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OPTIMISING SAFE SYSTEMS OF WORK USING VIRTUAL REALITY (VR) TO ENHANCE RESCUE AND EVACUATION SKILLS

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Abstract

The ability to implement a safe system of work is an important skillset for everyday tasks, especially for wind technicians working at height in the renewables industry. An effective and safe control measure is critical to the success of every work at height activity. For wind technicians, the use of VR can potentially be deployed as a stop-gap tool useful for optimizing the retention of core rescue and evacuation skills. VR can serve as a useful tool for intermediate practice drills between formal two-year training as most technicians are unlikely to perform any emergency rescue within this timeframe. The significance of deploying a VR tool for promoting rescue and evacuation skill retention is based on the premise that the ability of humans to recall specific rescue steps may not be as strong as it is generally assumed. Therefore, this preliminary study designed a prototype VR rescue game using realistic graphics to add depth and realism to the game. The game is designed to be played by a single individual with gameplay averaging 5 - 10 minutes per session with purposive target audience (wind technicians, construction professionals, and students) required for user experience and usability testing. The VR simulation will serve as a useful source for reinforcing wind technician's hands-on rescue and evacuation skills, thus improving safe work practices.

Keywords: Virtual Reality (VR), Safe Systems of Work, Rescue and Evacuation, Work at Height.

1. INTRODUCTION

This study builds on applied human learning by exploring the integration of Virtual Reality (VR) hands-on practice for rescue and evacuation purposes for the wind industry. The premise of this study is that skill decay at all levels often involves knowledge and skills that were once mastered but ceased to be accessible because of non-routine practice and lack of appropriately timed retention [13]. Studies focusing on skill and knowledge retention have been on relatively simple tasks, e.g., where participants are required to recollect and recite memorized items from a list and, over time, begin to forget them [2]. However, to achieve an efficient safe system of work within the wind industry, it is pertinent to enhance rescue and evacuation skills through a routine process of practice and the adoption of VR is considered a viable option. This is significant as the learning and retention of the rescue and evacuation skills are complex discrete procedural skills. The knowledge of the device and associated steps required to holistically undertake successful rescue as opposed to simplified list learning is critical to keep afresh. Similar effects of forgetting can be seen in the works of [5] in the recall and performance of complex skills such as forgetting in a practicing physician, or skill decay in cardiopulmonary resuscitation [17].

The motivation for this study results from the practical problems associated with the retention of the work at height rescue and evacuation skills after periods of non-routine practice or training. It was recognized that technicians registered on the rescue and evacuation refresher training after 24 months struggled to remember much of the skills they learned over this period [12 & 13]. The refresher participants considered to have more knowledge and experience also struggled to perform reliably better on all rescue and evacuation safety critical tasks. Currently, there is no formal method in place by the wind industry to address this gap resulting from non-routine practice in terms of augmenting recue and evacuation skills using VR. The aim of this study is to explore if VR can potentially be deployed as a stop-gap tool useful for optimizing the retention of core rescue and evacuation skills of wind turbine technicians.

2. BACKGROUND

Rescue & Evacuation

Procedural tasks account for a significant proportion of wind technicians' rescue and evacuation task, and technicians often do not retain much of what they have learnt because of the length of time of non-routine practice of the rescue device, complexity of the rescue and evacuation device, amount and quality of initial height safety and rescue training, and amount and quality of experience acquired on-the-job. Rescue and evacuation practice are non-routine; however, wind technicians are expected to react correctly and with minimal errors when carrying out or implementing 'live' rescue in a dynamically changing situation. Kluge et al., (2009) stated that in past years, several accident reports in Europe and USA show that the risk of operator errors increases in non-routine situations which is considered to have some similarity to the current trend in the wind energy sector involving rescue and evacuation. Industries such as aviation, nuclear power plants and refineries with highly automated operations counter rescue and evacuation skills with refresher or recurrent training by asserting that refresher training is mandatory and these are regulated by law [3]. This is apparent because some form of skill rehearsal can moderate skill decay during longer periods of non-use [20]. Although these kinds of training dictate contents [3]; the time interval for skill refreshing [16] and training environments such as the usefulness of simulators [25]; lack specifics regarding the instructional methods most suitable for refresher training.

Previous study indicated that outcomes of wind technician's assessment at acquisition and one-month retention showed a statistically significant drop in mean performance scores. This suggests that skill decay actually does occur within 4 weeks after acquisition of rescue and evacuation training for wind technicians and after an extended period of time, skill decay becomes gradual [14]. This suggests that non-routine discrete procedural skills in operation and maintenance that are not practiced over a period of time are difficult to retrieve and the power law of forgetting confirms that over time, what is known decays at a negatively accelerating pace [27,28]. Another factor associated with this problem is that several types of equipment used in rescue and evacuation training skills are similar, but sometimes not identical to the equipment the wind technicians might end up using on the job. Therefore, in addition to memory loss, job performance may be further degraded if technicians have difficulty transferring skills learned during training to slightly different equipment design on the job. Ways to counter the loss of this discrete procedural rescue and evacuation skill could be by developing 'device-specific' training and instructional resources that are more resistant to forgetting and more likely to promote transfer of skills to similar tasks and devices, or the development and implementation of a VR training [12,13]. However, most literature are unclear about the best refresher training instructional methods and their implementation.

The use of actual performance data from VR training is considered a good strategy that could be useful for optimizing safe systems of rescue and evacuation procedures. A skilled wind turbine technician is expected to be able to perceive and encode the current situation as well as select and execute the correct rescue and evacuation actions of a series of actions rapidly and precisely during emergency situations, but this is not the reality with wind turbine technicians undertaking refresher training [12,13]. Therefore, in the absence of extensive deliberate practice and with the passage of time, technicians will struggle to be able to automatically evoke the correct reaction to familiar stimulus situations. According to [6]], the development of skills is induced by the environment, and only the skills induced most consistently will typically be at the highest level that the individual is capable of. One major factor that does inhibit deliberate practice by wind technicians can be associated with high operational deployment and their itinerant work pattern. This impinges on the available time to practice already acquired non-routine rescue and evacuation skills, thus resulting in less experience and difficulty dealing with the complexities of rescue and evacuation under intense pressure. Therefore, lack of hands-on rescue and evacuation experience with higher task complexity can leave technicians at all levels not only unable to make difficult, split-second decisions, but also unaware of the problems they face during such rescue and evacuation scenario. Hence, it can be speculated that practice brings improvement, and more practice brings more improvement while non-practice brings no improvement. Safe working at height all of which require robust procedures involve suitable and sufficient training, practice and experience.

Virtual Reality (VR)

VR is the simulation of the real world that allows participants to interact with the virtual assets and experience different degrees of immersion in the simulated environment [1]. These degrees of virtual immersion include non-immersive, semi-immersive, and fully immersive VR models [30]. The adoption of VR simulation involves the use of 3D or collaborative 4D objects and environments to create immersive and engaging learning experiences. There are existing suggestions that traditional safety training and delivery methods are not engaging enough and VR for safety training is gaining traction for construction professionals to aid in hazard identification and visualization [15,29]. The main idea behind

VR gameplay for wind technicians is for knowledge and skill impartation, practice and reinforcing a technician's skill and knowledge using interactive scenarios to reflect real-life hands-on rescue and evacuation situations. The principle is to use a 3D immersive technology to recreate the rescue and evacuation scenario with the use of a Constant Rate Descender (CRD). The CRD which is optimized for personal rescue is an industrial standard rescue device with additional lifting function and with the help of the hand wheel, casualty being rescued can be lifted over a short distance to release their lanyard before being lowered safely. With the adoption of the VR gameplay, the technicians will be able to interact with the rescue and evacuation devices, carry out a rescue procedure, and make decisions and mistakes without putting anyone at risk or danger until they master the use of the rescue and evacuation kit. By allowing technicians to practice in a virtual environment, they can see what they have learnt and optimize their approach and process towards a successful rescue and evacuation plan [18,19,22].

The benefits of adopting this method of VR gameplay are the ability to bring theoretical understanding to practical implementation in a life-like situation; and being able to reinforce the competency of technicians in real-time. The VR gameplay can be used to simulate real-life situations, the way the rescue devices respond and replicate the soft skills of human-machine interactions and behaviors [26]. Being able to model the behavior of interaction with the rescue device, and the safety procedures following a high detailed definition could allow the VR gameplay to be used as an intervention training for technicians. The aesthetic "rendering" of the visuals will have diminishing returns on fidelity past the point at which it is recognizable to the trainee. This will allow the technicians to interact with the device, adopt best practice of safe systems of work (SSoW) without being involved in real-life dangers. This can save money, cut down on workforce downtime, logistics and most especially, boost proficiency. Also, adopting the VR rescue and evacuation gameplay as a form of intervention could reduce the real risk of personal injury or damage to expensive devices. This is because a safe injury free environment that replicates the detailed use of the rescue device can aid the technician's knowledge and understanding of the device without being put in harm's way. It is also important to note that in comparison to skill acquisition; there is no specific study of skill retention that have been performed focusing on wind turbine technicians undertaking rescue and evacuation using VR.

3. DESIGN METHODS

This study adopted participatory design involving practitioners from the wind industry, gamification, and educational features that could aid retention. The adoption of the VR game simulation and the functionalities involved a PC using the High-Tech Computer Corporation (HTC) Vive Pro 2 VR headset (**Figure 1**).

Figure 1: Equipment used to build and test the game. 1) Desktop PC – CPU: Intel® Core™ i7-6700K CPU @ 4.00GHz, RAM: 32 GB RAM, SSD: 1 TB, GPU: Nvidia GTX 1070 8GB. 2) HTC Vive Pro 2 headset and controllers. 3) Wall mounted HTC Vive base station sensors.

A tethered VR system to a Desktop PC was used to ensure realistic graphics could be displayed on the headset without much performance issues often associated with untethered VR headsets. This was chosen to ensure a greater sense of presence and engagement when using a high-fidelity VR headset [7]. Also, using an untethered VR headset would have meant that a greater stylized aesthetic would have to be chosen to compensate for performance issues, which could reduce knowledge retention performance due to less realism [24]. Therefore, an accurate immersive virtual world and training procedure is needed to ensure the best learning and knowledge retention possible. The simulation was developed in the game engine Unity (version LTS 2022.3.7f1) using a variety of 3D modelling software to model the assets for the virtual world such as Autodesk Maya, Substance Painter and Blender. The specific modelling packages used were at the discretion of the digital artists on the project and models were exported in FBX format into the Unity game engine. These were then situated in the correct places to build the virtual world.

The development of the VR rescue and evacuation game adopted the Scrum iterative agile methodology commonly used due to its efficient approach in games development [10,23]. In Scrum, the VR project was split into sprints that typically last between one to four weeks. A sprint is a focused body of work on specific goals, and this is achieved by incorporating a planning stage at the beginning and a retrospective stage at the end of each sprint. The retrospective stage allows the project team to analyze working processes during the sprint and any future considerations on how to improve the efficiency of development as the project continues [21]. The sprints for this study were weekly and the whole project was set over a period of 24 weeks with 24 iterations of the project during the entire process of development. The study was split into two phases - the first preproduction phase (**Figure 2**) was where the game concept and design were constantly prototyped to figure out what the game design should be and how to gamify the educational experiences to reflect the reality of rescue and evacuation. This was where the specific emergency scenario was chosen and how interaction mechanics with the CRD device were trialed. The second phase - production (**Figure 3**), made use of the solid foundation from preproduction to refine the game content to become professional looking whilst making small iterative changes to improve the user experience, scenario with regards to the educational aspects, and overall game design based on playtesting and feedback.

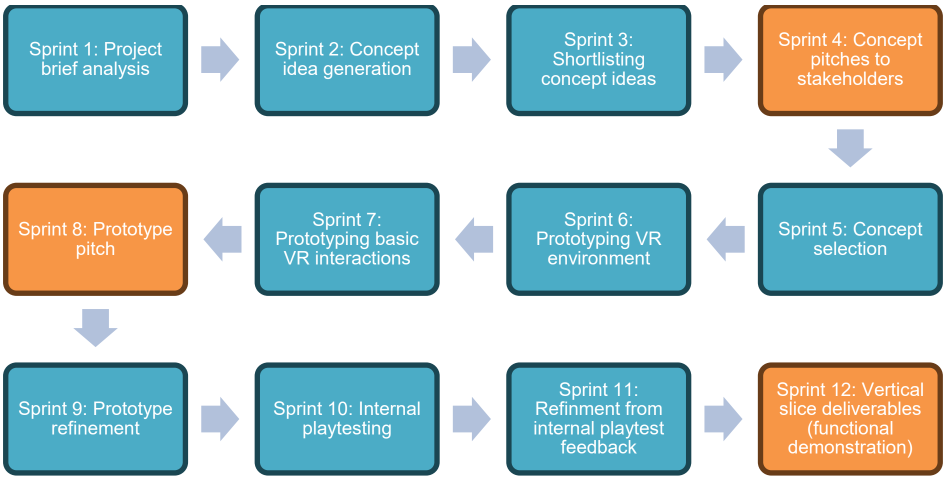

Figure 2: Sprints preproduction phase of game development, (Sprints in orange 4, 8, 12 represent feedback points from stakeholders).

The key milestones for the project were planned upfront to coincide with key sprints which are highlighted in orange (sprints 4, 8, 12, 16, 20, and 24). This study adopted Scrum and agile methodology and the final focus of each sprint was dependent on the state of the project at that time. It was useful to have points in the project where stakeholders provide formal feedback on the progress of the project to ensure consistency for the game. Constant playtesting was another step that helped shaped the project positively. While the development team play tested the game regularly, there were also two formal playtest sessions. An internal playtest in preproduction where stakeholders that were not part of the development team tested the game for the first time, and an external playtest with seven gamers familiar with playing games to get feedback about usability and experience. This continuous playtesting allowed a reactive and agile approach to the game development ensuring that time and resources were spent where they were most needed, and the focus of the game throughout was at the forefront of the design of the project.

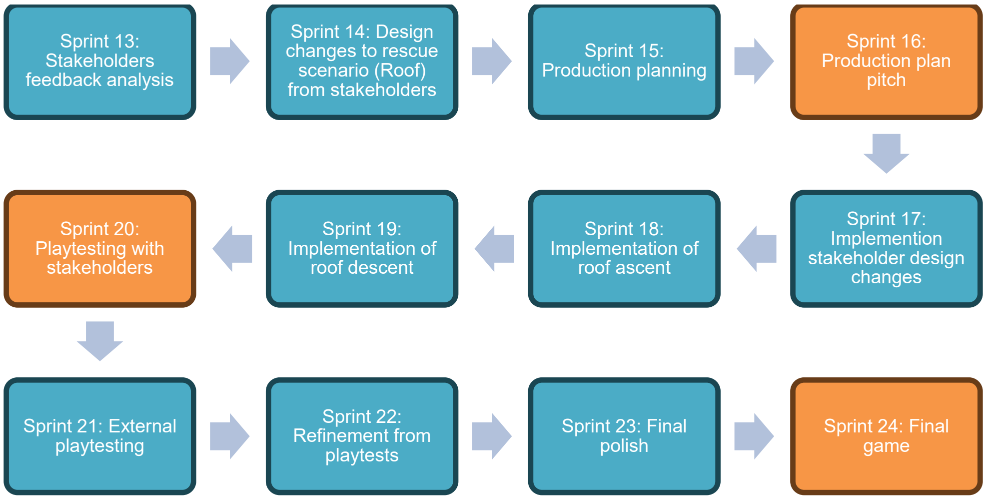

Figure 3: Sprints in the production phase of game development, (Sprints in orange 16, 20, 24 represent feedback points from stakeholders).

The VR gameplay was designed to be carried out by a single player by following the emergency rescue procedure for a wind turbine technician using a CRD with additional lifting function to evacuate an injured party (another wind turbine technician) from a dangerous situation. The precise rescue scenario was developed mainly in the prototyping stage in preproduction and after feedback at multiple points from stakeholders and playtesting. The final scenario was aimed at rescuing a colleague that had become unconscious inside the wind turbine's nacelle with smoke filling the room due to a malfunction of equipment. The nacelle houses all of the generating components in a wind turbine, including the generator, gearbox, drive train, and brake assembly. This scenario presents an immediate danger to the casualty due to smoke inhalation. Therefore, the urgency to undertake timely rescue of the casualty puts the player under pressure and test their recall of the safety procedure in real-life situation. An outline of the safe rescue and evacuation steps are outlined in **Figure 4**.

Figure 4 shows the intended gameplay sequence for the entire game. Before entering the game, players are briefed regarding rescuing and evacuating a casualty in the nacelle. Apart from this, no other information is provided to the player about the experience. The player starts in a cabin on site (**Figure 4, image 1**) to familiarize themselves with the controls and being in a VR space. It was found during playtesting that testers needed some clarification regarding the controls and time to get used to interacting in VR. Therefore, this cabin acts as a tutorial hub to ensure players get used to the controls and know how to navigate and interact in the game. Subsequently, the players must follow the sequence of events in **Figure 4** to safely perform the rescue and evacuation procedure.

1 Tutorial hub to familiarize controls.

2 Walk to Wind Turbine

3 Wind Turbine and entry to elevator

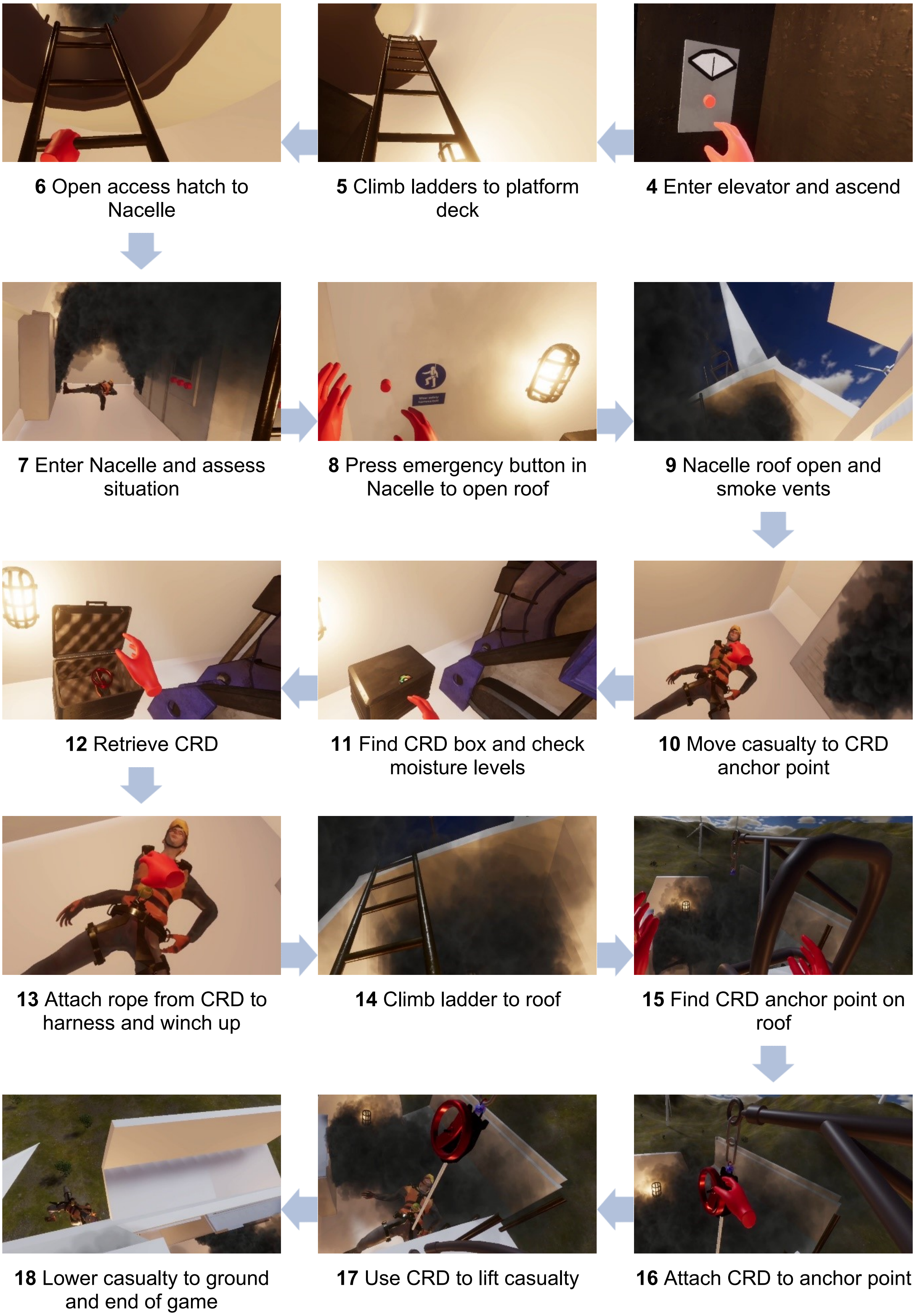

Figure 4: Gameplay description and sequence of gameplay events

Table 1 shows the descriptors used for the external game design playtesting session to assess user experience. The user experience focused on how the experiences of the players can be improved and how players interact with the game, such as navigation, ergonomics, and usability when playing the game [9].

Table 1: Descriptors of playtesting questionnaire variables

Descriptor	Meaning	Question
Utility Value	Utility value means the perceived importance of an activity because of its usefulness for other tasks or aspects of an individual's life.	How has this VR gameplay provided some level of understanding that improves rescue skills?
Engagement	This is the players relationship to the act of executing a rescue process.	How has the VR gameplay improved your degree of attention, curiosity, and interest when undertaking rescue?
Relatedness	The degree to which the VR game influences players prior knowledge to build upon existing cognitive schema.	How did the VR gameplay improve your knowledge of wind turbine rescue?
Self-Efficacy	The degree to which players feel confident in their ability to apply what was learned in playing the VR game.	How confident are you to apply what was learned in reality?
Expectations	The degree to which the VR game met or did not meet the expectations of wind turbine rescue skill	Would you say the VR gameplay met the expectations of wind turbine rescue skills?
Retention	The degree to which portions of the VR game have been retained over a period of time after the VR game was completed.	How long do you think you can retain these skills after the VR gameplay?

The VR game was designed through a user-centered perspective to ensure that the technology is usable by considering the real users' experience and their own requirements within a specific domain [8]; that is, ease of figuring out how to play the VR game and improve on the rescue and evacuation skills, cognitive affordance, and accessibility towards reaching a wider practitioner audience. This user-centered usability-approach provided a base for understanding the requirements for the practical application of the rescue device within VR. Developing the VR game is useful for optimizing safe systems of work and reinforcing skill retention of technicians' rescue and evacuation hands-on practices. A usable system should be easy to use and learn to work with the least number of design errors by always keeping the game state clear and comprehensible through art, animations, sound effects, camera behavior, and user interface. User stories were created based on the requirements of this study leading to several prototypes of small portions of the VR game which were tested internally to ensure that the ideas in the user stories were appropriate, meaningful, fulfils the goal of the game and fit with the game design intentions.

4. STUDY OUTCOMES AND DISCUSSIONS

The practical cost and time of hands-on site-based training of wind turbine personnel is considerable. To maximize the efficiency of training and reduce training costs, efficient training aids, especially serious game development that focuses on specialized fields and special target users becomes imperative. Therefore, this study adopted the concept of participatory design to include stakeholders in the design process whilst also integrating the theory of gamification and educational features that aids retention of skills in the game design [4]. The aim of this game was to reinforce the rescue and evacuation skills of wind technicians and the practicality of using the rescue device during emergencies. This also incorporated aspects such as enjoyable experience and a training resource centered on motivating technicians to interact and engage with the VR game without any physical barriers. Przybylski et al., (2010) suggests that when users enjoy interacting with a game or derive fun from it, such users are more likely to retain such information, and this is beneficial for skill retention. For the rescue and evacuation skill to be retained, the VR game had to be designed as close to reality as possible, easy for the user to navigate, fully immerse the user within the VR environment, and without complex interfaces. Designing the VR game meant incorporating simple fun features to lessen the cognitive load on the player whilst maintaining the believability, enjoyment, realism and ease of use of the simulation to minimize the time taken by the players to understand how the VR environment works. Usability testing of the game, which is considered an important lifecycle of game development was done using seven (7) external players for the initial playtesting session (**Table 2**). This enables the design team to evaluate players enjoyment, emotion, and cognition. The data collection adopted the Likert Scale to measure the players responses using the Google Forms questionnaire. The study used the Likert Scaling unidimensional method which involves the construction of an instrument that associates qualitative constructs with quantitative metric units for ease of understanding in line with the descriptors in **Table 1**.

Table 2: Descriptors with data collection from seven playtesting sessions.

Descriptor	Question	Participants Responses				
Utility Value	Has this VR gameplay provided some level of understanding that improves rescue skills?	Strongly Agree	Agree 2	Neutral 4	Disagree 1	Strongly disagree
Engagement	Has the VR gameplay improved your degree of attention, curiosity, and interest when undertaking rescue?	Strongly Agree 2	Agree 3	Neutral 1	Disagree 1	Strongly disagree
Relatedness	How did the VR gameplay improve your knowledge of wind turbine rescue?	To a large extent	To a moderate extent 4	To some extent 1	To a small extent 2	Not at all
Self-Efficacy	How confident are you to apply what was learned in reality?	Very confident	Quite confident 1	Somewhat confident 2	Not confident 4	
Expectations	Would you say the VR gameplay met the expectations of wind turbine rescue skills?	Yes 4	No 3			
Retention	How long do you think you can retain these skills after the VR game play?	I would say most likely a day or two. A few years. Pretty long, the rescue seems simple enough. A long time. Maybe couple of days - a week.				

Other associated questions included the ease of the controls and if players understood their functionalities. Six players alluded to the fact that the game controls were easy to understand while one indicated the controls were not clear. This lack of clarity could be due to the lack of experience with VR in general (learning the standards of the controllers; and then connecting the standard use of the controller to the particulars of the game in question). In terms of the gameplay, players were also asked if they felt lost during gameplay and six players indicated they struggled with their spatial awareness while one player was fully aware of the environment during gameplay without feeling lost. Four players indicated the gameplay felt natural. However, there were other suggestions regarding the speed of undertaking the rescue process which some felt was a bit slow and lacked urgency. The process of holding on to and climbing the ladder was considered seamless but further development and playtesting sessions are essential to consider the sensitivity of the touchpads that control motion within the game. Five players indicated they felt immersed in the gameplay. However, the game visuals could be further developed to compensate with issues of blurred vision within the game which is common with incorrectly adjusted VR headsets. Also, the amount of detail in models could be improved to make it more realistic and immersive. Depending on the type of blurring the player experiences, it could be related to performance issue where the environment rendering updates too slowly to cope with rapid head movements, or the result of the headset Inter-Pupillary Distance (IPD: the distance between the lenses on the headset) not adjusted for the individual user. Furthermore, five players indicated that the assets within the scene helped promote the location and the mood of the player involved in the rescue and evacuation scenario. One player indicated the assets within the scene helped promote their location and mood moderately whilst one player claimed otherwise. However, six participants overwhelmingly indicated that the indoor and outdoor lighting of the game added to their gameplay experience. They considered their interactions with the rescue kit (the CRD), ladder, functional wind turbine, and other work tools added to the reality of the gameplay.

This study contributes to theory and practice by exploring different characteristics of rescue and evacuation and implementing a VR alternative capable of supplementing real-life training. By adopting VR for rescue and evacuation training, the study captured the dynamics of the player learning pattern relevant to the use of the rescue and evacuation device and how it can be further refined to make it more realistic through additional and robust playtesting sessions with multiple stakeholders. By using micro behavior of learning and forgetting [31], the study implemented a method of assessing the players through observation during the procedural use of the rescue and evacuation device. This initial validation through observation with seven players engaged in the work at height rescue and evacuation training can provide researchers and practitioners with data useful for the evaluation of skill and knowledge retention and for strategic training and planning purposes.

5. CONCLUSIONS

Formal training alone does not improve skill retention in the absence of deliberate practice. This study focuses on learning and retention of a discrete procedural complex task as opposed to simple tasks involving recollecting memorized items. Also, there is currently no formal method in place by the industry to address this gap in knowledge resulting from non-routine practice, and determining the health and safety training and competence requirements of employees remains the responsibility of the employers. The output from this initial study can enable trainers and employers to personalize some aspects of the training to meet the required needs of wind technicians rather than the generic training that is non-beneficial and does not address their immediate needs. This can be invaluable to employers in fulfilling their legal obligations under the Health and Safety at Work Act 1974 and Management of Health and Safety at Work Regulations 1999 regarding assessment of competence, training, knowledge and experience of employees. The information reported in this paper is an ongoing VR game development project and is subject to further refinements and playtesting sessions. Although the game development was over a period of 24 weeks, there is opportunity to fully test the efficacy of this study by testing with large number of intended participants. Furthermore, not all fail states have been implemented in this current game and future development will consider what happens when the player is unable to perform the task or situation in place.

REFERENCES

1. Alrehaili, E. A., & Al Osman, H. (2022). A virtual reality role-playing serious game for experiential learning. Interactive Learning Environments, 30(5), 922-935. https://doi.org/10.1080/10494820.2019.1703008
2. Anderson, J.R. (2005). Cognitive Psychology and Its Implications. 6th ed. New York: Worth Publishing.
3. Casner, S.M., Geven, R.W. & Williams, K.T. (2013). The effectiveness of airline pilot training for abnormal events. Human Factors, 55(3), pp.477-85.
4. Chen, S. M., Shieh, M. D., Cheng, S. Y. (2023). Serious Game Design for High-Risk Training – The Case of Offshore Wind Turbine Maintenance Personnel Training, In: Fang, X. (eds) HCI in Games. HCII 2023. Lecture Notes in Computer Science, vol 14046. Springer, Cham. https://doi.org/10.1007/978-3-031-35930-9_18
5. Ericsson, K.A. & Charness, N. (1994). Expert performance: Its structure and acquisition. American psychologist, 49(8), pp.725-47.
6. Fischer, K.W. (1980). A Theory of Cognitive Development: The Control and Construction of Hierarchies of Skills. Psychological Review, 87(6), pp.477-531.
7. Buttussi, F. & Chittaro, L. (2018). Effects of Different Types of Virtual Reality Display on Presence and Learning in a Safety Training Scenario, in IEEE Transactions on Visualization and Computer Graphics, vol. 24, no. 2, pp. 1063-1076, doi: 10.1109/TVCG.2017.2653117
8. Gheisari, M., and Esmaeili, B. (2019). Applications and Requirements of Unmanned Aerial Systems (UASs) for Construction Safety. Saf. Sci. 118, 230–240. doi:10.1016/j.ssci.2019.05.015
9. Irizarry, J., Gheisari, M., and Walker, B. N. (2012). Usability Assessment of Drone Technology as Safety Inspection Tools. Itcon J. Inform. Technol. Construct. 17, 194–212.
10. Keith, C. (2010). Agile Game Development with Scrum. Boston, MA: United States of America: Pearson Education.
11. Kluge, A., Sauer, J., Schuler, K. & Burkolte, D. (2009). Designing Training for Process Control Simulators: A Review of Empirical Findings and Current Practices. Theoretical Issues in Ergonomics Science, 10, pp.489–509

12. Lawani, K, Hare, B & Cameron, I. (2019). Evaluating wind technicians performance on safety critical rescue steps', Proceedings of the ICE - Management, Procurement and Law, vol. 172, no. 1, pp. 17-24. https://doi.org/10.1680/jmapl.18.00002
13. Lawani, K, Hare, B & Cameron, I. (2018). Integrating early refresher practice in height safety and rescue training', Safety Science, vol. 110, no. A, pp. 411-417. https://doi.org/10.1016/j.ssci.2018.03.029
14. Lawani, K, Hare, B & Cameron, I. (2015). Scheduling refresher-based rescue and evacuation training for wind turbine technicians. in Proceedings of ICSC15: The Canadian Society for Civil Engineering 5th International/11th Construction Specialty Conference. pp. 95-1-95-10. https://doi.org/10.14288/1.0076484
15. Lawani, K, Sadeghineko, F, Tong, M, Hare, B & Ho, G. (2023). Barriers faced by AEC companies in Macao in adopting innovative technologies to improve health & safety. in E Fidelis, F Sherratt & A Soeiro (eds), Proceedings of the CIBW099W123: Digital Transformation of Health and Safety in Construction. Universidade do Porto, Porto, Portugal, pp. 421-430, https://doi.org/10.24840/978-972-752-309-2
16. Martinussen, M. & Hunter, D.R. (2010). Aviation Psychology and Human Factors. Boca Raton, FL: CRC Press.
17. McKenna, S. & Glendon, A. (1985). Occupational first aid training: Decay in cardiopulmonary resuscitation (CPR) skills. Journal of Occupational Psychology, 58, pp.109-17.
18. Mencke, N., Winge, A., & Lombardi, P. A. (2017). Towards the application of virtual reality technologies for the training on major construction sites. INTED2017 Proceedings, 1, 7215–7220. https://doi.org/10.21125/INTED.2017.1671
19. Moore, H. F., & Gheisari, M. (2019). A Review of Virtual and Mixed Reality Applications in Construction Safety Literature. Safety, 5(3). https://doi.org/10.3390/safety5030051
20. Patrick, J. (1992). Training: Research and Practice. San Diego, CA: Academic Press.
21. Przybyłek, A., and Kotecka, D. (2017). Making Agile Retrospectives More Awesome. Prague, Czech Republic: Federated Conference on Computer Science and Information Systems (FedCSIS), 1211–1216. doi:10.15439/2017F423
22. Sacks, R., Perlman, A., & Barak, R. (2013). Construction safety training using immersive virtual reality. Construction Management and Economics, 31(9), 1005–1017. https://doi.org/10.1080/01446193.2013.828844
23. Scrum.org (2021). What Is Scrum? [online]. Available from: https://www.scrum.org/resources/what-is-scrum/
24. Skulmowski, A. (2022). Is there an optimum of realism in computer-generated instructional visualizations?. Educ Inf Technol 27, 10309–10326. https://doi.org/10.1007/s10639-022-11043-2
25. Vincenzi, D.A., Wise, J.A., Mouloua, M. & Hancock, P.A. (2009). Human Factors in Simulation and Training. Boca Raton, FL: CRC Press.
26. Vinciarelli, A., Esposito, A., André, E., Bonin, F., Chetouani, M., Cohn, J.F., Cristani, M., Fuhrmann, F., Gilmartin, E., Hammal, Z. and Heylen, D. (2015). Open challenges in modelling, analysis and synthesis of human behaviour in human–human and human–machine interactions. Cognitive Computation, 7, pp.397-413
27. Wixted, J.T. (2004). On common ground: Jost's (1897) law of forgetting and Ribot's (1881) law of retrograde amnesia. Psychological Review, 111, pp.864–79.
28. Wixted, J.T. & Ebbesen, E.B. (1991). On the form of forgetting. Psychological Science, 2(6), pp.409-15.
29. Wolf, M., Teizer, J., Wolf, B., Bükrü, S., Solberg, A. (2022). Investigating hazard recognition in augmented virtuality for personalized feedback in construction safety education and training. Advanced Engineering Informatics [online]. 51(2022), pp.1-14. Available from: DOI: 10.1016/j.aei.2021.101469
30. Zhang, Z., & Pan, W. (2021). Virtual reality supported interactive tower crane layout planning for high-rise modular integrated construction. Automation in Construction, 130, 103854. https://doi.org/https://doi.org/10.1016/j.autcon.2021.103854
31. Shail, M.S. (2019). Using micro-learning on mobile applications to increase knowledge retention and work performance: a review of literature. Cureus, 11(8). doi: 10.7759/cureus.5307