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An exploration into the contributing cognitive skills of lifeguard visual search

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Abstract

Lifeguard drowning detection in swimming pools and beach settings is influenced by experience. The current experiment explores the cognitive skills that might underlie this experience effect. Lifeguard and non-lifeguard performance in a domain-free multiple object avoidance (MOA) task and a partially domain-free functional field of view (FFOV) task was compared to performance on an occlusion-based drowning detection task. Lifeguards performed better than non-lifeguards on the MOA task and the FFOV central task (identifying whether an isolated swimmer was drowning). However, only performance in the central FFOV task was associated with performance in the occlusion-based drowning detection task, and this was the only part of the two tasks that was not domain-free. These results suggest lifeguard drowning detection is mainly driven through the learned ability to process behaviours of drowning swimmers quicker than non-lifeguards. Therefore, it may be possible to train novices' ability to detect drowning swimmers through an exposure task.

KEYWORDS
drowning detection, experience effects, functional field of view, lifeguard visual search, multiple object avoidance

1 | INTRODUCTION

Lifeguarding is a challenging visual task, which can have devastating consequences when failures in visual supervision occur. The visual search of a lifeguard shares similarities with other real-world visual surveillance tasks, where missed targets have life-or-death implications (radiology, airport security, and military). The very real impact of these searches makes it important to understand the skills that contribute to successful target identification. Understanding these contributing processes could lead to improvement in future training and performance.

Previous research exploring lifeguard drowning detection found differences between lifeguards and non-lifeguards in their detection accuracy and response times (Laxton & Crundall, 2018). However, the eye-movements of lifeguards and non-lifeguards do not necessarily reflect this detection superiority (Laxton et al., 2020; Laxton et al., 2021; Smith et al., 2020). In both the Laxton et al. (2020) and Laxton et al. (2021) studies there was a suggestion that small non-significant gains in both the time to first fixate the target, and the amount of processing time required, added up to produce a significant superiority in response times to drowning targets. Despite this repeated trend across two separate studies, no clear pattern of significance was forthcoming.

In another recent study, Vansteenkiste et al. (2020) recorded the eye movements of lifeguards during their shifts at a beach. They suggested that their experienced lifeguards had a more flexible visual search strategy that was responsive to task demands (with experienced lifeguards having longer fixations on task-relevant stimuli). Novice lifeguards were more easily distracted and did not have as much variation in their fixation durations, suggesting less-flexible visual search (similar to novice drivers, Crundall & Underwood, 1998). The lack of outcome measures relating to drowning targets makes it difficult to conclude anything about the efficacy of the visual search differences however, though the differences in fixation duration argue for processing differences rather than scanning differences. Vansteenkiste et al. argued that the novices appeared to know where to look, but not what behavioural cues should retain their attention.

Understandably, given the paucity of research in this field, no clear explanation for experienced lifeguard superiority in detecting drowning targets lies within the measures of eye movements. Indeed, the limited evidence is contradictory in some places, with Laxton et al. (2020, 2021) suggesting that shorter processing times reflect lifeguarding experience, while Vansteenkiste et al. (2020) found longer fixations to be the hallmark of expertise. A possible reconciliation of these findings might be that experienced lifeguards can process drowning targets faster than novices or controls, but in a situation where no target appears, they may be more likely to dwell on the most likely potential target in anticipation of a drowning event. Unfortunately, using coarse eye movement measures may be insufficient to identify why experienced lifeguards are superior, as the reason for any group differences may be caused by many things. For instance, short fixations on a possible target may reflect fast processing, or inadequate processing leading to a false rejection. An alternative approach is to investigate a select number of theoretically chosen cognitive tasks which may measure a variety of subskills underlying the complex behaviour. If performance on such highly targeted tasks relates to performance on a drowning detection task, this may allow firmer conclusions about the nature of lifeguard superiority.

1.1 | Functional field of view

A range of cognitive skills could be argued to underlie drowning detection, but the extent and usefulness of one's peripheral attention seems particularly appropriate. To successfully monitor a swimming pool zone, a lifeguard must rapidly respond to any changes in the environment. These changes will often occur in peripheral vision first, with attention then oriented to the source of the perturbation. Expert advantages in the detection of parafoveal targets have been noted in other domains, such as in elite sportspeople (Matos et al., 2019; Murphy, 2017), where greater sensitivity to extra-foveal target features is a typical characteristic of experienced athletes.

This behavioural difference between novice and experienced participants can be captured with a functional field of view (FFOV) task or a useful field of view test (UFOV). While the former task refers to a broad range of in-house tests developed by a variety of research groups across the world (e.g., Atchley & Dressel, 2004; Crundall et al., 1999; Williams, 1982; Williams, 1989), the UFOV is a very specific task that uses a set of simplified and validated stimuli (Ball et al., 1988). Whether one chooses the FFOV or UFOV, such tests are designed to capture the level of information that is available to a participant at varying eccentricities from the point of fixation.

One interesting aspect of these peripheral attention tasks is the impact of a stimulus at the point of fixation, as the extent of foveal processing can have a concomitant reduction on participants' abilities to spot extra-foveal targets (Lavie, 1995; Wood & Owsley, 2014). This may be especially relevant for a lifeguard who is likely to be looking at one swimmer (foveal target), when another swimmer gets into trouble in a different area of the pool (extra-foveal target). If a novice lifeguard finds it harder to process a foveated swimmer (i.e., determine whether that swimmer is a target), they may also suffer from a reduced FFOV as attention is redeployed from peripheral regions to increase attentional resolution at the point of fixation (Crundall et al., 2002). Similar foveal processing is induced in the UFOV test, with participants required to identify whether the image at the centre of fixation represents a car or truck, with a concomitant impact on peripheral target detection.

While there has been very limited research into the cognitive skills that contribute to lifeguard surveillance, other applied domains have employed UFOV and FFOV tests (Atchley & Dressel, 2004; Gasper et al., 2016; McManus et al., 2015; Wood et al., 2011). In one domain-specific example, Crundall et al. (1999) explored differences between experienced and inexperienced drivers. As expected, they found that experienced drivers had the best responses to peripheral targets, and inexperienced drivers had the worst. When on-road hazards were present (e.g., a car ahead suddenly displays brake lights), peripheral target detection decreased for both driver groups, though the inexperienced drivers always performed more poorly. This suggests the appearance of a hazard was fixated by drivers, with attentional resources reallocated from extra-foveal regions to the point of fixation in order to process the hazard. In a later study by Crundall et al. (2002) it was found that the FFOV of experienced drivers degraded to the same absolute level as that of learner drivers (and was therefore a relatively greater degradation than that suffered by learner drivers), but this happened in very short bursts. Experienced drivers appeared more able to process the hazard quickly during this burst of intense concentration at the point of fixation, and then rapidly reallocate resources back to the extra-foveal regions. Thus, it appeared that the two groups utilised different strategies for processing hazards regarding the time course of deployment of extra-foveal attention. Experienced drivers may have developed a strategy to reduce the time they are inattentive to peripheral locations, leading to a higher likelihood of detecting peripheral dangers.

On this basis we argue that the deployment of extra-foveal attention may relate to lifeguard superiority in drowning detection tasks. Following evidence that experienced lifeguards may process targets differently from control participants (Laxton et al., 2020; Laxton et al., 2021; Vansteenkiste et al., 2020), we thought it appropriate to include domain-relevant targets at the point of fixation to assess the impact of potential processing differences on extra-foveal target detection.

1.2 | Tracking multiple objects

A second skill that may contribute to lifeguard drowning detection is the ability to track swimmers around the pool, following their trajectories, noting any changes in behaviour and observing when people enter or leave the pool area, or transition from shallow to deep areas. This skill is similar to that of the domain-free cognitive task of multiple object tracking (MOT).

In typical MOT tasks, observers are shown a fixed number of identical objects (typically circles or "balls") in a display. A number of these balls are identified as target items, by either being briefly highlighted or by briefly flashing in the display. All the balls then begin to move, following individual random trajectories. After a varied tracking period, the items stop moving and the observer must identify whether a probed item falls within the target set. Subsequent trials often increase the number of balls on the screen, increasing task difficulty via a staircase method. The tracking task provides a measure of sustained attention to the positions of multiple objects because observers must continuously update their representations of objects' positions. Accuracy in MOT is noted to decline as the number of targets increases, which suggests a capacity limit to tracking (e.g., Cavanagh & Alvarez, 2005; Pylyshyn & Storm, 1988; Sears & Pylyshyn, 2000), and there appears to be individual variation in the extent of this skill (Meyerhoff & Papenmeier, 2020; Wilbiks & Beatteay, 2020).

Real world applications of MOT often involve assessing special populations who are predicted to have domain-free tracking advantages due to domain-specific expertise. For instance, Allen et al. (2004) assessed the MOT skills of professional radar operators. This profession requires operators to monitor, control and supervise multiple aircraft via a screen as they move through the environment in real time. They found professional radar operators were able to track more balls than undergraduates in both single and dual task conditions, suggesting that they have developed a degree of resistance to attentional demands during simultaneous tasks.

The MOT task is generally passive in nature, with the observer often fixating a central location and covertly tracking a subset of items (Hyönä et al., 2019). This passive observation may not be reflective of real-world tasks, such as lifeguarding, which generally require more active viewing, with more eye and head movements. Often in real world tasks people are required to interact with the environment around them to some degree. For example, a car driver needs to be able to control the car whilst also maintaining visual attention. In lifeguarding there is a changing priority hierarchy, where some swimmers become more important (i.e., those displaying precursors to drowning behaviours) and others less so (those display normal swimming activity) over the duration of a surveillance shift. To account for such task demands recent research has explored more interactive versions of the standard MOT task and in relation to applied domains such as sport and driving (Thornton et al., 2014; Mackenzie & Harris, 2017, Mackenzie et al., under review).

These interactive avoidance tasks usually require participants to interact with one or more items on the screen to avoid collisions (e.g., between the randomly moving balls). The number of items that participants can have on-screen at any one time has been noted to be higher than the number of items that are tracked in traditional MOT tasks, however this is likely to be due to participants only needing to track a subset of distracters at any one time (Thornton et al., 2014), based on the changing characteristics of the other balls (i.e., their trajectory).

The multiple object avoidance (MOA) task is one recent variant of a typical MOT task designed to explore cognitive control and visual attention. In the MOA task, one item, or ball, is controlled by the participant while several other balls move around the screen with random trajectories. The participant must move their controlled ball in such a way as to avoid a collision between their ball and the others. If the controlled object collides with one of the other balls, the task ends. If a participant avoids any collisions, more balls are added to the display over time (Mackenzie et al., 2021; Mackenzie & Harris, 2017).

During the MOA task participants are required to make predictions of when a non-controlled ball is going to become a target worthy of increased attention by using the individual path and pace of the moving balls to predict potential collisions. These predictions need to be constantly updated as the balls move around, and as new balls are added to the display. The further back in time a prediction can be made and the more of these predictions that can be held in working memory, the better the participant can avoid a collision. This relates to the lifeguard's task, which requires them to monitor and prioritise swimmers for future attention based on visual cues for potential drowning danger. Essentially the lifeguard is predicting which of the swimmers are most likely to get into trouble, in the same way that the participant in an MOA task must predict and prioritise the balls in order to avoid a collision.

Mackenzie and Harris (2017) suggest that throughout the MOA task eye-movements are required to successfully avoid a collision, and is therefore more reflective of active, dynamic tasks where shifting subsets of tracked distractors must be monitored and an active, overt visual search is required. Mackenzie et al. (2021) recently replicated the success of applying the MOA in the driving domain, and extended it to the sporting domain, finding that experienced sports players demonstrated superior MOA ability than non-sports players. MOA may therefore be a better test to identify any underpinning skills of lifeguard superiority, as lifeguards are unlikely to use a central fixation location to track swimmers peripherally (which can be a successful strategy in MOT tests) and are required to prioritise swimmers for attention based on predictions about who might become a potential danger (i.e., require lifeguard intervention).

1.3 | The current study

Based on the discussion of the literature above, this experiment aimed to explore any differences between trained lifeguards' and non-lifeguards' skills in a FFOV task and a MOA task. Task scores for these two cognitive tests were compared to performance on a shortened version of the occlusion drowning-detection task that was employed in Laxton et al. (2021). This test requires participants to scan naturalistic videos of swimmers in a pool and identify any swimmer in distress. Laxton et al. (2021) found that experienced lifeguards outperformed non-lifeguards. Use of this test in the current study was intended to identify whether the underlying cognitive tasks relate to drowning detection, and to confirm that there is a lifeguard superiority effect in the current sample.

The partially domain-free FFOV task aimed to measure the information extracted by lifeguards and non-lifeguard participants from extra-foveal regions via briefly presented peripheral targets (small grey squares). To maintain participants' fixation at the centre of the screen they also had to process a dynamic central target (a small video window containing a swimmer who was either displaying drowning behaviours or engaged in casual fun swimming). The domain-free MOA task aimed to measure how long MOA could be maintained, with the task increasing in difficulty as time progresses (one new ball added to the display every 10 s).

It was predicted that lifeguards would perform better on the drowning occlusion task, replicating Laxton et al. (2021). More interestingly however, we hypothesised that higher performance on the MOA and FFOV would be positively associated with drowning-detection performance in the occlusion task, with lifeguards being more successful in both tasks compared to the non-lifeguards.

2 | METHOD

2.1 | Participants

A total of 60 participants were recruited to take part in a visual search study (with a mean age of 24.33, *SD* 10.88, 31 female). A total of 30 of these participants (mean age 21.5, *SD* 4.88, 11 females) had completed the UK Royal Life Saving Society (RLSS) National Pool Lifeguard Qualification (NPLQ) prior to testing and had a varying amount of experience in poolside lifeguard duties (3.98 years of lifeguarding experience on average, *SD* 4.77). The remaining 30 participants (mean age 27.17, *SD* 14.16, 20 females) had no lifeguarding experience. Lifeguards were recruited from advertisements on social media sites including Linkedin, Twitter and Facebook, and were all from the United Kingdom. Non-lifeguard participants were an opportunistic sample from the United Kingdom.

2.2 | The three tasks comprising the current study

All participants were tested on three tasks: A drowning occlusion task, a FFOV task, and a MOA task. The following sections provide the design and stimuli of these individual tests, detailing how performance on these tests was assessed. These subtests are then combined in the following Design and Procedure sections.

2.2.1 | Occlusion task

The occlusion task used by Laxton et al. (2021) was chosen to provide this measure of drowning detection ability. A comparison of lifeguard and non-lifeguard touch-screen accuracy for detecting a drowning target in the occlusion task was planned to verify that the task is sensitive to lifeguard experience.

A total of 10 clips containing a drowning swimmer among many other swimmers were included in this experiment (i.e., clips from a pool that required a real-life intervention by a lifeguard, downloaded with permission from YouTube[1]). These clips had previously been used to develop an occlusion-based test by Laxton et al. (2021). For the current study, we selected those clips that showed the largest difference in accuracy between lifeguards and non-lifeguards in the Laxton et al. study. Three clips that did not contain a drowning swimmer were also included. These were chosen at random from an existing clip set. The 10 drowning clips and 3 non-drowning clips were randomised for all participants within a single block. Non-drowning clips were included to reduce participant guessing.

The clips used in the occlusion task show a wave-pool in the United States. Each clip was presented up to a point where the drowning target was visibly in distress (with an average of 2.8 s of visible distress). The clip then freezes, and the picture becomes blurred, removing any clues as to which swimmer might be drowning, but retaining sufficient information for participants to indicate which blurred swimmer they thought was in distress prior to occlusion. Participants were required to either touch the location of the distressed swimmer on the screen, or touch a black box in the right-hand, bottom corner of the screen to indicate no drowning had been seen (see Figure 1). Accuracy of responses was recorded, with a responsive window placed around the target area (measuring 250 $\times$ 140 pixels in the horizontal and vertical axes respectively). The response window accounted for 0.8% of the total screen area. Correct responses were noted if a drowning swimmer was correctly identified, or if the trial was correctly identified as a no drowning trial. If a response was given outside of the responsive window, then an incorrect response was noted. Videos clips played to full length, with the occlusion screen presented at the end of the video.

The occlusion trials were run in a randomised block, with a feedback screen after each trial. Participants were able to make localised responses on the touch screen of the laptop.

2.2.2 | Functional field of view task

The FFOV task can be split into two separate sections, a central task with an isolated target, and a peripheral task where a target briefly appears in the space around the central target. There were 56 central targets, 28 of which were a drowning swimmer presented in a small video window at the point of fixation. A further 28 central targets merely contained a swimmer engaged in fun play. The peripheral targets were positioned in one of eight locations, four near the central target (200 pixels from the centre of the screen) and four further away from the centre (325 pixels from the centre of the screen). The location of the peripheral targets (left, right, above and below the central target) was not considered to be a factor as there was no theoretical reason to predict an asymmetry in FFOV as one might expect in other domains such as reading (Jordan et al., 2014; Paterson et al., 2014).

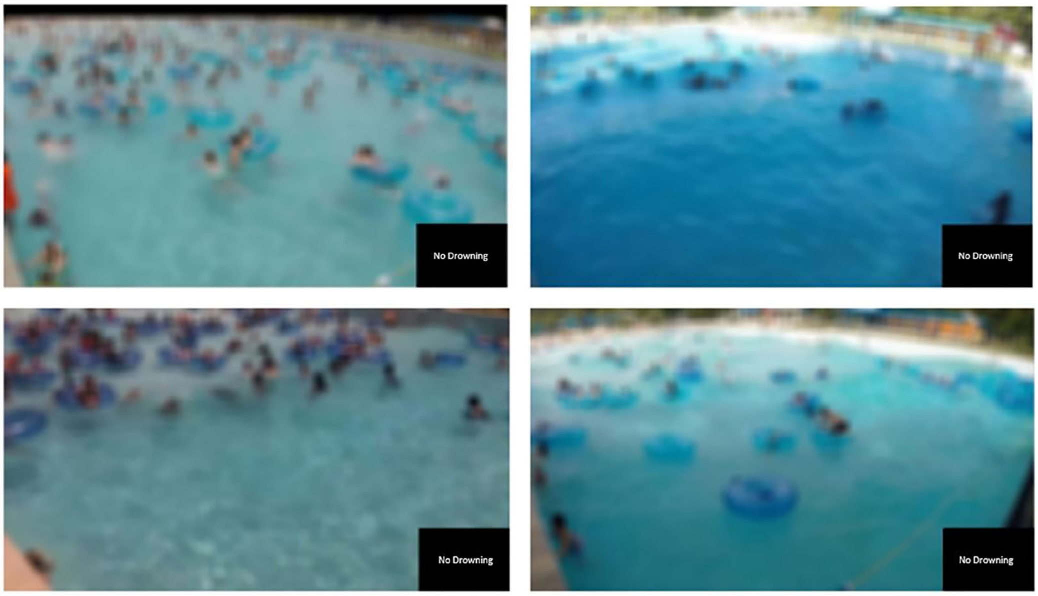

FIGURE 1 Four screenshots taken of the blurred occlusion screen used for the occlusion task

The stimuli for the central target consisted of closely cropped, three-second videos of a swimmer either in difficulty ("drowning"; e.g., displaying the instinctive drowning response; Pia, 1974) or engaged in fun play ("non-drowning", e.g. splashing, jumping). These small videos (150 × 150 pixels) were taken from the same YouTube channel as the occlusion clips, although different footage was used for the two tasks. Drowning targets were determined as such because they evoked a response from the lifeguard in the full clips. These targets were presented in the centre of the screen on a grey background. The target swimmer was always visible within the central window and was presented in isolation without other distracting swimmers.

During presentation of this central target a 50 × 50 pixel grey outline of a square (see Figure 2) appeared in one of eight locations that were vertically or horizontally aligned with the central target. Four of the targets were considered "near" to the central target (200 pixels, 6.8 degrees of eccentricity), while the other four were classed as "far" from the centre (325 pixels, 11.8 degrees of eccentricity). Target locations were chosen randomly without replacement, with a random stimulus onset asynchrony of between 0.5 and 2.5 s following the appearance of the central target. The peripheral target appeared for 300 ms. A central fixation cross was displayed before presentation of each trial for 500 ms.

After each trial two further screens were displayed. The first asked participants to respond with a 1 on the keyboard if the central target was drowning and a 0 if not. The second screen asked where the peripheral target was displayed. This response screen had all the potential peripheral locations displayed and required participants to make a touch screen response on a location via a laptop touch screen. The experiment was created in Psychopy, using Python coding and presented on a screen resolution of 2880 × 1620.

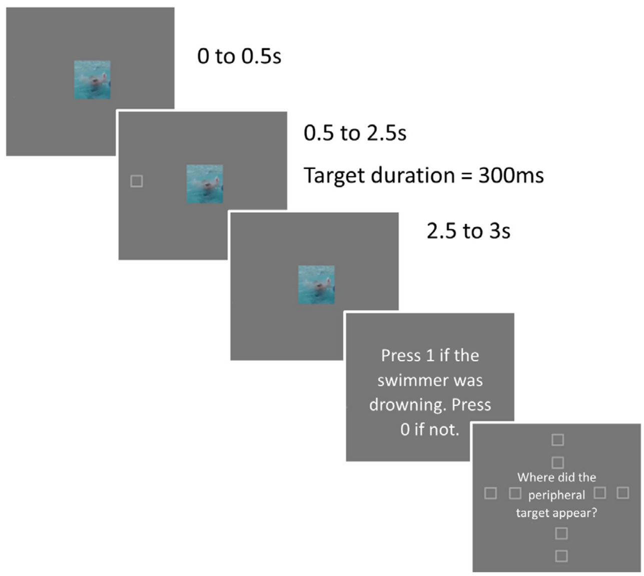

FIGURE 2 The timeline of a trial in the FFOV test

2.2.3 | The multiple object avoidance task

Analysis of performance on the MOA merely compared performance across the two groups (lifeguard vs. non-lifeguard). Each trial started with a blue ball, which was controlled by moving a finger on the laptop touchpad. The ball could be moved freely around an 800 × 800 pixel window. Three red balls were also presented at the beginning of each trial and moved randomly around the screen (see Figure 3). A new ball was added to the array every 10 s until the blue ball inevitably collided with one of the red circles. The time MOA was maintained

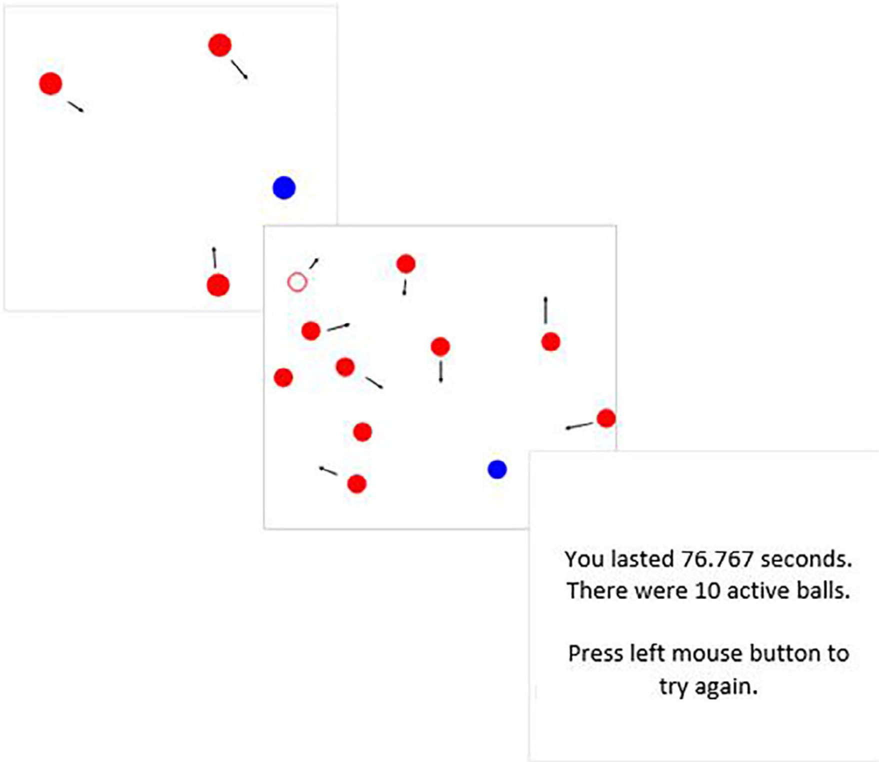

FIGURE 3 Three screen shots from the MOA task. Top: The test starts with three red balls. The participant must move the blue ball to avoid a collision. Middle: Successful participants have an extra ball added every 10. Here a tenth ball has just been added. It remains transparent for 1000 ms s, during which time collision detection is suspended. Bottom: The feedback screen after a collision has occurred

was recorded as the main dependant variable. These measures were averaged across five trials. Each trial lasted until the participants had a collision between their control ball and one of the distracters. The speed of the moving red balls was randomised across trials, and each individual ball moved at a different speed. For a more detailed description of the task please see Mackenzie and Harris (2017).[2] This experiment was conducted on the same equipment as the FFOV task.

The three tasks (FFOV, MOA & occlusion) were run in one testing session, with the task order counterbalanced between participants. A Lenovo Yoga touch screen laptop was used, with a screen resolution of 2880 × 1620, running Psychopy.

2.3 | Procedure

Testing sessions were arranged at various swimming pools and leisure centres around the United Kingdom with a quiet office or side-room acting as the laboratory. Non-lifeguard participants were tested under similar conditions. Participants were given written instructions and asked to fill in a consent form and demographic questionnaire. Prior to the study, participants were made aware of the nature of the experiment and that they would see short clips that may show swimmers in distress. They were also informed that none of the distressed swimmers suffered any injury, with all of them receiving a timely intervention from the lifeguard on duty. A practice trial was given before each of the three tasks. Upon finishing the three tasks, the participants were fully debriefed and thanked for their time and participation. This research was conducted with approval obtained from Nottingham Trent University ethics committee and run in accordance with British Psychological Society guidelines.

2.4 | Data analysis

A number of analyses were undertaken to explore the data. The design of the FFOV and occlusion task allowed for the calculation of simple signal detection (SDT) measures d' (sensitivity) and c (criterion), with participants making a decision regarding the presence of a drowning target. The measure of d' (a measure of sensitivity to the signal; zHits – zFalse Alarms) and c (the criterion bias to say "yes" regardless of the information; [zHits + zFalse Alarms]/2) were calculated for each participant and then compared in both the FFOV central target analysis and the occlusion task analysis across each experience group.

The analysis for each individual task is detailed in the below section. Mixed effects models were used to analyse task performance data. Traditional factorial ANOVAs do not account for variability across participants and stimuli (trials) which can inflate Type 1 Error. These were treated as random effects in the models. In addition, performance in the occlusion, FFOV Central and FFOV Peripheral tasks produced a discrete outcome per trial (1 or 0) and not continuous (as a factorial ANOVA would treat), requiring logistic regression. A linear mixed effects model was used in the case when MOA task performance was the outcome variable as performance is measured as a continuous variable (seconds) in this instance. All models were fitted using the package lme4 in R (Bates et al., 2015). In all cases, a series of models were run sequentially increasing the complexity starting with a null model (a model with a constant in place of fixed effects) through to main effects and where appropriate, interaction models. *p* values were generated by comparing models to each other using likelihood ratio tests.

3 | RESULTS

All participants contributed to the results, with no outliers removed. Analysis of the three separate tasks will be reported first, before the final section relates the performance of participants on the FFOV task and the MOA task to their performance on the drowning occlusion task.

3.1 | Analysis of the drowning occlusion task

Responses to the drowning occlusion task were analysed to confirm that these clips differentiate between the groups of lifeguards and non-lifeguards, as expected following the results reported by Laxton et al. (2021). This was considered essential to demonstrate that the occlusion task is sensitive to lifeguard experience and could therefore act as a criterion variable for the main regression of this study (predicting occlusion performance from FFOV and MOA performance). All data were analysed using binary mixed effects logistic regression with accuracy (correct, incorrect) as the outcome variable, experience (lifeguard, non-lifeguard) as the fixed effect, and participant and trial added as random effects.

The response rates to non-drowning trials were assessed first for the occlusion drowning detection data. On average, non-lifeguard participants successfully avoided making an incorrect response to 2.1 of the three catch trials, while the lifeguard participants successfully avoided making a response to 2.5 catch trials. Given the small number of catch trials, it was unsurprising to find that this difference was not significant where the main effects model did not fit the data better than a null model (G^2 [1] $= 3.06$, $p = .08$).

Correct responses to drowning-present trials were assessed. Trials with a drowning target were considered incorrectly responded to if a response was made to an incorrect location, or a no drowning response was made. On average, lifeguard participants correctly responded to 67% ($SD = 22.3\%$) of drowning targets, while the non-lifeguards successfully responded to 36% ($SD = 19.4\%$) of drowning targets. The main effects model fitted the data better than the null model (G^2 [1] $= 26.22$, $p < .001$) indicating that non-lifeguards were significantly less likely to be correct than lifeguards (OR $= 0.18$, $SE = 0.31$, $z = -5.43$, $p < .001$). This confirms the success of this task in differentiating participant groups based on lifeguarding experience as noted previously by Laxton et al. (2021).

A linear model with independent comparisons compared d' and criterion SDT measures across the two participant groups (lifeguard and non-lifeguard). Lifeguards were found to have significantly higher sensitivity than non-lifeguards (t[58] $= 4.87$, $p < .001$) with d's of 1.15 and 0.003, respectively. There was no difference in criterion scores (t[58] $= 1.67$, $p = .10$; with scores of $-.71$ and -0.51 for lifeguards and non-lifeguards respectively).

3.2 | Analysis of the FFOV task

The responses to the central target were analysed. A response was noted as correct if a drowning target was successfully identified or a non-drowning target correctly rejected. Responses are therefore binary in nature. Responses were analysed in a 2×2 mixed effects binary regression with Group (lifeguard; non-lifeguard) and Trial Type (Catch, Target) entered as fixed effects and Trial number and Participant ID entered as random effects.

Whilst there was a main effect of Experience (G^2 [1] $= 7.31$, $p = .01$) and Target Type (G^2 [1] $= 5.44$, $p = .02$), the interaction model fit the data best (G^2 [1] $= 12.21$, $p < .001$). Pairwise comparisons with a Tukey correction revealed that the likelihood of being more accurate was significantly higher in lifeguards ($M = 83.3\%$) compared to non-lifeguards ($M = 73.0\%$) for the target trials (OR $= 0.47$, $SE = 0.19$, $z = 4.09$, $p < .001$). There was no difference in accuracy between lifeguards (87.0%) and non-lifeguards (86.4%) for the Catch trials (OR $= 0.95$, $SE = 0.2$, $z = 0.23$, $p = .82$). The predicted accuracy as modelled by the regression can be viewed in Figure 4.

The responses to the peripheral targets were then analysed. A response was noted as correct if a response was given in the correct location and eccentricity. Responses are binary in nature (correct/incorrect). Responses were analysed in a 2×2 mixed effects binary regression with group (lifeguard; non-lifeguard) and eccentricity (near, far) entered as fixed effects, while trial number and participant ID were entered as random effects. It was revealed that neither the main effects model (G^2 [1] $= 0.44$, $p = .51$) nor the interaction model (G^2 [1] $= 0.04$, $p = .84$) fitted the data better than a null model. Thus, there was no evidence of accuracy differences between experience groups or between eccentricities of targets. The predicted accuracy as modelled by the regression can be viewed in Figure 4.

Measures of d' and c were calculated for each participant on their central task performance. These measures combined the hit rate for each participant across all drowning swimmers and compared them to the number of false alarms, where participants reported a drowning swimmer in catch trials.

A linear model with independent comparisons compared these SDT measures across the two participant groups (lifeguard and non-lifeguard). Lifeguards were found to have significantly higher sensitivity to drowning swimmers than the non-lifeguards (t[58] $= 2.69$, $p = .01$), with d' means of 2.34 and 1.95, respectively. There was no difference between the groups in terms of criterion values (t[58] $= 1.76$, $p = .08$), with mean criterion values of -1.63 for lifeguards and -1.36 for non-lifeguards.

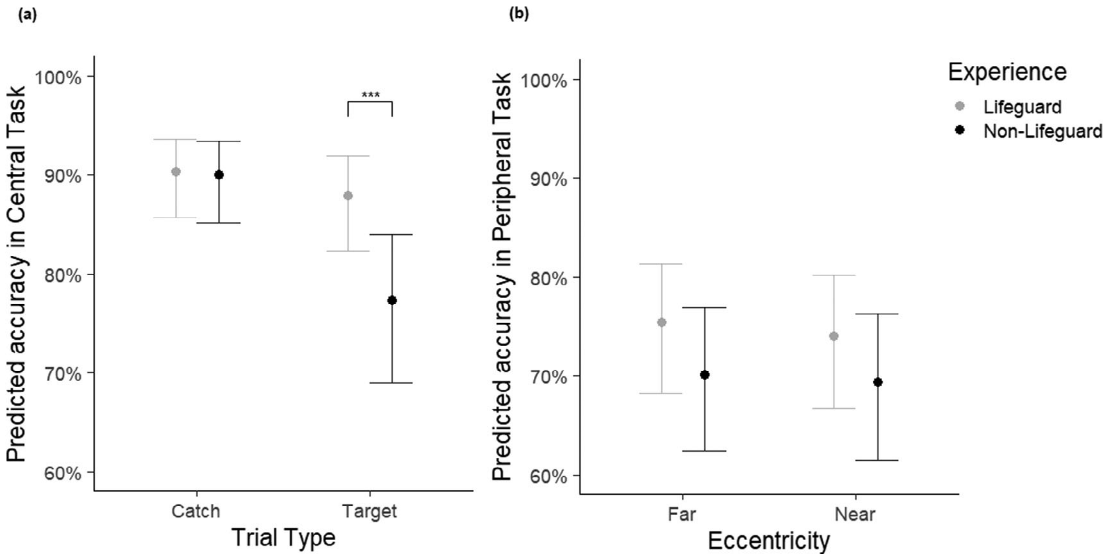

FIGURE 4 Upper and lower confidence intervals for modelled predicted performance in (a) the central task (experience by trial type) and (b) peripheral task (experience by eccentricity). **p* < .05; ***p* < .01, ****p* < .0001

3.3 | Analysis of the MOA task

The measure of performance on this task was the duration of trial time, with a longer trial time reflecting better performance at successfully avoiding a collision. Trial times were analysed in a one-way linear mixed effects model with experience (lifeguard; non-lifeguard) as a fixed effect and MOA trial and participant ID as random effects. The main effects model fit the data better than a null model (χ^2 [1] = 6.85, $p = .01$) with lifeguards ($M = 26.4$ s) performing significantly better than non-lifeguards ($M = 21.8$ s) (Figure 5).

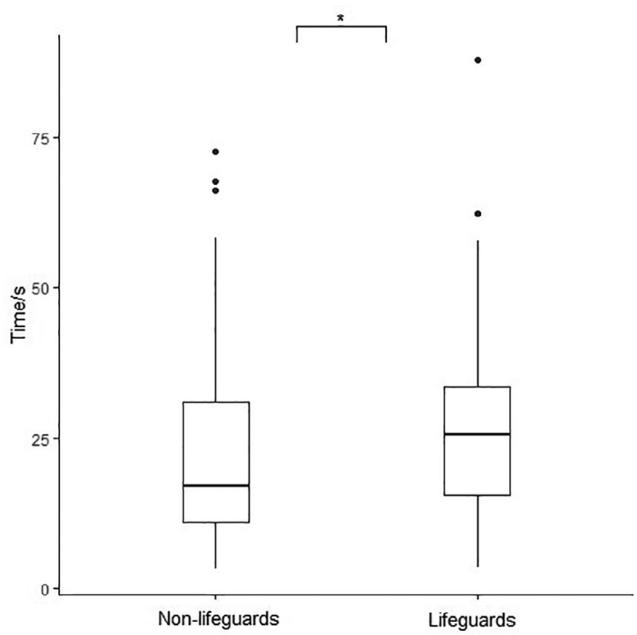

FIGURE 5 MOA trial duration in seconds for lifeguards and non-lifeguards. Data show range, median and interquartile ranges. **p* < .05; ***p* < .01, ****p* < .0001

3.4 | Predicting occlusion task performance from experience, FFOV and MOA performance

A binary mixed effects regression was conducted to identify how the predictors of experience (lifeguard and non-lifeguard), FFOV performance on central targets (lifeguarding domain-specific task), FFOV performance on peripheral targets (non-domain specific task), and MOA performance predicted accuracy on the occlusion task. Participants and trials were added as random effects. The means and *SD*s for each variable can be seen in Table 1, along with inter-variable correlations (for averaged performance data).

It was revealed that the main effects model fitted the data best (G^2 [4] = 37.27, $p < .001$). Experience significantly predicted performance in the occlusion task with lifeguards obtaining higher scores than non-lifeguards (OR = 0.27, B = 1.30, $SE = 0.33$, $z = 4.0$, $p < .001$). Higher performance on the FFOV Central Task predicted higher scores on the occlusion task ($B = 0.05$, $SE = 0.02$, $z = 2.75$, $p < .01$). Performance on the FFOV Peripheral Task ($B = 0.02$, $SE = 0.01$, $z = 1.82$, $p = .07$) and MOA task ($B = 0.02$, $SE = 0.02$, $z = 0.86$, $p = .39$) did not predict performance on the occlusion task.

Whilst it did not fit the data any better than the main effects model, the interaction model was also significant ($p < .001$). Of theoretical interest here is how each task (central, peripheral and MOA) predicted occlusion performance within Lifeguards and Non-lifeguards. Within Lifeguards, performance in the FFOV Central Task predicted higher scores on the occlusion task ($B = 0.1$, $SE = 0.03$, $z = 3.25$, $p = .001$). Performance on the FFOV Peripheral task ($B = 0.02$, $SE = 0.01$, $z = 1.78$, $p = .08$) and MOA task ($B = 0.03$,

TABLE 1 Means, *SD*s, and correlations between variables for all participants

		1.	2.	3.	4.	5.	*M*	*SD*
All participants	1. Occlusion	1					51.5%	25.96%
	2. Experience	.602**	1					
	3. MOA time (seconds)	.299*	.338**	1			24.21	7.08
	4. FFOV central	.424**	.337**	.120	1		82.41%	8.27%
	5. FFOV peripheral	.248	.138	.193	−.026	1	70.02%	18.09%
Lifeguards	1. Occlusion	1	–				67%	22.3%
	3. MOA time (seconds)	.102	–	1			26.6	6.50
	4. FFOV central	.483**	–	−.020	1		85.2%	6.81%
	5. FFOV peripheral	.207	–	−.027	−.123	1	72.5%	16.0%
Non-lifeguards	1. Occlusion	1	–				36%	19.4%
	3. MOA time (seconds)	.156	–	1			21.8	6.93
	4. FFOV central	.137	–	.026	1		79.6%	8.78%
	5. FFOV peripheral	.216	–	.297	−.049	1	67.5%	19.9%

Note: All data were averaged.
*$p < .05$.
**$p < .01$.

$SE = 0.03$, $z = 1.02$, $p = .31$) did not predict occlusion task performance in lifeguards. Within non-lifeguards, performance on the FFOV Central Task ($B = 0.02$, $SE = 0.02$, $z = 1.08$, $p = .28$), FFOV Peripheral task ($B = 0.01$, $SE = 0.01$, $z = 1.16$, $p = .25$) and MOA task ($B = 0.01$, $SE = 0.03$, $z = 0.44$, $p = .66$) did not predict occlusion task performance.

4 | DISCUSSION

Previous studies have demonstrated lifeguards have better performance on a variety of drowning detection tasks (e.g. Laxton et al., 2020; Laxton et al., 2021; Page et al., 2011). This study aimed to identify whether participants' abilities on two cognitive tasks might underlie their performance on such drowning tasks. An FFOV task and MOA task were chosen, with performance on these tasks compared to a drowning occlusion task adapted from Laxton et al. (2021).

In summarising the results, it is first worth noting that the drowning occlusion test identified a significant difference in performance between the lifeguards and non-lifeguards, both in terms of the percentage of drownings correctly identified, and in terms of sensitivity (d'). This confirms the findings of Laxton et al. (2021) which used a longer version of the drowning occlusion task. The significant difference between the groups on this drowning occlusion task in the current study confirms that it is a suitable measure of lifeguard skill for the subsequent regression analyses. Furthermore, Cohen's d suggests that the effect size for this shortened version of the occlusion task was greater (1.48) that the longer version used in Laxton et al. (2021); with Cohen's d of 1.12. This is understandable as the clips chosen for the current study were those that demonstrated the greatest difference between experience groups in the Laxton et al. (2021) study. One final point of note with this analysis is the lack of difference between the criterion measures produced by the two groups, where criterion is the bias to say yes regardless of information. Again, this is an understandable result given that the occlusion method has been adopted in the driving domain precisely because it reduces criterion bias compared to other procedures that rely on response time measures (Crundall, 2016).

Analysis of the FFOV test was predicted to reveal an advantage for lifeguards in the detection of context-free peripheral stimuli while simultaneously processing a domain-relevant target at the point of fixation. However, there was no evidence for this effect in peripheral target responses, though lifeguards demonstrated a superiority in their responses to the central task. Previous findings have noted experts in other domains to have a larger field of view, detecting both central targets and peripheral targets more accurately (Crundall et al., 2002; Robbins & Chapman, 2019; Wolfe et al., 2017). However, in these previous studies of the driving domain, targets were not presented in isolation. Instead, peripheral targets were presented randomly during the presentation of a full screen driving clip during which drivers were asked to search for hazards. The eccentricity of the peripheral target from the point of fixation, and the processing difficulty of what the participant was looking at (hazard or non-hazard) was determined by the participant's scan of an unfolding dynamic scene. It is possible that FFOV experiential effects were found in these driving studies because there was a genuine reason that drivers might want to reorient attention based on a peripheral cue (i.e., a sudden peripheral onset might indicate the appearance of a pedestrian entering the roadway). In the current study however, following the design of many traditional FFOV studies (Harada et al., 2015; Power & Conlon, 2017), there was no domain-relevant need to attend to extrafoveal regions, as the information of primary interest (the drowning/non-drowning swimmer) was always placed at the centre of the screen. If the peripheral targets had appeared overlaid on a full video display of a swimming pool, with participants encouraged to search wherever they wanted, lifeguards may have had an increased reason to deploy extrafoveal attention, thus producing the predicted experiential effect on peripheral target detection.

Despite the lack of group differences on peripheral target detection, the lifeguard superiority noted for central targets was of interest. This suggests that lifeguards are sensitive to the features of a drowning swimmer and can more accurately differentiate between drowning and non-drowning targets. This provides a possible explanation for lifeguard superiority in previous visual search tasks (e.g., Laxton et al., 2020; Laxton & Crundall, 2018; Page et al., 2011): While eye movements have yet to suggest a strong experiential benefit in moving the eyes or scanning the scene (Laxton et al., 2020, 2021), lifeguards' superior performance may actually be dependent on the ability to process a drowning target once fixated. Previous researchers have argued that experts across a range of domains have shorter processing times of domain-relevant stimuli (Gegenfurtner et al., 2011). While this may often manifest in shorter fixation durations, this might not always be the case (Laxton et al., 2020) especially if there is no impetus to further move the eyes once the target is detected. This may be a particular difference between driving (noted above) and lifeguarding. During driving, despite detecting a hazard ahead, drivers may still feel the urge to move their eyes to check for secondary hazards, or to ensure that any manoeuvre they perform to avoid the primary hazard does not come into conflict with other road users. In contrast, lifeguards may feel it unlikely that a second swimmer will become distressed at the same time as the primary target, and therefore remain fixated on the target. Longer fixations by lifeguards were also noted by Vansteenkiste et al. (2020), particularly when looking at task relevant regions.

Analysis of the MOA task revealed lifeguards to be better at processing and predicting the trajectories of nearby dynamic peripheral objects, resulting in avoiding a collision between their controlled ball and an increasing number of distracter balls for a longer period. It was expected that the lifeguards would do better in this task as it potentially reflects an underpinning cognitive skill that relates to the monitoring the location of multiple swimmers in a pool and predicting if or when a swimmer could become a problem. The question remained however whether this cognitive ability contributes to lifeguards' ability to detect drowning targets in a pool. To this end, regression analyses were conducted to assess whether performance on the drowning occlusion task could be predicted from the measures recorded in the MOA task (time on task prior to a collision) and the FFOV task (central and peripheral target performance). An overall regression demonstrated that lifeguarding experience was the strongest predictor of performance in the drowning occlusion task. The only other significant predictor was performance on the central FFOV targets. When this analysis was repeated separately for lifeguards and non-lifeguards, the central FFOV predictor only remained significant for the lifeguard group. The difference between lifeguards and non-lifeguards that was previously noted in the MOA task did not manifest as a significant predictor in any of the regression models, however.

Several conclusions can be drawn from these results. First, lifeguarding experience is crucial to performance on the drowning occlusion task. It has the strongest influence on performance, but it is supported by performance on the central FFOV targets. When separate regression models are calculated for the two groups, accuracy on classifying these central targets accounts for a significant amount of variance in the lifeguard group. Some lifeguards perform better than others on the drowning occlusion task, and individual differences in their ability to process and classify the features of a drowning target may partially explain this variation in performance on the drowning occlusion task. This opens the door to further training to improve lifeguard performance by focusing on classification of dynamic drowning characteristics. The non-lifeguards also vary in their performance on the drowning occlusion task, but this is not due to their ability to process drowning characteristics. This is understandable as they have not received any formal training in what behaviours to look for in drowning targets.

Lifeguard superiority on the MOA task may reflect a natural ability which coincides with their decision to enter a profession where rich dynamic visual scenes provide attentional challenges. Alternatively, the underlying skill that MOA taps into may have been improved and honed in the lifeguarding domain. However, lifeguards' ability to avoid other balls in the MOA task does not appear related to their ability to spot a drowning target. It may be that lifeguards have developed skills in predicting the behaviour of multiple moving objects from scanning pools full of swimmers, where they monitor for events such as the movements of identified at risk swimmers, people entering and exiting the pool or tracking numbers in the pool. However, this may not be a skill that will necessarily help in the detection of a drowning swimmer. To be able to recognise a swimmer in distress, the searcher may need to apply explicit attention to the behaviour being displayed by the swimmer to detect a drowning, rather than just monitoring and predicting the movements of swimmers. Thus, while lifeguarding superiority in this task is interesting, we have no evidence to suggest that it contributes to the detection of distressed swimmers. This result stands in contrast to previous research that has found performance on an MOA task to be linked to driving performance (Mackenzie & Harris, 2017). It is likely that differences in the attentional demands of the different domains are responsible for these divergent results.

5 | CONCLUSION

To conclude, this experiment aimed to explore if two domain-free skills (peripheral target detection in an FFOV task and MOA) may contribute to superior lifeguard performance. The results show that lifeguards perform significantly better at MOA and the central task of the FFOV when compared to non-lifeguard participants. However, only performance on the FFOV central task was associated with performance on a drowning detect test in the lifeguard participants, and this was the only part of the two tasks that was not domain-free. These results suggest that lifeguard drowning detection is mainly driven through the ability to process the behaviours of drowning swimmers quicker than non-lifeguards. Using the findings in this study, it may be possible to train novice lifeguards' ability to detect drowning swimmers through an exposure task that improves the perceptual processing and ultimate classification of drowning behaviours.

CONFLICT OF INTEREST

The authors declare no conflicts of interest.

ENDNOTES

[1] Footage can be found at https://www.youtube.com/channel/UCnERyC7dwJwTvEyzYz6uxHw .

[2] The MOA will be available Open Source on the Open Science Framework once Mackenzie et al. (under review) is published.

DATA AVAILABILITY STATEMENT

Data available on request due to privacy/ethical restrictions.

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