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Virtual reality lifeguarding scenarios as a potential training solution for pool lifeguards

David Lim [a], Mark Wiggins [a,*], Meredith Porte [b], Piers Bayl-Smith [a], Kim Curby [a], Kirk Olsen [a], Melanie Taylor [a]

[a] School of Psychological Sciences, Macquarie University, Australia
[b] School of Computing Sciences, Macquarie University, Australia

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ABSTRACT

Background: Ensuring that pool lifeguards develop the skills necessary to detect drowning victims is challenging given that these situations are relatively rare, unpredictable and are difficult to simulate accurately and safely. Virtual reality potentially provides a safe and ecologically valid approach to training since it offers a near-to-real visual experience, together with the opportunity to practice task-related skills and receive feedback. As a prelude to the development of a training intervention, the aim of this research was to establish the construct validity of virtual reality drowning detection tasks.

Method: Using a repeated measures design, a total of 38 qualified lifeguards and 33 non-lifeguards completed 13 min and 23 min simulated drowning detection tasks that were intended to reflect different levels of sustained attention. During the simulated tasks, participants were asked to monitor a virtual pool and identify any drowning targets with accuracy, response latency, and dwell time recorded.

Results: During the simulated scenarios, pool lifeguards detected drowning targets more frequently and spent less time than non-lifeguards fixating on the drowning target prior to the drowning onset. No significant differences in response latency were evident between lifeguards and non-lifeguards nor for first fixations on the drowning target.

Conclusion: The results provide support for the construct validity of virtual reality lifeguarding scenarios, thereby providing the basis for their development and introduction as a potential training approach for developing and maintaining performance in lifeguarding and drowning detection.

Application: This research provides support for the construct validity of virtual reality simulations as a potential training tool, enabling improvements in the fidelity of training solutions to improve pool lifeguard competency in drowning detection.

1. Introduction

In 2019–2020, 11% of drowning-related deaths in Australia occurred in aquatic pools (Royal Life Saving Australia, 2002). Lifeguards play an important role in accurately recognising drowning swimmers and quickly responding to these emergencies (Wright et al., 2020). Exploring cost-effective and feasible interventions that improve the drowning detection skills of lifeguards could potentially minimise fatalities in aquatic pools. Applications of virtual reality technologies within lifeguard training programs have utility, as they afford opportunities for trainees to practice and improve their operational skills in a low risk, high fidelity simulated work environment (Tichon, 2007).

1.1. Drowning detection and expertise

Visual scanning refers to the observation of features within the environment and the assessment of these features to enable effective decision making (Fenner et al., 1999). In the instance of drowning detection, pool lifeguards must be able to oversee the safety of swimming patrons by scanning the water, identifying potential swimmers in distress, and responding to those swimmers before drownings occur (Wright et al., 2020). Drowning swimmers can be submerged under water for a prolonged period, during which they are deprived of oxygen, heightening the risk of neural damage (Lanagan-Leitzel and Moore, 2010). Therefore, fast and accurate drowning detection is vital for

* Corresponding author.
E-mail address: mark.wiggins@mq.edu.au (M. Wiggins).

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reducing injury and saving lives.

Lifeguards are typically trained to identify two categories of drowning behaviour: active drowning and passive drowning (Lanagan-Leitzel, 2012). Active drowning consists of characteristics where swimmers resist submerging themselves under water and exhibit behaviours such as flailing arms, heads tossed backwards, and vertically positioned bodies (Pia, 1974). Passive drowning occurs when swimmers quickly transition from normal swimming behaviour and find themselves lying motionless on the surface of the water or slipping towards the bottom of the pool with their bodies face-down (Fenner et al., 1999).

Detecting drowning swimmers can be challenging due to shared similarities between drowning-related characteristics and normal swimming behaviours (Lanagan-Leitzel, Skow and Moore, 2015). Active drownings can easily be mistaken for swimmers engaging in leisure activities as they splash in the water, while passive drownings are commonly mistaken for a 'dead man's float' where swimmers intentionally float face down or submerge themselves in the water (Laxton and Crundall, 2018). The ability to distinguish subtle differences between behaviours associated with drowning from normal swimming activities requires extensive training (Langendorfer et al., 2022).

The improved drowning detection associated with lifeguard experience likely results from prior exposure to behavioural cues related to drowning and distress (Laxton et al., 2021a, 2021b). These cues are retained in memory and are activated nonconsciously in response to environmental features with which there is a match. In complex, dynamic environments such as those occurring during lifeguarding, the application from memory of learned cue associations is nonconscious, reducing cognitive load while ensuring rapid and accurate responses (Wiggins, 2021).

Consistent with approaches to Naturalistic Decision-Making (NDM), including the Recognition-Primed Decision (RPD) model, a greater repertoire and more precise cues provides the foundation for accurate and rapid situational assessment (Klein, 2008). Patterns of cues in the environment are matched, as near as possible, to patterns of cues that are resident in memory. This initiates a comparative process to determine whether the associated explanation matches the situation (Klein et al., 2021). Where a match is established, a response is initiated.

According to the RPD model, cues are acquired through active engagement with the environment. Therefore, cues associated with drowning behaviour likely develop through both practice and prior exposure to drowning events, allowing lifeguards to become more sensitive than non-lifeguards towards drowning-related features when monitoring patrons (Laxton et al., 2021a, 2021b; Laxton, Mackenzie & Crundall, 2022).

1.2. Strategies to artificially increase experience include training

Training programs have used video footage to help lifeguards learn to quickly recognise and respond to swimmers in distress (Wright et al., 2020). However, there are difficulties in obtaining pool drowning footage due to the lack of availability of recorded drownings and ethical concerns around filming real incidences of distress (Laxton et al., 2021a, 2021b). Previous research has instead relied on recordings of dangerous or risky aquatic behaviours that could potentially lead to drowning events (Lanagan-Leitzel, 2012; Lanagan-Leitzel and Moore, 2010). However, there remain issues with drawing conclusions from training programs using observations of risky but not necessarily drowning behaviours (Schwebel et al., 2007).

Concerns have been raised in using videos containing drownings simulated by trained lifeguards as representations of actual drowning incidences, since mock drownings may be too dissimilar from realistic drowning behaviours that occur naturally in aquatic pools (Laxton and Crundall, 2018). For example, live swimmers may be unable to simulate realistic drowning features such as facial expressions, and instead, include behaviours to avoid drowning such as avoiding water running up the nose (Hunsucker and Davison, 2008). Mock scenarios are also costly and impractical as they can potentially place trainers in danger and scenarios must be physically reset to recreate the scene (Wright et al., 2020).

Mannequins have been introduced into training curricula to help lifeguards gain practical rescue experience but may not be an adequate learning tool to sufficiently improve drowning detection (Laxton and Crundall, 2018). Evaluations of the effectiveness of pool lifeguard training programs suggest that lifeguards have difficulty detecting submerged mannequins (Wright et al., 2020). For example, pool lifeguards have difficulty recognising a submerged mannequin simulating a small child at the bottom of the pool (Patterson, 2007). Dummy alternatives likely lack the realistic drowning behaviours on which lifeguards rely when detecting drowning swimmers (Wright et al., 2020).

Previous research examining novel training interventions in the context of lifeguarding have been constrained by the level of realism that can be afforded through simulation (Laxton et al., 2021a, 2021b). When responding to computer-based animations that simulated beach drownings, lifeguards with eight years of experience were five times more accurate in detecting drowning targets than inexperienced lifeguards with less than one year of experience (Page et al., 2011). Although this provides support for the comparability of animated simulations to real-life aquatic settings, the animated scenarios employed by Page et al. (2011) lacked distractions (e.g., other swimmers engaging in leisurely activities) and provided only one perspective for observing swimmers. Laxton and Crundall (2018) used naturalistic stimuli containing recordings of regimented swimming in a pool, but participants viewed footage from computer screens with a fixed visual angle and provided push-button responses, failing to allow for natural lifeguarding behaviour.

Traditional lifeguard educational programs incorporating video materials and practical demonstrations simulating drowning scenarios with mannequins or actors are unlikely to offer the complex and dynamic visual environment that lifeguards are required to observe (Smith et al., 2020). Lifeguard programs using virtual reality-based simulations offer opportunities beyond other types of training scenarios that are set in real-life environments. For example, the inclusion of a variety of distractors and distractor behaviours that are consistent with the natural environment and across a range of situations that lifeguards are required to monitor, could support the rapid development of lifeguarding skills, such as the speed and accuracy of drowning detection (Wright et al., 2020).

1.3. Virtual reality as a potential training tool

Virtual reality environments allow users to immerse themselves within a three-dimensional space and interact with graphical representations of people and objects (Parsons and Mitchell, 2002). They are responsive to behaviour, such that any changes in head or body positions are associated with immediate adjustments in computer renderings to display an updated point-of-view (Sherman and Craig, 2019). Different artificial environments can be constructed using virtual reality by incorporating a variety of facsimiles of real-world objects (Winn, 1993). Implementing virtual technologies that afford control over the nature of exposure in training programs has been shown to develop competencies within fields such as medicine (Seymour et al., 2002), navy (Hays and Vincenzi, 2000), and the sports industry (Bedir and Erhan, 2021).

The way in which people interact within virtual environments appears to be similar to the behaviours observed in real-life settings (Ragan et al., 2015). Given that virtual reality permits users to engage in multiple perspectives and directly interact with objects within a scene, it allows users the freedom to make decisions and exercise agency to a degree similar to real-life (Sherman and Craig, 2019). Previous research investigating drowning detection involved viewing drowning footage from a fixed angle that prevented lifeguards from monitoring swimmers without obstruction (Lanagan-Leitzel, 2012; Lanagan-Leitzel and Moore, 2010; Laxton and Crundall, 2018). Virtual reality is able to overcome these limitations by allowing users to locate themselves in different positions within space, thereby enabling observations from different perspectives (Galvan Debarba et al., 2017).

Virtual reality facilitates the emergence of expert-related knowledge and skill acquisition by allowing users to learn directly from experience (Winn, 1993). Expertise typically develops over-time via exposure to true-to-life environments (Craig, 2013). However, the prevalence of drowning-related fatalities in lifeguarded areas is rare, such that a lifeguard may rarely, if ever, experience a drowning (Lanagan-Leitzel, Skow and Moore, 2015). Virtual reality allows for the consolidation of rare experiences within a short timeframe, allowing users to learn from their experiences quickly, thereby artificially accelerating the rate of skill acquisition (Jordan et al., 2001; Tichon, 2007).

The challenge in developing virtual training solutions lies in establishing the transfer of skills from the training context to the operational environment. Harris et al. (2020) propose a framework to test the validity of virtual training simulations in enabling skilled performance. An important part of this process lies in ensuring that the virtual simulation represents the features embodied in the actual task and engages realistic behaviour. This requires that the construct validity of the simulation is established as a precursor to the successful transfer of training. Higher levels of construct validity are demonstrated: (a) where a simulated environment is sensitive to differences in performance between skilled and unskilled practitioners; and (b) where skills acquired during training are demonstrated to improve across trials.

1.4. The present study

Consistent with an intent to test construct validity, the primary aim of the present study was to test whether there are differences between qualified pool lifeguards and non-lifeguards in the accuracy and speed with which they detect drowning swimmers during 13 min and 23 min virtual reality-based, aquatic pool simulations. The secondary aims were to investigate whether there are differences between pool lifeguards and non-lifeguards in their behaviour prior to the drowning occurrence; and whether improvements in performance occur over successive simulations. Consistent with Harris et al. (2020), it constitutes an assessment of the sensitivity of the simulation to both differences in skilled performance and differences in exposure over time.

It was hypothesised that for both 13 min and 23 min virtual drowning scenarios, pool lifeguards would detect drowning swimmers more accurately than non-lifeguards (H1). It was also hypothesised that from the point at which targets began to drown, pool lifeguards would detect drowning targets more rapidly than non-lifeguards (H2), would produce their first fixation on the drowning target at a faster rate (sec) than non-lifeguards (H3), but would record a shorter dwell time than non-lifeguards on the target prior to drowning (H4). Finally, it was hypothesised that with exposure to the simulation scenarios, the accuracy, response latency, first and dwell time would improve over successive trials (H5).

2. Method

2.1. Participants

A total of seventy-one participants (32 female, 38 male and 1 preferred not to say) were recruited for the study. Participants' ages were categorised into four groups: 18–24, 25–34, 35–44, and 45–54, to maximise confidentiality and anonymity in recruiting from a relatively small population of lifeguards who were employed within a single organisation. There were 60 (84.51%) participants classified as 18–24 years old, five (7.04%) participants classified as 25–34 years old, five (7.04%) participants classified as 35–44 years old, and one (1.41%) participant classified as 45–54 years old.

Thirty-seven participants comprised pool lifeguards who were recruited from within a non-government organisation and council-managed public swimming pools. Thirty-three participants comprised first-year university students who received course credit for their participation. One student reported previous experience as a pool lifeguard and was allocated to the lifeguard group. Four of the non-lifeguard participants indicated that they had experience and/or certification in beach lifeguarding. As beach lifeguarding involves skills and certifications that are distinct from pool lifeguard training standards (Tan, 2013), the four participants were allocated to the non-lifeguard group. The remaining participants had no pool lifeguarding experience.

Participants were required to have no recurring history of motion sickness or light sensitivity to participate in the study. If participants experienced dizziness or simulation-related sickness, the study was terminated immediately, and the data were not recorded.

2.2. Apparatus

2.2.1. Virtual headset

Interaction with the virtual scenarios occurred using the HTC VIVE virtual reality system. The HTC VIVE is a head-mounted device equipped with dual AMOLED displays with a resolution of 1080 × 1200 pixels for each eye. This provides a 110° field of view. Two hand controllers were used to navigate throughout the scenario and included the option to teleport to different locations around the virtual pool. The hand controllers were also used to identify the drowning victim by locating the cursor over the victim and depressing the system button which recorded the time at which the event occurred.

2.2.2. Eye-tracker

The HTC VIVE headset was retrofitted with Tobii Eye Tracking Glasses using the system's standard operating procedures including a five-point calibration. Tobii Eye Tracking glasses record natural gaze behaviours based on a 120 Hz binocular sampling rate. Gaze behaviour recorded during the aquatic pool simulation task was used to calculate the total time (in seconds) spent fixating on the swimmer before the onset of the drowning occurrence. Other metrics derived from the gaze data included the time (in seconds) taken to first fixate on the drowning swimmer following the onset of the drowning event.

2.3. Materials

2.3.1. Aquatic pool simulator

The drowning detection task was programmed using Unity, a computer-based virtual-reality platform. Participants entered a virtual reality simulation which allowed a 110° field of view (See Fig. 1). The simulation modelled an outdoor venue with a 50-m Olympic sized pool with eight lanes on a clear, sunny day. All of the participants were immersed in the same scenarios and encountered the same features. The scenarios included patrons of different ages and genders undertaking various aquatic activities such as swimming and playing. Other features included trees on top of a hill behind the pool and a lifeguard observing patrons at the opposite end of the pool. The sun was positioned in the sky such that sunlight reflected off the pool water and caused sun glare when observing the scene from different angles (see Fig. 2).

The drowning detection task consisted of three scenarios of different durations and with different features (see Table 1). Participants completed all three scenarios, with the presentation of the three simulated scenarios in the following order: Scenario One, Scenario Two, and Scenario Three. Scenarios One and Three comprised a drowning a victim, while Scenario Two constituted a control scenario during which no drowning occurred. This was intended to minimise participants' expectation that a drowning would necessarily occur during the scenario.

The drowning detection task was designed so that the 13 min scenario (Scenario One) preceded the 23 min scenario (Scenario Three) to ensure that any learning effect that might have been attributed to exposure to the scenarios remained consistent across both lifeguard and

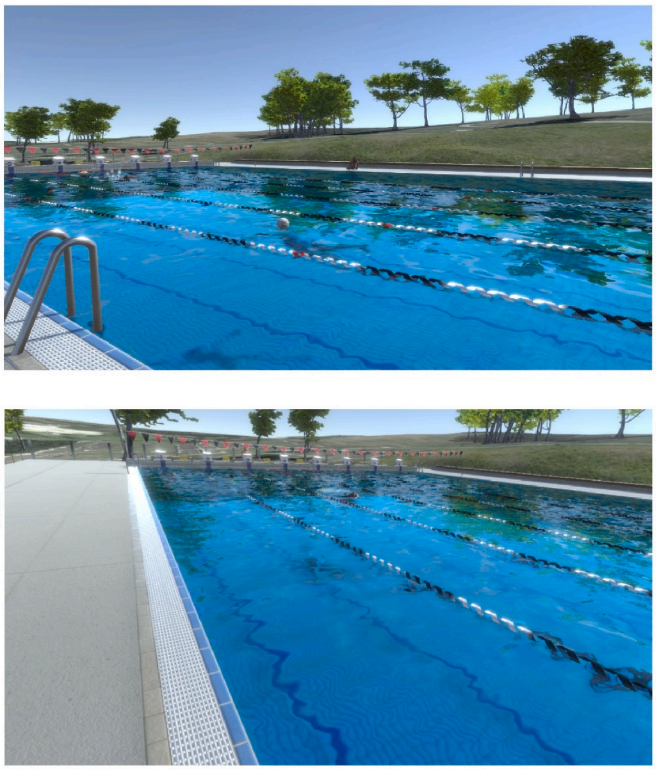

Fig. 1. Example of the Virtual Reality Simulation for Scenario One. The first image depicts the target before the drowning: the elderly patron in the second lane closest to the handrails. The second image shows the drowned target lying motionless at the bottom of the pool.

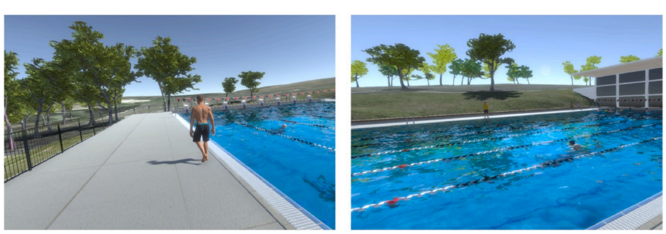

Fig. 2. Example of the Features of the Virtual Scenario demonstrating the fidelity and different effects of sun glare.

Table 1
Description of virtual reality scenarios simulating an open aquatic pool.

Name	Scenario One	Scenario Two	Scenario Three
Duration of scenario (in minutes)	13	10	23
No. of drowning incidents	1	0	1
Drowning trigger time	9 min	–	19 min
Time of drowning onset	561.73–630 s	–	1143.84–1194 s

Note. Scenario 1 and Scenario 3 consisted of one drowning target. Scenario 2 acted as a control scenario with no drowning target.

non-lifeguard participants. The participants took approximately 52 min to complete the scenarios. Passively drowning targets were included in the drowning scenarios as these targets are more difficult to detect than active drowning targets as they exhibit fewer salient characteristics (e.g., such as an absence of movement) that overlap with normal drowning features (Laxton and Crundall, 2018). The drowning targets in Scenario One and Three comprised an elderly woman and a middle-aged man, respectively, who drowned passively. Prior to the drowning event, the targets were swimming within the lanes before abruptly becoming motionless near the surface of the water, and then slowly descending and remaining motionless at the bottom of the pool.

The program was designed such that once a fixed time had elapsed (drowning trigger time), a drowning was initiated once a swimmer passed through a specified location in the lane.

The drowning onset time is the time when the swimmer reaches the specified location, and begins to drown (stops swimming, lies motionless, and begins descending to the bottom of the pool). The swimmers' speeds were slightly randomised such that once swimmers reached the drowning location, the actual drowning onset time varied between participants. The drowning trigger time and the time of drowning onset are listed for the various scenarios in Table 1.

Participants identified the drowning victim by locating the controller cursor over the victim and depressing the system button and the time was recorded. For participants whose drowning onset time was not recorded automatically when the system button was depressed, audio recordings of participant trials were processed through Audacity software to identify the scenario time corresponding to the time at which the participant identified the drowning target via verbal confirmation. The drowning onset time for each drowning-related scenario was calculated by subtracting the response latency score from the scenario time at which participants confirmed that a swimmer had drowned. Using the drowning onset time, the visual dwell time was calculated as the total time that participants spent fixating on the drowning swimmer prior to the onset of the drowning. The first fixation time was also measured by the first fixation on the drowning target, following the drowning onset time.

2.4. Measures

The accurate detection of a drowning victim was recorded if the participant identified the drowning victim within 3 min of the target having submerged. First fixation and response latency data were necessarily restricted to those targets that were detected accurately within the 3 min period. Drowning detection and response latency were determined based on the accurate detection of drowning swimmers within 3 min of the target having submerged under water (drowned). Response latency was measured as the time (in seconds) elapsed between the presentation of the drowning event, and the verbalisation by the participant that a drowning was occurring or had occurred. Fixations represent the period of time that the eye remains stationary, ostensibly to acquire information from a visual target (Rayner, 2009). The first fixation to the drowning target was calculated as the time (in seconds) elapsed between the presentation of the drowning event and the first fixation on the drowning target. Visual dwell time was calculated as the total time (in seconds) spent fixating on the drowning swimmer, prior to the drowning event.

2.5. Procedure

Approval for the study was obtained from the Macquarie University Human Research Ethics Committee (Approval Code: 52,021,355,825,005; 520,221,129,236,609). Participants were directed into the simulation room and, following informed consent, were tested individually in 90-min sessions. Participants first completed an online demographics questionnaire on a laptop, consisting of information such as age, sex, and any previous employment history as a lifeguard. Having completed the questionnaire, participants were given standard verbal instructions pertaining to the virtual reality task.

For the virtual reality task, participants wore a virtual reality headset and were asked to adopt the role of a lifeguard on duty at a local outdoor swimming pool. Before entering the simulations, the participants were advised that they would be undertaking a 50-min shift observing patrons, during which they would be provided with two, 3-min breaks. The researcher acted as a lifeguard supervisor who was present while participants were asked to observe the patrons at the pool. The participants were asked to let the supervisor know of anything that might be a safety concern, including minor issues that they observed, and notify the 'supervisor' by expressing their concerns verbally. They were also informed that they were permitted to turn their head and move physically around the pool but not to remove the headset until advised by the researcher. Following each scenario, participants were invited to remove the headset during the 3 min break.

2.6. Data analysis

Accuracy data were analysed separately for the two drowning scenarios using 2 × 2 contingency tables and corresponding chi-square analyses. Response latency, first fixation, and dwell time data were examined using 2 × 2 mixed-repeated ANOVAs, incorporating classification as a lifeguard or non-lifeguard as a between-groups variable and the two scenarios as a within-groups variable.

3. Results

3.1. Data management

A total of three participants experienced dizziness, nausea or eye sensitivity issues while wearing the virtual reality headset. For 15 participants, data were not recorded due to technical issues with the virtual reality headset and the scenarios ending prematurely. Measures of accuracy for each drowning detection task were available for 60 participants for the 13 min scenario and 63 participants for the 23 min scenario. Of the 36 participants who correctly identified the target in the 13 min scenario, response latency was recorded from all (n = 36) participants, first fixation time was recorded for 86.11% (n = 31) of participants, and visual dwell time was recorded for 86.11% (n = 31) participants. Of the 51 participants who correctly identified the target in Scenario Three, response latency was recorded from all (n = 51) participants, first fixation time was recorded for 94.12% (n = 48) of participants, and visual dwell time was recorded for 94.12% (n = 48) of participants. Comparisons between pool lifeguards and non-lifeguards indicated that there were no differences in the representation of age groups, X^2 (3, N = 59) = 3.15, p = .37. However, a difference was evident in sex, with a greater representation of females in the non-lifeguard group (69.6%) compared to the lifeguard group (30.4%), X^2 (1, N = 58) = 4.86, p = .03.

3.2. Accuracy in detecting drowning targets

A series of 2 × 2 Chi-Square tests of independence was employed to establish whether experience-related differences existed in the accuracy of drowning detection in scenarios of different durations. For the 13 min scenario, a statistically significant difference was evident between employment as a lifeguard and accuracy, X^2 (1, N = 60) = 12.11, $p <$ .001. The effect size was moderate, Cramer's V = 0.45. A similar difference was evident for the 23 min scenario, X^2 (1, N = 63) = 7.58, p = .006, with a moderate effect size (Cramer's V = 0.35). Therefore, H1 was supported, with pool lifeguards detecting drowning swimmers with greater accuracy than non-lifeguards in both the 13 min (82.8% and 38.7%, respectively) and 23 min scenarios (93.9% and 66.7%, respectively). The four participants with beach lifeguard training/certification varied in accuracy with two participants detecting the drowning target in both the 13 and 23 min scenarios and two participants failing to detect either drowning target.

3.3. Response latency in detecting drowning targets

As response latency data were non-normal, a square root transformation was applied to the raw data prior to analysis. With Box's M (1.69) non-significant, F(3) = 0.51, p = .68, the results failed to reveal a statistically significant main effect of employment as a lifeguard, F(1, 30) = 0.21, p = .65, η^2 = 0.007, nor a statistically significant interaction between employment as a lifeguard and the duration of the scenario, F (1, 30) = 1.36, p = .25, η^2 = 0.04, failing to provide support for H2. However, a statistically significant main effect of scenario was evident, F (1, 30) = 9.67, p = .004, η^2 = 0.244. An inspection of the mean response latencies (prior to transformation) indicated that participants who correctly identified the drowning target recorded a lower response latency in the 23-min scenario (M = 10.67 s, SD = 17.02) than the 13-min scenario (M = 32.1 s, SD = 33.69), consistent with a learning effect proposed in H5 (See Table 2).

3.4. First fixations to the target

For the first-fixation times, a square root transformation was applied initially to the raw as they were non-normal. With Box's M (1.47) non-significant, F(3) = 0.44, p = .73, the results failed to reveal a statistically significant main effect of employment as a lifeguard, F(1, 24) = 0.02, p = .88, η^2 = 0.001, nor scenario, F(1, 24) = 0.35, p = .56, η^2 = 0.01, failing to provide support for H3. The results also failed to reveal a statistically significant interaction between employment as a lifeguard and the duration of the scenario, F(1, 24) = 0.20, p = .66, η^2 = 0.008.

3.5. Visual dwell time prior to the drowning onset

In the context of visual dwell time, and with Box's M (2.42) non-significant, F(3) = 0.72, p = .54, the results failed to reveal a statistically significant interaction between employment as a lifeguard and the duration of the scenario, F(1, 25) = 0.29, p = .597, η^2 = 0.011. However, a statistically significant main effect was evident for employment as a lifeguard, F(1, 25) = 5.53, p = .027, η^2 = 0.181, and scenario, F(1, 25) = 16.44, $p <$ .001, η^2 = 0.397. An inspection of the mean dwell times indicated that for both the 13 min and 23 min scenarios, non-lifeguards fixated on targets for longer periods than pool lifeguards, prior to the drowning event, consistent with H3 (See Table 2). Furthermore, all participants who correctly identified the drowning target recorded a greater visual dwell time in the 23 min scenario (M = 20.84 s, SD = 10.89) than for the 13 min scenario (M = 13.04 s, SD = 5.40), consistent with greater exposure and providing support for H5.

4. Discussion

The primary aim of the present study was to examine whether differences exist between qualified pool lifeguards and non-lifeguards in the accuracy and speed with which they detect drowning swimmers during virtual reality-based aquatic pool simulations. Together with

Table 2
Response latency, first fixation, and visual dwell times of lifeguards and non-lifeguards.

Group	13 min scenario			23 min scenario		
	n	M	SD	n	M	SD
Response Latency						
Lifeguard	23	38.16	37.60	23	10.66	13.26
Non-Lifeguard	9	24.25	27.11	9	9.82	10.95
First Fixation						
Lifeguard	18	15.48	28.02	18	12.99	19.60
Non-Lifeguard	9	10.74	12.02	9	7.15	10.94
Visual Dwell Time						
Lifeguard	18	11.30	5.25	18	18.38	9.39
Non-Lifeguard	9	16.51	4.01	9	25.74	12.54

Note. No differences were evident between lifeguards and non-lifeguards in response latency and first fixations. Lifeguards spend less time (sec) visually fixating on the target, prior to the drowning event.

performance during the drowning-related tasks, the secondary aims were to investigate whether there are differences between pool lifeguards and non-lifeguards in their behaviour prior to the drowning event and whether performance improvements occur over successive simulations.

As hypothesised, a greater frequency of pool lifeguards detected drowning swimmers during both the 13 and 23 min scenarios. Amongst pool lifeguards and non-lifeguards who correctly detected the drowning swimmers, there were no statistically significant differences in the speed with which drowning targets were detected correctly, nor the first fixations on the drowning target in either scenario. However, compared to non-lifeguards, pool lifeguards who correctly detected the drowning target spent less time dwelling visually on the target prior to the drowning event. In combination, the results suggest that, in virtual reality scenarios, pool lifeguards demonstrate more accurate detection of drowning swimmers and are likely engaging in more effective scanning behaviour than non-lifeguards.

4.1. Accuracy, visual dwell time, and learning

Across both the 13 and 23 min scenarios, pool lifeguards detected drowning swimmers with greater frequency than non-lifeguards suggesting that the representation of drowning swimmers during the virtual scenarios corresponded to representations afforded by training and experience as a lifeguard. Through training simulations and/or real-world engagement, lifeguards likely become sensitive to perceptual features that are associated with drowning and from which they can derive meaning and establish an accurate assessment of a situation (Laxton et al., 2021a, 2021b).

Deriving meaning from perceptual features is consistent with models of naturalistic decision-making, including RPD. Associations between perceptual features and events or actions constitute cues that are triggered nonconsciously by patterns of features that are evident in the operational context. In distinguishing the behaviour of lifeguards from non-lifeguards, the results suggest that the simulations demonstrated a degree of construct validity consistent with the framework advocated by Harris et al. (2020).

It also appeared that participants' performance improved over the successive trials indicating that a learning effect occurred. Despite an intervening control scenario, accuracy for both non-lifeguards and lifeguards in the 23 min scenario exceeded their performance in the preceding 13 min scenario, with a corresponding reduction in response latency in detecting the drowning victim. Together with the differences in behaviour between lifeguards and non-lifeguards, improvements in performance contribute further to the construct validity of virtual simulations in the context of lifeguarding.

From an applied perspective, the results suggest that a repertoire of task-related cues in memory, together with the application of efficient surveillance techniques, is likely to be associated with the timely identification of drowning victims. This is an approach that is encouraged in lifeguard training and that can potentially be augmented through exposure to virtual scenarios, enabling lifeguards to engage with cues in different contexts. For example, cues could be occluded by other patrons or by permanent structures, surveillance could occur at night or in bright sunshine, causing the reflection and/or refraction of light, and/or lifeguards could be distracted by patrons engaged in unsafe activity or seeking information.

4.2. Limitations and future directions

Although the drowning detection skills during the virtual scenarios appear to be consistent with what might be expected of lifeguards in practice, the scenarios were limited to 13 min and 23 min, with an intervening control scenario. Typical shifts for pool lifeguards can extend to 4 h, requires interaction with patrons and other lifeguards on shift, and can involve other activities, in addition to lifeguarding. This complexity should be replicated in future evaluations to assess the capacity of participants to sustain performance over extended periods in virtual contexts. The outcomes will have important implications for the subsequent application of these tools for training and development.

The scenarios in the present study were also limited to daylight hours, and in a pool that was symmetrical. Future research needs to be directed towards testing the effectiveness of virtual scenarios during dawn, dusk, and at night when visual perception tends be more challenging. Similarly, complex recreational pools that are irregularly shaped and/or contain mechanical wave features likely present more challenges for lifeguards, particularly in positioning to maximise oversight of the visual scene.

Increasing the complexity and difficulty associated with the simulated scenarios will enable further evaluations of the validity of virtual lifeguard training and provide opportunities to test the sensitivity amongst lifeguards with greater and lesser experience. In the present study, participants differed in their qualification as a lifeguard and while this provides the basis for an initial evaluation, sensitivity should be demonstrated amongst lifeguards who are qualified but differ in experience (Page et al., 2011). Importantly, this would involve an assessment of false-positive and false-negative responses to distinguish response bias from signal detection.

The construction of an interface and the provision for feedback will provide opportunities to evaluate the user experience and usability of the training tool as it is introduced into the training curriculum. This provides the opportunity to assess the pedagogical viability and the stage during the training and development program at which the simulation should be introduced.

4.3. Conclusions

The present study was conducted to examine whether differences exist between qualified pool lifeguards and non-lifeguards in the accuracy and speed with which they detect drowning swimmers during a virtual reality-based aquatic pool simulation. It was intended to establish the initial construct validity of virtual simulations as a potential precursor to their implementation as training tools in the context of drowning detection in an aquatic swimming pool. Compared to non-lifeguards, pool lifeguards demonstrated more accurate detection of drowning targets and spent less time fixating on the target, prior to the drowning event in the 13 and 23 min virtual scenarios. The results also suggest that pool lifeguarding experience is associated with the application of scanning techniques that facilitate sustained attention and that exposure to successive virtual scenarios improves the performance of both lifeguards and non-lifeguards in detecting drowning victims. From an applied perspective, the outcomes provide strong evidence of the value of virtual reality for lifeguard training and assessment.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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