance of using evidence-based instructional design principles in a developing immersive simulations. This is theoretically supported by the Immersion Principle of Multimedia Learning (Makransky, 2021) which states that immersive virtual environments promote better learning when they incorporate multimedia design principles. That is, immersive media do not necessarily improve learning but effective instructional methods within immersive virtual environments do improve learning.

The finding that no significant difference in self-efficacy between conditions was observed stands in contrast to previous research that suggests VR simulations increase self-efficacy more than standard methods (e.g., Buttussi & Chittaro, 2018; Klingenberg et al., 2020; Makransky, Andreassen, et al., 2020). Several differences between our main study and previous studies could account for this discrepancy: First of all, our sample was non-WEIRD, which may have affected trainees’ self-reported answers (Henrich et al., 2010). Furthermore, the study was conducted with professional seafarers, who had significantly higher mean self-efficacy scores ($M = 4.35$, $SD = 0.52$), compared to the students in the pilot study ($M = 3.76$, $SD = 0.69$), $t_{(112)} = 4.149$, $p < 0.001$. This indicates that the seafarers had a high initial level of self-efficacy based on actual experience on board a vessel, making the effect of a single training intervention less impactful than for a student sample. In accordance with previous research, this indicates that level of professional experience may influence VR-based outcomes (Sanchez-Sepulveda, Torres-Kompen, et al., 2019).

In contrast to previous findings comparing VR to less immersive media (e.g., Makransky, Terkildsen, & Mayer, 2019; Parong & Mayer, 2021), participants in the VR condition reported lower extraneous cognitive load than participants in the personal trainer condition. One explanation of the finding could be that the VR simulation was learner-paced meaning that trainees could control the pace of the lesson through their interactions, whereas the personal training took place in groups of two to four, making it more instructor paced. This emphasizes affordances of VR, such as the opportunity for creating individualized, immersive, and interactive content, which allows for ‘learning by doing’ (Cavalcanti et al., 2021; Renganayagalu et al., 2021). This may be specifically relevant for the non-WEIRD sample of seafarers who were not as accustomed to traditional training methods as the students at the maritime school, and who, due to their experience at sea, may have found it easier to relate the content of the simulation to real life scenarios. Thus, results from this study point to the many opportunities offered by VR in training, and opens the doors to exploring these effects with a diverse group of users in the future.

In regard to our second research question, concerning best practices for implementing VR-based training, some important empirical contributions can also be inferred. The finding that the VR simulation that was used alone was just as effective as when the VR simulation was used in conjunction with a follow-up reflection exercise in the pilot study provides some support for the viability of using VR broadly. It suggests that embedding generative learning strategies such as reflection exercises within the simulation can promote the successful implementation of VR-based training. Furthermore, it underscores importance of the relationship between learning content and choice of design when developing VR simulations for training (Makransky & Petersen, 2021; Radianti et al., 2020), and highlights the importance of iterative feedback from users and designers during the development process. In this study, this was made possible by developing the VR simulation through a collaboration between experts within the domains of instructional design, technological development, and maritime safety training.

5.1 | Practical implications

The finding that VR training was superior to the personal trainer condition in the main study is promising. Firstly, because the main study was conducted as part of a real training intervention within an organizational context, which echoes Radianti et al. (2020) call for more VR-based research that is integrated within actual interventions. Secondly, because it was conducted with a non-WEIRD sample of employees from a country on UN’s list of the 50 least developed countries who did not have a high level of technology literacy. As an example, several seafarers needed help to begin the pre-test survey on an iPad because they were not familiar with the technology. Nonetheless, after a brief introduction to the controls and the HMD, it was surprising to see how quickly the seafarers adapted to the scenario and interacted naturally with the virtual environment. The successful implementation of the VR simulation highlights the potential immersive technologies have with a broad range of users in the future. This is becoming relevant with digitalization of education and training, and the continuing development of online platforms, such as the Metaverse, which will likely improve remote collaboration in the future (Gartner, 2022; Kelly, 2022).

Furthermore, this article highlights the benefits of using VR in future maritime safety training, where relevant stakeholders may take advantage of its ability to create situated learning experiences in a safe environment. Besides being a cost-effective way of administering standardized training across a broad range of geographic locations, it may reduce the current transfer gap in safety training by making training available to anyone, anywhere, anytime (Ryan et al., 2019). Furthermore, the finding that a VR simulation can increase enjoyment and motivation is consistent with expectations employees in the
5.2 | Limitations and future research

Although the results of this study are promising, several limitations and future research directions should be highlighted. One limitation in this study was the inability to test the training on board a vessel. From an organizational training perspective, the ultimate goal would be to have VR headsets on board vessels for just in time training. Future studies should therefore investigate the potential of using VR simulations on location rather than in formal training centres as in this study. Furthermore, it was not possible to assess actual safety behaviour on board a vessel in a real mooring scenario in this study due to practical and ethical considerations. Although intentions are considered antecedents of actual behaviour (Ajzen, 1991), research has consistently shown that people do not always follow their intentions (Sheeran & Webb, 2016). Previous studies have found that VR safety training simulations as superior to traditional training methods when assessed in terms of actual safety behaviour in a realistic environment (e.g., Makransky, Borre-Gude, & Mayer, 2019). Nevertheless, future studies should attempt to investigate the effect of VR safety simulations on actual safety behaviour and transfer of training.

The finding that a reflection activity did not improve training outcomes following the VR simulation suggests that it was possible to introduce generative learning activities within the VR simulation. This finding is promising and highlights the need to conduct more research related to instructional design features that can improve learning and training outcomes in immersive simulations. In general, more research is also needed to investigate if the mounting evidence related to using VR simulations in education and training generalizes to non-WEIRD samples.

6 | CONCLUSION

This article demonstrates the value of VR-based safety training by comparing it to standard training solutions in the maritime industry. In a pilot study, students from a maritime school engaged in training either through a manual, a personal trainer instruction, a VR simulation, or a VR simulation followed by reflection on the topic of dynamic risk assessment during a mooring operation. Results showed that personal trainer instruction was superior to a manual, and that when reflection was already embedded into a VR simulation, adding a post-simulation reflection exercise did not further improve training outcomes. Based on our findings from the pilot study, we employed two conditions (personal trainer instruction and VR) in a main study on maritime safety training with a group of experienced seafarers from the Kiribati Islands, which is among the 47 least developed countries in the world according to the United Nations (2020). Results demonstrated that the VR simulation group had significantly higher levels of enjoyment, motivation, perceived learning and behavioural change intentions and significantly lower extraneous cognitive load compared to personal trainer instruction. This indicates that VR has potential benefits over standard training solutions and is effective in delivering training to a non-WEIRD population with limited technological experience. To conclude, this research draws attention to the prospects of immersive technologies not only as potential viable solutions for future organization training, where flexible, standardized, cost efficient, just-in-time training solutions are needed, but also as an emerging media that can be employed with a broad range of users.

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

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DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available on request from the corresponding author.

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**SUPPORTING INFORMATION**

Additional supporting information may be found in the online version of the article at the publisher’s website.

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