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Visual search for drowning swimmers: investigating the impact of lifeguarding experience

ABSTRACT

How does domain expertise influence dynamic visual search? Previous studies of visual search often use abstract search arrays that are devoid of applied context, with comparatively few studies exploring applied naturalistic and dynamic settings. The current research adds to this literature by examining lifeguard drowning-detection across two studies using naturalistic, dynamic search tasks. Behavioural responses and eye-movement data were recorded as participants watched staged video clips and attempted to identify if a swimmer was drowning. The results demonstrate lifeguard superiority in response times to drowning events, compared to non-lifeguards. No differences between lifeguard and non-lifeguard eye-movements were noted however. This suggests that the experiential benefit in response times results from other underlying processes, rather than any scanning benefits. This research highlights the complex nature of naturalistic and dynamic searches, while demonstrating the robust nature of simulated videos in producing experience effects in visual search.

Key words: Dynamic visual search; Lifeguard surveillance; drowning detection; experience effects; eye-movements

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INTRODUCTION

In many applied domains, experienced participants often out-perform novices in relevant visual search tasks. Examples include diverse domains such as driving, sports and radiology (Chapman & Underwood, 1998; Nodine et al., 2002; Spitz et al., 2016). The current work extends this research to lifeguarding, assessing visual search for a drowning swimmer in a swimming pool. Below, we will explore general theories of how experience influences visual search and scene comprehension, before applying these to the lifeguarding context.

Experience influences visual scene processing

The ability to process a visual scene improves with experience via repeated exposure to the same environments and task demands (Stainer, Scott-Brown & Tatler, 2013; Torralba et al., 2006; Wolfe et al., 2012). The following sections will consider some of the experiential effects upon scene processing that are pertinent to lifeguarding.

Contextual knowledge within a scene

In real-world scenes, the environment constrains the logical locations where targets appear (Eckstein, 2011). For instance, a 'dog' target is likely to be found on the ground, though a cat might equally be found in a tree. The knowledge that cats climb trees, but dogs do not, is gained through experience of these animals. The contextual guidance model (Torralba et al., 2006) describes how such experience combines with bottom-up saliency calculations, creating *scene priors* to aid prioritisation of bottom-up features (i.e. the tree, when searching for a cat).

The scene prior is applied to the visual scene based on a rapid processing of global image features (gist processing). Once the gist of a scene has been processed (typically within 100 ms; Potter, 1976; Luck et al., 1994), the observer can apply contextual knowledge to guide attention to target-relevant areas of the visual scene. Irrelevant, yet salient features of the scene, are de-emphasised if they fall outside of the prior, while salient features within the favoured locations are enhanced. This creates a scene-modulated saliency map which focuses attention to regions of the search scene where the target is expected to be (the cat in the tree, a car on the road, a bird in the sky, etc.). While some scene modulations may appear to require very generalised experience (cats climb trees, birds fly), more fine-grained modulations may require increasingly specific scene expertise (e.g. bees like lavender, certain tumours may only be found in certain parts of the body).

While contextual knowledge for target feature guides the searchers' attention to different locations in a search display, observers of real-world scenes often have an incomplete knowledge of all target's features (e.g. location, colour, size). This negatively impacts search performance, particularly when imperfect target templates contain inaccurate information or extraneous features to target previews (Hout & Goldinger, 2015).

Visual processing within a scene

Experience with particular targets lowers the thresholds for their subsequent identification, allowing faster acceptance of these targets in the future, and fewer responses to non-target items (Borowsky & Oron-Gilad, 2013; Randel, Pugh & Reed, 1996). For example, in category learning, merely learning which features are more diagnostic of category membership increases the speed at which those features are processed (Guest & Lamberts, 2010). Experience in certain domains helps improve visual processing of items in scenes, with shorter fixations and scanning time in people who have a level of experience compared to novices. Konstantopoulos, Chapman and Crundall (2010) found that driving instructors appeared to have shorter processing times, with shorter fixations distributed across a wider area of the driving display, and broader scanning of the road compared to learner drivers. It appears that, with more experience in driving, overt attention can be moved more quickly, and less processing time is needed.

Situation Awareness

Situation awareness refers to the ability to perceive the relevant objects within a scene, comprehend their relationship to one another and predict how the scene will develop (Endsley, 2015). Situation awareness is influenced by domain experience, as viewers may be more aware of the probabilities that certain visual cues may lead to specific outcomes (Endsley, 1995; Kass, Cole, & Stanny, 2007).

Good situation awareness may improve the searcher's capacity for acquiring information about the events happening around them, particularly in dynamic, real-world search situations such as driving. Situational awareness develops as an individual gains experience of certain domains and any key stimuli that may require attention. These experiences allow the searcher to develop a catalogue of events that are likely to occur in similar situations, allowing viewers to prioritise areas of the scene based on what might happen next (Crundall, 2016). This prioritisation could be considered to provide *prediction priors.* Adopting the terminology of Torralba et al. (2006), such prediction priors could act as a higher-level form of scene selection that is extrapolated following attention to objects within the scene priors.

Dynamic scenes

There have been numerous applied visual search studies that aim to assess an individual's search skills and processing speeds (Godwin et al., 2015; Henderson et al., 2007; Meuter & Lacherez, 2016). Visual stimuli in these applied real-world scenes have often been restricted to static images (although see Kunar & Watson, 2014). However, in real-world search tasks, visual scenes are typically not static, with items in the visual field moving, such as searching through a crowd in surveillance tasks. These types of dynamic searches are more complex and have an additional level of difficulty, with moving targets becoming occluded or undergoing changes in appearance or behaviour over time.

There is evidence to suggest that individuals with certain domain experience will perform better or more effectively in these complex tasks. For instance, Howard et al. (2010) found that people with expertise in watching soccer were more likely than non-experts to be looking at task-relevant locations of a videotaped match whilst monitoring the game for upcoming goals (where 'task-relevant' locations were actually an emergent property of the eye data analysis). Experts using contextual knowledge to guide search of dynamic scenes to task relevant areas has been also suggested in research of CCTV operators. Howard et al. (2013) found that, compared to novices, expert CCTV operators showed greater consistency in eye positions and greater consistency in judgements of suspicious behaviours whilst monitoring CCTV footage. The authors suggested that the consistency between the trained CCTV operators was a result of their specialised knowledge, and thus knowing what to look for (see also Crundall and Eyre-Jackson, 2017).

Dynamic scenes have also been used to explore visual processing in sport-related domains (see Kredel, Vater, Klostermann, & Hossner, 2017, for a review). For example, Martell and Vickers (2004) explored elite and non-elite gaze strategy in a live defensive zone task for ice hockey. The results showed that the athletes use two different strategies to temporarily regulate their gaze. Furthermore, elite athletes fixated tactical locations more rapidly than non-elites in successful plays.

An introduction to the lifeguarding context

The various sub-processes considered above have been studied in a variety of applied settings including driving, airport security, and radiology (Biggs & Mitroff, 2014; Crundall, 2016; Nodine et al., 2002). One under-researched area of application however is that of lifeguarding. Lifeguards have an important, but extremely difficult job of supervising swimmers in a pool or beach setting. This includes searching for any swimmers that may be experiencing distress or drowning in the water. Explicit practical training in visual search of a pool is not currently part of lifeguard training in the UK, though search techniques are discussed with trainees (e.g. how to monitor a particular 'zone'). Beyond problems with limited training, the swimming environment makes scanning difficult due to factors such as heat, long periods on duty and a large overlap in drowning and swimming characteristics (Griffiths & Griffiths, 2013; Lanagan-Leitzel, Skow, & Moore, 2015). While drowning in lifeguarded pools within the UK is incredibly rare, there are instances where supervision fails, resulting in injury or death. To prevent these fatal incidents, UK lifeguards are trained to recognise certain behaviours that are associated with drowning and distress.

A common form of drowning behaviour is termed *active drowning,* where targets typically display the *Instinctive Drowning Response* (Pia, 1974). These swimmers will usually be vertical in the water, with their arms flailing and splashing the water. The head will typically submerge and re-emerge and will be usually tossed back as the swimmer gasps for air. They will have no forward propulsion through the water and are unlikely to respond to shouted instructions. This struggle will last for as long as the person's energy permits, however research suggests a 60 second struggle is typical before energy is fully depleted. In non-swimmers and children this struggle may only last for 20 seconds (Pia, 1974). Swimmers in a crisis stage of drowning will not be able to call for help, as breathing takes precedence (Doyle & Webber, 2007).

In contrast to active drownings, *passive drownings* refer to those swimmers who have lost consciousness in the water, usually from some form of medical emergency. The transition from normal swimming to unconsciousness can happen quickly and the victim will either slip slowly under the water or remain face down and motionless on the surface (Fenner et al., 1999). Once at the bottom of a pool, the swimmer may be left unattended for a prolonged period with greater risk of permanent brain damage. In a study reported by Brener and Oostman (2002) lifeguards' responses to detect a submerged manikin were recorded. The manikin was introduced in a live pool setting, unbeknownst to the lifeguards. On average it took successful lifeguards 1 minute and 14 seconds to notice the manikin, with only 9% of lifeguards detecting the manikin within 10 seconds (which is the target time as taught by the '10:20 system' which gives lifeguards 10 seconds to a spot and 20 seconds to respond; Ellis and Associations, 2007). The response to the submerged manikin was highly variable, with 14% failing to spot the manikin before 3 minutes had elapsed.

Although lifeguards are taught to recognise characteristics of drowning and distress, these behaviours are not always indications that a swimmer is in trouble. For example, splashing or submersion on their own are also common in swimming play behaviours, or even in swimmers with a weak technique. The lifeguard needs to be flexible in appraising these behaviours. Lifeguards also need to be aware of behaviours that could lead to drowning and distress, such as dangerous behaviour, poor swimmers entering deep areas of water, or otherwise vulnerable swimmers. These complexities have led to lifeguards differing in opinion in regard to which behaviours and events are critical. Lanagan-Leitzel (2012) found that when watching video footage of people swimming at a leisure facility, lifeguards disagreed on the events that should be rated as critical and in need of monitoring. Trainers reported nearly double the number of critical events compared to the lifeguards, however there was limited consistency in the different events reported. The events that were reported by the majority of lifeguards and trainers were also reported by a large number of non-lifeguard participants, suggesting that salience of many critical events was more important for detection than expertise.

Lifeguard expertise and visual search

Of the limited literature on visual search in lifeguards, experience has been shown to have a positive impact upon their search skills, leading to a greater frequency of critical events being identified. For instance, Lanagan-Leitzel and Moore (2010) found that lifeguards and participants who had received short instruction in drowning detection performed better in the detection of critical events than naive participants with no knowledge of drowning behaviours. They found lifeguards only identified 54% of critical events, while those participants who were given brief training identified 45%. Eye movement data suggested that lifeguards had superior search in terms of their fixations, with shorter fixations, fewer fixations of the water and more fixations to the critical events.

In a similar study using schematic animations of swimmers, Page et al. (2011) found that lifeguards were significantly more accurate in detecting swimmers who disappeared under the water. Even though the provision of contextual knowledge improved performance (e.g. the location of a rip current in the simulated scene; in effect, a domain-specific scene prior) performance remained poor in absolute terms for both experienced lifeguards (31.6%) and novices (16.7%). Page et al., (2011) found only 12 out of 69 lifeguards looked in the correct area of the beach scene in unbiased conditions (when no contextual information was given), with only 7 of those 12 detecting the drowning victim, possibly arguing for a Look But Fail To See Error (LBFTS; Crundall et al., 2012). This error has been well researched in the applied domain of driving (Clabaux et al., 2012; Herslund & Jørgensen, 2004; Underwood, Humphrey, & van Loon, 2011). Commonly, drivers who report a LBFTS error look directly at the other road user but see them when it is too late or not at all. It has been noted that when an individual experiences a LBFTS error their cognitive resources are often engaged in another task, such as approaching a junction (Casner & Schooler, 2015). It is also possible that a person's expectations on what they will see will bias their processing. For example, when a driver approaches a junction, they believe that looking down the road will either reveal a car or an empty road. However, in the absence of a car, the driver is may be tempted to make a quick decision that the road is empty before they realise that they are actually looking at an unexpected oncoming motorcycle (Crundall et al., 2012).

The findings of Page et al. (2011) either suggest that a lot more could be done to improve the detection of drowning victims in aquatic environments, or alternatively, that we need more realistic tests that better capture lifeguards' skills. While Lanagan-Leitzel and Moore (2010) used naturalistic video, events were uncontrolled and possibly confounded many factors. Unfortunately, the highly controlled yet highly artificial stimuli used by Page et al., (2011) may have swung too far in the other direction, with the simplistic animated footage making generalisations back to pool or beach environments difficult (Page et al., 2011).

In a recent study, Laxton and Crundall (2018) aimed to bridge the gap between the previous two studies by using dynamic, naturalistic stimuli with experimental control. This study employed video clips of regimented swimming across the width of the pool (Figure 1). Whilst distractor swimmers engaged in regimented lap swimming, some naturalistic behaviours were also captured, including pauses to alter goggles, chatting with others in the pool and underwater swimming. The results showed that lifeguards were superior in both accuracy and speed of responses to a mock drowning incident. In addition, fewer active drownings were missed compared to passive drownings, but response times to active drownings were slower. While the results were promising in terms of identifying superior lifeguard performance, the research was not without limitations, as any false alarm responses (made before drowning onset) ended the trial prematurely, potentially systematically reducing performance of participants with low thresholds for reporting events. Non-lifeguard participants were over-represented in their premature responses (17% vs. 7% for non-lifeguards and lifeguards respectively), raising the possibility that, if given the opportunity to see the full trial, the non-lifeguards may have performed similarly to the lifeguard participants in detecting actual drowning targets.

[Insert Figure 1 here]

Despite shortcomings in all the above studies, they consistently demonstrated a superiority in some aspects of lifeguards' performance. The current studies aim to build upon these findings, replicating the superiority effect and increasing our understanding of it, using a more exacting design. The first experiment explores differences in eye-movements and behavioural responses between non-lifeguards and lifeguards using a modified version of the drowning detection task used by Laxton and Crundall (2018). By removing the possibility of a false alarm terminating the clip early, it is possible that non-lifeguards' performance on this task will improve above performances noted in Laxton and Crundall (2018). Even though this will create a fairer comparison between groups, we still predict that the lifeguard superiority effect will be present. We further predict that eye-movement data will provide additional insight into the mechanisms underlying this superiority (e.g. faster first fixations to the target and greater probability of fixating the target).

The second experiment manipulated the instructions, with half of the participants given explicit guidance on behavioural characteristics of active and passive drownings. This manipulation was intended to assess whether non-lifeguards' poor performance was affected by a lack of expectations regarding drowning characteristics. A further improvement to the design of the second experiment was to include a wider range of participant expertise, by assessing four distinct groups whom we predicted to show increasing levels of superiority benefit: non-lifeguards, lifesavers, lifeguards and lifeguard trainers (described further in experiment 2). A final innovation for was to collect localised responses via a touch screen, adding a dimension of spatial accuracy that was missing from Experiment 1.

EXPERIMENT 1

The first experiment manipulated the number of swimmers in the search array (3, 6 or 9 swimmers) and the type of drowning (active, passive and a no-drowning control condition) across 45 staged video clips. Lifeguard and non-lifeguard performance was measured in terms of response times and accuracy to drowning targets, and their eye movements were recorded in an effort to detect visual search differences across the two groups. We predicted that lifeguards would perform better than non-lifeguards, and that this would be reflected in their eye movements. This superiority should be exacerbated in the hardest conditions (i.e. the largest set size, which will be more akin to the typical number of swimmers they might have experience of observing, and when the target is a passive drowning victim), though it was also a possibility that the hardest conditions may be so difficult as to cause a floor effect across all participants, nullifying the group differences that occur in the easier conditions.

METHOD

Participants

Forty-two participants were recruited to take part in a visual search study (with a mean age of 24.01, SD = 6.07, 22 female). Twenty-one of these participants (mean age 21.14, SD = 4.27, 23-47 age range, 11 females) had completed the UK National Pool Lifeguard qualification prior to testing and had a varying amount of experience in poolside lifeguard duties (2.46 years of lifeguarding experience on average, SD = 3.25). There were 5 lifeguards who worked on a full time basis (30 – 40 hours a week), a further 8 worked on a weekly part-time basis (between 5 and 20 hours a week), and 4 lifeguards worked less than 10 hours over a month. There were an additional 4 lifeguards that only worked during school holidays (both full and part time hours).

The remaining twenty-one participants (mean age 27.97, SD = 5.87, 16-31 age range, 11 females) had no lifeguarding experience. Lifeguards were recruited from a local leisure centre and non-lifeguard participants were an opportunistic sample.

Design

A 2 x 2 x 3 mixed design was employed, comparing experience (lifeguards to non-lifeguard participants), drowning type (15 active drowning trials and 15 passive drowning trials) and set size of the search array (with 3, 6, or 9 swimmers). In addition to the active and passive drowning targets, 15 non-drowning trials were also included. Of the 15 trials for each of the drowning and control stimuli sets, five trials contained 3 swimmers, five trials contained 6 swimmers and five trials contained 9 swimmers. During presentation to participants, all trials were randomised within a single block. All participants viewed all trials. Accuracy and response times to detect the drowning target were recorded. A response was considered accurate if the participant pressed the button during following the onset of the target until the end of the clip (i.e when the swimmer began to drown). Response times were measured from target onset. To overcome the problem with premature responses being recorded as incorrect in a previous experiment (Laxton & Crundall, 2018) participants in this experiment could make multiple responses. However, if participants made a premature response that was not followed by a correct response in the target time window this was coded as an incorrect false alarm. Alternatively, if no response was made during a clip this was also coded as incorrect (a 'miss'). Participants' eye movements in each trial were also recorded.

Apparatus and Stimuli

The stimuli were the same as those used by Laxton and Crundall, 2018 (Figure 1), and were recorded on a Samsung Galaxy EK-GC 100, 23 mm handheld digital camera, with a field of view of approximately 70 degrees. The videos were presented on a Dell computer screen connected to an SMI RED500 eye tracker sampling at 500Hz. Participants were tracked from an ideal distance of 60cm from a display screen measuring 49 cm x 29.5 cm (44 x 28 degrees of visual angle), with a resolution of 1600x900. In total there were 45 video-clips, and these were presented in colour with either 3, 6 or 9 swimmers traversing the width of the pool. The choice of filming swimmers crossing the width, rather than swimming the length of the pool, was made due to restrictions in the visible angle available to the camera. Nonetheless, the camera position reflects an operational standing lifeguard position employed during unstructured swimming sessions. In two-thirds of the videos a staged active or passive drowning would occur, and the other one-third were catch trials with no drowning event.

The clips lasted 29 seconds on average (SD = 1.5s) and were presented without sound. The drowning incidents lasted an average of 11.9 seconds (SD = 2.9s) with clips ending immediately following the drowning. This should have allowed all lifeguards sufficient time to spot the drowning victim if following the 10:20 method (Ellis and Associates, 2007). Both types of drownings happened quasi-randomly within the second half of an average length video clip.

Volunteer actors were recruited to display both active and passive drowning behaviours and the silent presentation of the final clips allowed the cameraperson to use verbal cues and a whistle during filming to direct the action. Background swimmers (distractor swimmers) were instructed to engage in lap swimming, however, were free to choose their own style of swimming, which varied in pace and whether it was done above or below the surface. Swimmers were also permitted to take pauses for natural behaviours, such as taking a rest, talking with others, or altering goggles/swim hats, although these behaviours typically occurred at the sides of the pool. Importantly the freedom of choice about swimming behaviour for distractor swimmers meant a range of behaviours was in play at the time at which a drowning occurred (in the drowning clips). Table 1 shows the range of behaviours that occurred at the point of drowning onset. In all set sizes, the most frequent behaviour was continuous swimming; however, there were enough other behaviours present to ensure that clips contained novelty of action.

The trials were presented in a single randomised block. Each clip was preceded by a gaze-sensitive fixation cross that would only allow the trial to start if the participant was fixating the cross for a minimum of 500 ms. This ensured that calibration was retained through-out the study. If problems occurred, it was possible to recalibrate participants.

Table 1. The percentage of distractors engaging in certain behaviours at the point of drowning onset.

Behaviour of distractor swimmers at drowning onset	**% of distractors across set size**		
	Set size 3	Set size 6	Set size 9
Turning/pushing off at wall	20	16	16.25
Underwater swimming/push-off	20	4	5
Resting at side	10	8	8.75
Chatting (at side or while swimming)	10	-	7.5
Swimming a recognised stroke (e.g. frontcrawl, breaststroke)	40	54	52.5
Unusual swimming (e.g. doggy paddle, corkscrew)	-	12	5
Altering swim accessories	-	6	5

Procedure

Testing sessions were arranged at various pools and leisure centres, to better recruit lifeguards, with a quiet office or side-room acting as the laboratory. Non-lifeguard participants were tested under similar conditions on University premises. Participants were given written instructions and asked to fill in a consent form and demographic questionnaire. Prior to the study, participants were made aware that they would be searching for any potentially drowning victims from a lifeguard's perspective, and that the study would contain active, passive and non-drowning trials. Definitions of the drowning types were also provided (no such descriptions were provided in the Laxton and Crundall, 2018, study). Participants were told they could make multiple responses, if they thought that a later potential drowning event superseded a potential event that they had already responded to in the same clip. They were however encouraged to only respond once to any drowning incidents they observed and were told that a maximum of one simulated drowning event would occur per clip to reduce the number of premature responses. If a drowning was identified, participants were told to press the zero key on the number pad of a standard keyboard. Once all instructions had been given, participants had the opportunity to complete a practice trial, which was followed by a final opportunity to ask any remaining questions before the study began. Participants' eye movements were calibrated at a distance of 60 cm without head restraint using an 8-point calibration, followed by a similar 8-point validation test. If the validation procedure recorded fixations that deviated more than 0.5 degrees from a validation target, a recalibration was undertaken. Upon finishing the test, the participants were fully debriefed and thanked for their time and participation. The total testing time took approximately 30 mins.

Data analysis

First the data were scanned for influential outliers above or below 3SD from the means of the behavioural measures. None were removed from the final data sets.

A number of analyses were undertaken to explore the data. 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 experience group and then compared.

Mixed Analyses of Variance (ANOVA) compared set size (3, 6 and 9) across group (lifeguards and non-lifeguards) and drowning type (active or passive). As participants' lifeguarding experience was the focus of this research, only significant interactions including this factor are explored. If set size produced a significant main effect or was involved in a significant interaction with experience, then planned comparisons were employed, comparing set sizes 3 and 6, and set sizes 6 and 9 (including the experience factor in order to identify the locus of the interaction). Where significant interactions required further exploration, t-tests were used. Bonferroni corrections compensated for these multiple comparisons.

All eye-movement data was processed by and prepared for analysis using the programme BeGaze. The minimum duration for a fixation to be measured was 80 ms and fixations were calculated from saccadic velocity, with a peak velocity of 400^{o}/s. The measures explored within these eye-movement data were the number of targets fixated, time taken to first fixate the targets (measured from drowning onset), percentage dwell time (number on samples on target post-drowning onset/total possible time that one could have looked at the target) and number of fixations on targets. The time between first fixation and first correct response time was also analysed to provide a measure of processing time.

RESULTS

Signal detection analysis

Accuracy for detecting a drowning target (i.e. making a response within the drowning window) was subjected to signal detection analysis. Neither *d'* ($t(40) = 1.01$, $p = 0.320$) (2.8 vs. 2.5 non-lifeguards and lifeguards respectively) or *c* ($t(40) = -1.27$, $p = 0.208$) (-2.3 vs. -1.9 non-lifeguards and lifeguards respectively) were found to differ significantly between the two groups. This suggests that there was no difference between the participants likelihood to detect the target and their likelihood to say 'yes' to the signal. All subsequent analysis focuses on trials on which there was a target.

Behavioural responses

The percentage of trials with a drowning target that were correctly responded to were then analysed. Trials with a drowning target were considered incorrectly responded to if no response was made following the onset of drowning activity.

Premature responses made to drowning-present trials were analysed. Premature responses occurred on 9.05% of all trials. Non-lifeguard participants were responsible for 3.02% of premature responses and lifeguards were responsible for 6.03%. There was no statistical difference in the premature responses made by lifeguards and non-lifeguards ($t(40) = -1.8$, $p = 0.07$).

Correct responses were converted into percentages of the total drowning trials in each condition (Table 2) and subjected to a group x drowning type x set size (2 x 2 x 3) mixed ANOVA. Unlike Laxton and Crundall (2018), a main effect was not forthcoming for participant group on accuracy rates ($F(1,40) = 1.3$, MSe = 387.5, $p = .259$, $\eta_p^2 = .03$). Though the lifeguards identified 89.5% of targets compared to the non-lifeguards 84.6%, this difference was not significant. The difference between accuracy for active trials and passive trials,and the main effect of set size also failed to reach significance.

Table 2. Behavioural measures for Experiment 1

	Accuracy (%)			**Response times (ms)**		
	Mean	***SD***	***95% CI***	**Mean**	***SD***	***95% CI***
Experience group						
Non-Lifeguards	84.6	*16.9*	*78.5, 90.7*	4935*	*1258*	4419, 5451
Lifeguards	89.5	*10.0*	*83.4, 95.7*	4215*	*1018*	3704, 4712
Drowning type						
Active	84.9	*17.6*	*79.5, 90.4*	5092*	*2106*	4618, 5565
Passive	89.2	*15.4*	*84.4, 90.0*	4041*	*1558*	3674, 4428
Set size						
3	89.5	*15.6*	*84.8, 94.3*	4125*	*1782*	3735,4515
6	87.6	*18.3*	*82.1, 93.2*	4723*	*1878*	4286, 5160
9	84	*16.2*	*78.9, 89.1*	4865	*2045*	4428, 5303

- P <.05

One important interaction was noted between set size and experience ($F(2,80) = 4.6$, MSe = 231.8, $p = .012$, $\eta_p^2 = .10$). Repeated contrasts revealed this interaction to lie between set size 6 and set size 9 ($F(1,40) = 8.1$, MSe = 461.9, $p = .007$, $\eta_p^2 = .17$) . As can be seen from Figure 2, lifeguards only show superiority at the two lower set sizes.

[Insert Figure 2 here]

Response times were then subjected to a similar 2 x 2 x 3 ANOVA (group x drowning type x set size. One participant, who did not respond to any drownings in the set size 6 condition, was removed from the analysis.

Main effects were found for all three factors. First a group effect was noted (F(1,39) = 4.2, MSe = 2603666, p = .026, η_p^2 = .10), with lifeguards identifying drowning targets faster than non-lifeguard participants (4215 ms vs. 4935 ms). The main effect of drowning type (F(1,39) = 2.80, MSe = 3198316, p < .001, η_p^2 = .35) revealed passive drownings were identified over a second faster than active drownings (4051 ms vs. 5092 ms). The main effect of set size (F(2,70) = 8.7, MSe = 1449725, p < .001, η_p^2 = .18) reflects an ostensible increase in RTs with an increase in distractors (4125 ms, 4723 ms and 4865 ms for set sizes 3, 6, and 9, respectively). Planned repeated contrasts demonstrate that set size 3 evoked faster RTs than set size 6 (F(1,39) = 12.2, MSe = 2274287, p = .009, η_p^2 = .25) however there was no difference in RTs between set size 6 and 9 (F(1,39) = .47, MSe = .499, p = .270, η_p^2 = .01). No interactions were found with experience.

Eye-movement measures

How many targets were fixated?

The number of drowning swimmers that received a fixation after drowning onset were analysed. A fixation on a drowning target was only considered relevant if it occurred within the drowning window. Two potential participants did not reach a satisfactory calibration with the eye-tracker and these results were omitted from the results. There was a good tracking ratio average for all trials (average 90.23%), however it should be noted that two participants’ averages fell between 70-80%.

The number of targets that received a fixation were converted into percentages of total targets (see Table 3) and subjected to a group x drowning type x set size (2 x 2 x 3) mixed ANOVA.

Table 3. Eye movement measures for experiment 1

	Number Of Targets Fixated (%)			**Time To First Fixation (Ms)**			**Dwell Time(%)**			**Number Of Fixations**		
	Mean	*SD*	*95% CI*	Mean	*SD*	*95% CI*	Mean	*SD*	*95% CI*	Mean	*SD*	*95% CI*
Experience group												
Non-Lifeguards	94.3	*15.4*	89.8, 98.8	2023	*1273*	1526, 2202	39.5	*16.3*	33.6, 45.4	9.8	*3.8*	*8.5, 11.1*
Lifeguards	94.9	*11.3*	90.5, 99.4	1667	*1176*	1546, 2222	34.3	*14.4*	28.4, 40.2	10.0	*3.9*	*8.7, 11.3*
Drowning type												
Active	93.8*	*13.3*	90.1, 97.3	2136*	*1377*	1784, 2462	38.4*	*15.2*	34.2, 42.6	10.5*	*4.0*	*9.5, 11.6*
Passive	95.4*	*13.7*	92.5, 98.3	1615*	*991*	1435, 1812	35.5*	*15.9*	31.1, 39.9	9.2*	*3.5*	*8.3, 10.1*
Set size												
3	92.4*	*15.5*	88.0, 96.8	1856	*1244*	1537, 2176	38.9*	*16.2*	34.3, 43.5	8.9*	*3.7*	*7.9, 9.9*
6	94.0*	15.1	89.7, 98.4	1852	*1263*	1585, 2120	37.8*	*15.7*	33.2, 42.5	10.0*	*3.8*	*8.9, 11.1*
9	97.4*	*8.1*	95.5, 99.2	1912	*1174*	1626, 2199	34.1*	*14.6*	30.0, 38.1	10.8*	*3.8*	*9.8, 11.8*

- *P* <.05

The main effect of group was not significant. However, main effects were found for both drowning type and set size. The main effect of drowning type ($F(1,40) = 4.6$, MSe = 34.6, $p = .038$, $\eta_p^2 = .10$) identified that passive drownings were more likely to be fixated than active drownings (95.4% vs. 93.8%). The main effect of set size was also significant ($F(2,80) = 4.6$, MSe = 77.9, $p = .013$, $\eta_p^2 = .10$). Planned repeated comparisons between set size 3 vs 6 and set size 6 vs 9 showed no significant differences in fixation percentages. As such the additional t-test (Bonferroni adjusted) between set size 3 and 9 was run which showed that fewer targets were fixated at set size 3 than set size 9 (92.4% vs. 97.4%) ($t(41) = -2.6$, $p = .012$).

A three-way interaction between group x drowning type x set size was found to be significant ($F(2,80) = 3.3$, MSe = 91.9, $p = .043$, $\eta_p^2 = .08$). Figure 3 shows that this appears to be driven by the number of targets fixated by lifeguard participants, which seem to be differentially affected by the increase in set size across drowning target type. Lifeguards are close to ceiling in terms of the number of targets fixated in set size 6 for passive drowning trials, though this number decreases slightly in set size 9. However, with active drownings there is an increase in the number of fixated targets at set size 9 compared to set size 6. Non-lifeguard participants' likelihood of fixating the targets is the same, regardless of drowning type, and follows the pattern of results produced by lifeguards when fixating active targets.

To unpack this interaction two drowning type x set size mixed ANOVAs were carried out for each group. In the non-lifeguard conditions the main effects of set size and drowning type were not significant, however the interaction effect between drowning type and set size approached significance ($F(2,40) = 3.08$, MSe = 203.18, $p = .057$, $\eta_p^2 = .13$).

The second drowning type x set size ANOVA for the lifeguard group revealed a main effect of drowning type ($F(1,20) = 4.71$, MSe = 43.16, $p = .042$, $\eta_p^2 = .07$), with passive targets more likely to be fixated than active targets (96.2% vs 93.7% respectively). The interaction effect between drowning type and set size did not reach significance ($F(2,40) = 2.65$, MSe = 108.89, $p = .083$, $\eta_p^2 = .12$).

[Insert Figure 3 here]

Time taken to first fixate the targets

The time (ms) to make the first fixation on the target (calculated from drowning onset) was subjected to a similar 2 x 2 x 3 ANOVA. A main effect for drowning type was found (F(1,40) = 16.0, MSe = 1073289, p < .001, η_p^2 = .26), with passive drowning trials receiving an initial fixation an average of 500 ms before active drowning trial (1615 ms vs. 2136 ms). The other two main effects failed to reach significance. There were no interactions with experience.

Dwell times on targets

Dwell times (the amount of time the participants' eyes were on the target as a percentage of the time it was available for inspection; Table 3) were also analysed with a 2 x 2 x 3 ANOVA. There was a main effect of both drowning type (F(1,40) = 7.3, MSe = 1.9, p = .010, η_p^2 = .15) and set size (F(2,80) = 6.7, MSe = 15.3, p = .002, η_p^2 = .14). Passive drownings received a shorter dwell compared to active (35.5% vs. 38.4%; possibly reflecting the more captivating antics of active targets) and dwell decreased as set size increased (38.9% vs 37.8% vs 34.1%, respectively; presumably caused by the increase in other stimuli trying to capture attention).

Fixations to targets

The mean number of fixations on the targets was subjected to a 2 x 2 x 3 mixed ANOVA (group x drowning types x set size). No difference was found between experience groups (non-lifeguards 9.8 and lifeguards 10.0), however, main effects were found for drowning type and set size. First, drowning type (F(1,40) = 17.6, MSe = 6.7, p < .001, η_p^2 = .31) revealed that active drowning targets received more fixations than passive (10.5 vs. 9.2). The main effect of set size (F(2,80) = 13.6, MSe = 5.8, p < .001, η_p^2 = .25) noted a linear increase in the number of fixations as set size increased (8.9 vs. 10.0 vs. 10.8). Planned repeated contrasts revealed that set size 3 was different from set size 6 (F(1,40) = 9.2, MSe = 11.2, p = .004, η_p^2

= .19), and set size 6 was different from set size 9 (F(1,40) = 5.6, MSe = 10.2, p = .023, η_p^2 = .12).

One interaction was subsumed by a 3-way interaction between group x drowning type x set size (F(2,80) = 3.9, MSe = 4.6, p = .025, η_p^2= .09). From Figure 4, this appears to be driven by the difference in the number of fixations on active and passive targets made by non-lifeguard participants at set sizes 3 and 9. Lifeguard participants also appear to differ in the number of fixations given to active and passive targets at set size 9.

To unpack this interaction two drowning type x set size ANOVAs were conducted for each experience group. Some key differences were noted between the analysis for lifeguards and non-lifeguards. First, the main effect of drowning type remained for both groups, with active drownings receiving more fixations. This effect was stronger in the lifeguard group (η_p^2= .04 vs .24, for non-lifeguards and lifeguards respectively). The effect of set size also remained for both groups, however planned contrasts revealed that non-lifeguards fixated more targets at set size 9 compared to 6, while the lifeguards fixated more targets at set size 6 compared to 3. Finally the interaction between drowning type and set size was present for both groups, with active targets being fixated more than passive at set size 9. However, the increase from set size 6 to 9 for the non-lifeguards' fixations to active targets caused a cross over effect with the passive targets.

[Insert Figure 4 here]

Processing time between first fixation and response time

The time between the first fixation to the target and a behavioural response was calculated to assess processing time; responses where a target was not fixated were not included in the analysis. This was then subjected to a group x drowning type x set size (2 x 2 x 3) mixed ANOVA. One participant was removed from the analysis due to all fixation data being missing for one condition.

The main effect of drowning type (F(1,39) = 28.9, MSe = 3881618, p < .001, η_p^2 = .43) revealed that passive drownings required less processing time than the active drownings (2502 ms vs. 3854 ms respectively). The main effect of set size (F(2,78) = 5.0, MSe = 3071594, p = .009, η_p^2 = .11), when subjected to planned repeated contrasts, revealed that set size 3 differed to set size 6 (F(1,39) = 8.6, MSe = 5457085, p = .006, η_p^2 = .18), but set size 6 did not differ from set size 9 (F(1,39) = .001, MSe = 707340, p = .742) (2677 ms, 3433 ms, and 3424 ms, for the three increasing set sizes). The main effect of experience failed to reach significance, although lifeguards appeared to have shorter processing times compared to non-lifeguards (2981 ms vs 3376 ms, respectively).

One interaction between set size and drowning type was noted (F(2,78) = 3.3, MSe = 2919664, p = .43, η_p^2 = 0.08). Planned repeated contrasts show that the interaction lies between set size 3 and 6 (F(1,39) = 4.2, MSe = 5663559, p = .048, η_p^2 = .10). From Figure 12 this appears to be driven by the slowed time between set size 3 and 6 in active drownings. Post hoc Bonferroni adjusted t-tests support this interpretation, with the time between first fixation and response times being smaller in set size 3 for active drownings than at set size 6 (t(40) = -3.4, MSe = 387.4, p = .002) (2963 ms vs 4255 ms set size 3 and 6 respectively). Differences between active and passive drownings at set size 6 were also found (t(40) = 4.7, MSe = 350.9, p < .001), with passive drownings having a faster time between first fixation and response than active drownings (2611 ms vs 4256 ms respectively). A difference between active and passive drownings in set size 9 was also significant (t(40) = 4.6, MSe = 401.8, p < .001). Again, passive drownings had the faster time between first fixation and response time than active (2505 ms vs 4343 ms). It should be noted that the active drownings have the longer time to first fixate, therefore these shorter processing times of passive drowning are not curtailed by the end of the clip.

DISCUSSION

The results of this first experiment have confirmed the superiority of lifeguards in detecting drowning targets, at least in regard to their response times. Lifeguards were found to react to drowning swimmers faster, on average, than non-lifeguards. Regarding accuracy, lifeguards were found to outperform the non-lifeguard participants at the small and intermediate set sizes. Lifeguard superiority on both measures fits with previous studies that have demonstrated expert superiority in detecting targets in static image searches (Biggs & Mitroff, 2014: Nodine et al., 2002).

The accuracy results differ from those of Laxton and Crundall (2018). In that study, lifeguards were found to detect more simulated drownings and respond to them faster across all set sizes, whereas the current data showed no difference at set size 9 for accuracy. Compared to Laxton and Crundall (2018), it appears that the current non-lifeguard participants are ostensibly performing better at set size 9. While lifeguards across the two studies identified 90.8% and 89.5% of drowning targets, the non-lifeguard groups from the two studies correctly identified 75.7% of Laxton and Crundall's (2018) targets, increasing to 84.6% of targets in the current study. This was especially noticeable in the passive drowning condition with lifeguards identifying a relatively consistent 88.4% and 90.5% across the two studies, while non-lifeguards improved from 70.9% to 87.9%.

Why might non-lifeguard participants be better at spotting drowning swimmers in the current study compared to that of Laxton and Crundall (2018)? There are several possibilities: First, we should note that the current study differs slightly in design to the previous one. In the Laxton and Crundall (2018) study, participants were only allowed to make a single response which then terminated the video playback. The percentage of trials on which these premature responses were made was higher in that study than the current experiment (24% vs 9%). The difference between premature responses in these two studies is entirely due to a shift in criterion of the non-lifeguard group from 17% (Laxton and Crundall, 2018) to 3% in the current study. The lifeguards remained remarkably consistent with 7% and 6% premature responses across the two studies. It is possible that the termination of the clip in Laxton and Crundall (2018) increased performance anxiety in the non-lifeguards, resulting in the change in criterion bias. Removing the possibility of early terminations in the current study may therefore have tightened the criterion that non-lifeguards were using, resulting in better performance.

A second possible explanation for the improved performance of non-lifeguard participants in detecting drowning swimmers may be due to a further difference between the two studies. To better prepare participants for the task, the current study gave descriptions of the two drowning types. Laxton and Crundall (2018) did not do this, which may have increased the salience of active drowning over and above that of passive drownings, at least in the non-lifeguard group who may have only expected to see active drownings (perhaps because this type of drowning is more prevalent in television and film). By providing a description of passive drowning in the current study, the non-lifeguard participants may have become more sensitised to the lack of movement characterising passive targets, rather than simply searching for an increase in activity to denote a target.

One result of note is the interaction between set size and experience, where lifeguards were only found to outperform the non-lifeguard participants at the small and intermediate set sizes. Once set size increased to nine swimmers, accuracy between lifeguards and non-lifeguards became comparable. One interpretation of these results could be that the lifeguards are using a particular strategy in the low and intermediate set size, which is comparatively less useful for the largest set size. For instance, an ongoing serial search may be effective with 3 or 6 swimmers but becomes cumbersome with 9 swimmers. This may be particularly the case given these swimmers are moving and so it might be difficult to track which have been serially attended in the same (or similar) order. This might mean lifeguards "miss" drownings at the larger set size, particularly if also cycling through a serial search faster (as they produce faster RTs). Future research should take into consideration more in-depth scan path analyses to explore this possibility.

Interestingly no *overall* differences were found between participant groups in the eye tracking data. There was no significant difference between how quickly the lifeguards and non-lifeguards fixated the target. Similarly, there was no significant difference between the processing times required by groups from first fixation to response. A closer look at the data offers a potential explanation: lifeguards were 356 ms faster than non-lifeguards at fixating the target, and were 395 ms faster at responding to the target following first fixation. Though both of these differences were non-significant in their own right, they add up to provide a potential speed advantage of 751 ms. This is very close to the significant difference in overall response times between the groups, with lifeguards responding 720 ms faster on average. It appears that small gains in the time to first fixate, and small gains in processing time, add up to provide a significant superiority effect in their response times.

It is odd that lifeguards' search breaks down at set size 9, given that they are used to lifeguarding much busier pools. Laxton and Crundall (2018) did not find this. Instead they suggested that lifeguards appeared to change their strategies as they moved to the largest set sizes. It may be interesting to explore this further in even larger set sizes. While the current approach explores lifeguard search skills in a controlled environment, lifeguards are required to supervise much busier pools, therefore it may be more realistic to consider the effects of a much more cluttered pool on visual search. This may be particularly interesting for active drowning conditions when background swimmers are engaging in fun swimming (e.g., splashing), where features overlap to a greater extent. For example, the submergence and re-emergence of the *instinctive drowning response* (Pia, 1974) could easily be mistaken as playful activity.

This experiment has verified the lifeguard experience effect noted in Laxton and Crundall (2018). However, the eye-tracking measures did not find any clear difference between lifeguards and non-lifeguards, suggesting that lifeguard superiority arises from small gains in the time to first fixate the hazard, and post-onset drowning recognition. It is also possible that the instructions given to participants before the experiment shaped what they expected to see (improving detection of passive drowning compared to Laxton and Crundall, 2018). Therefore, a second study was designed, including participants with a wider range of lifesaving experience, to further the experiential superiority effect, and to test whether the provision of instructions regarding the different drowning types plays an important role.

EXPERIMENT 2

The effect of expertise for target detection in search is well documented (Curran et al., 2009; Laxton & Crundall, 2018; Nodine et al., 2002). Experiment 1 has shown lifeguard superiority in response times across all set sizes, and in terms of accuracy in low set sizes. However, more research is needed to understand from whence such superiority stems. Therefore Experiment 2 aimed to explore group differences across a wider range of experience, through the recruitment of two additional groups: lifeguard trainers and lifesavers. Lifeguard-trainers have the most experience and may outperform all other groups, including standard lifeguards. Lifesavers however are hobbyists who practice lifesaving skills primarily for competitive purposes (RLSS, 2020). They are not formally trained to scan for drowning targets or have the experience of lifeguards, and are therefore likely to perform at a level somewhere between lifeguards and non-lifeguards.

In addition, we were concerned that the provision of instructions on drowning types given to participants in Experiment 1 may have improved performance in non-lifeguards compared to the study of Laxton and Crundall (2018). To assess the impact of these instructions on participant performance, we decided to include the provision of instructions on behavioural characteristics as a factor in the current study.

Finally, one potential problem with the design in experiment 1 is that a button response could have been made following drowning onset and thus been registered as a hit even though the participant was actually incorrectly referencing behaviour in one of the distractor swimmers. There is no way to identify this error from the behavioural data. Even eye data can be misleading in this regard as participants fixate more than one swimmer following drowning onset, and the lag between identification and the response means that there is no guarantee the fixation at the point of response reflects their perceived target. To overcome this potential confound, this experiment was run from a laptop using touch screen technology to identify drowning targets, while still allowing for multiple responses. This localised response avoids button presses to non-targets coincidentally falling in the scoring window. We predicted that this new design would better differentiate between non-lifeguard and lifeguard responses to the drowning swimmers.

METHOD

Participants

One hundred and nineteen participants were recruited to take part in this study (with a mean age of 24.7, SD = 11.36, 68 female). Forty-two of these participants had completed necessary qualifications in lifeguarding prior to testing. The mean age of these lifeguard participants was 23.24 (SD = 9.04, 16-54 age range, 17 female). These participants formed our *lifeguard* participant group. Forty of the participants had no lifeguarding or lifesaving experience. This *non-lifeguard* group had a mean age of 23.7 (SD = 8.8, 16-50 age range, 30 female). A further 26 participants were members of a lifesaving club, who have not completed any lifeguarding qualifications or formal training, but practice lifesaving skills for competitions. This *lifesaving* group had a mean age 25.5 (SD = 17.06, 16-72 age range, 14 female). Finally, eleven participants formed our lifeguard *trainer* group, with a mean age of 32.4 (SD = 8.87, age range of 20-45, 7 female). All lifeguard trainers teach the full course content for lifeguards. None of the participants in Experiment 2 had been recruited in Experiment 1.

Lifeguard, lifesavers, and trainers were recruited from local pools and a lifesaving national competition. The non-lifeguards were an opportunistic sample from the U.K. Participants came from a range of educational backgrounds, ranging from GCSEs (UK school-leavers qualifications) to Doctoral qualifications.

Design

A 2 x 4 x 2 x 3 design was employed, comparing study information (informed vs. non-informed in regard to drowning characteristics), experience (trainers, lifeguards, lifesavers, and non-lifeguards), drowning type (15 active drowning trials and 15 passive drowning trials), and set size (3, 6, or 9 swimmers). In the informed condition, half the participants were told that the drownings could be either passive or active, and what behaviours might characterise these targets (*informed)*, whilst the other half of the participants were only told that a drowning may occur (*uninformed*). The rest of the design was the same as that used in Experiment 1, except for two modifications. First, participants could make multiple responses *until* a correct response was made (which would result in termination of the clip). The second modification was to include localised responses via a touchscreen, with the location coordinates for each response recorded. Rather than pressing a button to acknowledge a drowning target, as in Experiment 1, participants in Experiment 2 were required to touch the area of the laptop screen to identify a target. A responsive window was placed around the drowning target, which covered an area measuring 250 x 140 pixels, in the horizontal and vertical axes respectively. This spatial window around the target accounted for 0.8% of the total screen area. The responsive window was only active after the onset of the drowning and moved with the drowning victim. Participants were able to make multiple responses in a single clip, however each time a new response was made the reaction time and the coordinates would be updated in the response output log, and therefore a clip would terminate after a correct response to log participants' first response after drowning onset. If a response was made after drowning onset but was not within the response window an incorrect response was logged. An incorrect response was also recorded if a response was made during a no-drowning trial. The experiment was created to run as a single, continuous, randomised block with a fixation screen before each trial and feedback screens after each clip. All data analyses followed those used in experiment 1, though there were no eye movement data.

Apparatus and stimuli

The stimuli were the same as those used in the first experiment. However, there was an addition of a responsive window around the drowning swimmer. The responsive windows were not visible to the participants. In total there were 45 clips, and these were randomised within a single block. Before the presentation of each clip a central fixation cross appeared for 500ms. After each clip a feedback screen was presented. If a correct response was registered, either a correct identification of a drowning swimmer or no response made to drowning absent trials, then 'correct' feedback was given. If an incorrect response was given identifying a wrong location or a response given during a drowning absent trial, then 'incorrect' feedback was given. The experiment was created in Psychopy, using Python coding and presented on a Lenova Yoga laptop, with a screen resolution 2880x1620 (28 cm x 16 cm). Unlike in Experiment 1, eye movements were not recorded.

Procedure

Testing of lifeguards was undertaken at local pools and at a national lifeguard competition. The test was conducted in convenient locations, such as in a canteen area or in the poolside viewing area. Non-lifeguard participants were tested in similar conditions, using a common area with the Psychology department (to ensure similar levels of distractibility). Participants were first asked to fill in a consent form and given instructions for the task, and were then assigned to either the *informed* or *uninformed* group. Following a brief demographic questionnaire, a base rate reaction test was presented where participants were asked to touch all the green circles and ignore any red circles. This then moved automatically to a practice trial. All subsequent trials were preceded by a fixation cross for 500 ms. After completion of the experiment, participants were thanked for their time and fully debriefed.

RESULTS

Signal detection analysis

Measures of *d'* and *c* were calculated for each participant. The measure of *d*' revealed a main effect of group ($F(3,115) = 9.61$, MSe = .64, $p < .001$, $\eta_p^2 = .2$). On average the non-lifeguards' sensitivity to targets was lowest (2.02), while lifesavers (2.59), lifeguards (2.87), and trainers (3.06) were more sensitive to drowning targets. Post-hoc Bonferroni-corrected t-tests revealed that the non-lifeguards differed from both the lifeguards ($t(80) = -4.59$, $p < .001$, 95% CI[-1.2,-.4]) and the trainers ($t(49) = -3.58$, $p < .008$, 95% CI[-1.6,-.5]). No other differences between the groups were noted.

The measure of *c* revealed a main effect of group (F(3,115) = 11.17, MSe = .68, $p < .001$, $\eta_p^2 = .2$). On average non-lifeguards' criterion value to targets was -1.45, the lifesavers -1.98, the lifeguards -2.39 and the trainers -2.64, suggesting that participants with less experience are less conservative when judging someone to be drowning. Post hoc Bonferroni corrected t-tests noted that the non-lifeguards differed to both the lifeguards ($t(80) = 5.06$, $p <.001$, 95% CI[.6,1.3]) and the lifeguard trainers ($t(49) = 4.49$, $p < .001$, 95% CI[.7,1.7]). No other differences were noted between the groups.

Behavioural responses

The percentages of trials with a drowning target that were correctly responded to were analysed. Trials with a drowning target were considered incorrectly responded to if a response was made before the onset of a drowning, if no response was made, or if a response was made after onset in an incorrect location (in all there were only 12 incorrect location responses: 0.3%, all of which were from non-lifeguards). The remaining trials were subjected to a condition x group x drowning type x set size (4 x 2 x 2 x 3) mixed ANOVA.

The main effect for the information condition was not significant ($F(1,111) = .35$, MSe = 39.8, $p = .55$, $\eta_p^2 = .00$). A main effect was noted for group ($F(3,111) = 10.5$, MSe = 39.78, $p < .001$, $\eta_p^2 = .22$). Post hoc Bonferroni corrected t-tests revealed that lifesavers detected more targets than the non–lifeguards ($t(64) = -3.22$, $p = .002$), but there was no difference between the accuracy of the lifesavers and lifeguards ($t(66) = -1.01$, $p = .316$), or between the lifeguards and trainers ($t(51) = .28$, $p = .779$; see Table 4). The remaining two effects of set size and drowning type did not reach significance.

Table 4. Behavioural measures for experiment 2

	Accuracy (%)			**Response Times (ms)**		
	Mean	*SD*	*95% CI*	Mean	*SD*	*95% CI*
Experience Group						
Non-Lifeguards	87.6*	*16.2*	85.7, 89.6	5033	*1576*	*4785, 5326*
Lifesavers	93.8*	*10.8*	91.4, 96.3	4656*	*1249*	*4321, 4992*
Lifeguards	94.9	*9.8*	93.0, 96.8	4086*	*1194*	*3823, 4351*
Lifeguard Trainers	94.5	*10.8*	90.8, 98.4	4026	*1455*	*3512, 4548*
Drowning Type						
Active	92.7	*12.3*	91.8, 95.0	4729*	*1377*	*4509, 4968*
Passive	91.7	*13.6*	90.2, 94.1	4172*	*991*	*3986, 4366*
Set Size						
3	93.8	*12.2*	92.0, 95.5	4219*	*1332*	*3938, 4346*
6	93.3	12.2	91.6, 95.3	4647*	*1496*	*4399, 4831*
9	91.1	*14.3*	89.0, 93.2	4728	*1621*	*4357, 4854*

*P <.05

Response times to correctly identified targets were also subjected to a similar 4 x 2 x 2 x 3 ANOVA. The main effect of group was significant ($F(3,111) = 10.0$, MSe = 1493245, $p < .001$, $\eta_p^2 = .21$; see Table 4 for means). When the effect for participant group ($F(3,111) = 10.0$, MSe = 4479735, $p < 0.001$, $\eta_p^2 = 0.17$) was subjected to a planned repeated contrast it was revealed that non-lifeguards vs. lifesavers approached significance ($p < 0.07$), with lifesavers eliciting the faster responses (5033 ms vs. 4656 ms respectively). Lifeguards were 600 ms faster than lifesavers ($p < 0.05$) (4086 ms vs. 4656 ms respectively), but there was no difference between lifeguards and trainers (4086 ms vs. 4026 ms respectively).

The main effect of drowning type ($F(1,111) = 26.5$, MSe = 1597504, $p < .001$, $\eta_p^2 = .23$) revealed that active drownings were responded to more slowly than passive drownings (4729 ms vs. 4172 ms). The main effect of set size ($F(2,222) = 9.8$, MSe = 1268107, $p < .001$, $\eta_p^2 = .05$) was subjected to planned repeated contrasts which noted that the smallest set size produced faster responses than the intermediate set size ($F(1,111) = 17.2$, MSe = 2219662, $p < .001$, $\eta_p^2 = .08$). However, there was no difference between the set size 6 and set size 9 (with means of 4149 ms, 4601 ms, and 4601 ms for set sizes 3, 6 and 9 respectively). The main effect of information condition did not reach statistical significance.

Two interactions involving experience were significant (set size x experience, drowning type x experience), which were subsumed by the significant 3-way interaction between experience x drowning type x set size (F(6,222) = 3.32, MSe = 1021527, *p* = .004, η_p^2 = .07) (Figure 5). It appears that the non-lifeguards are responding slower to drownings in set sizes 6 and 9 for only the active drowning condition. In contrast, lifeguard trainers appear to be responding fastest to active drownings at set size 9.

[Insert Figure 5 here]

DISCUSSION

The results of this experiment have confirmed the predicted superiority of lifeguard participants in both accuracy of responses and in the response times. Untrained lifesavers demonstrated similar levels of accuracy as the lifeguards. Given that lifesavers are exposed to drowning characteristics, but are not formally trained in the pool scanning techniques that lifeguards are, this supports the notion that the advantage of lifeguard training in terms of drowning detection may not be due to formal training in visual search for drowners (knowledge of zones, the 10:20 scanning technique). Instead, knowing what to look for (drowning characteristics) may be key to ensuring drowning detection. However, lifeguards and lifeguard trainers had a clear advantage over the lifesavers in terms of the speed in which they responded to the drowning swimmers.

While non-lifeguards in Experiment 2 detected fewer drowning targets than all other participant groups, they appear to detect a similar level to the non-lifeguards in Experiment 1. This finding suggests that the improvement in non-lifeguard passive drowning detection in Experiment 1 compared to the Laxton and Crundall (2018) study, is a stable effect and is likely due to the improvements in experimental design rather than due to an aberrant non-lifeguard group. A premature response in the Laxton and Crundall study would prematurely terminate a trial, however in the current experiments, participants were able to make multiple responses and therefore were still able to correctly identify a drowning target after making a premature response. Also, the level of information given to participants regarding the drowning characteristics did not have any ostensible effect. In Experiment 2, half of the participants were given specific details on the behavioural characteristics of active and passive drownings. This knowledge did not appear to improve one's ability to detect a drowning target. This result suggests that improved performance of the non-lifeguards in

Experiment 1 compared to Laxton and Crundall (2018) was not a result of having been informed on the type of drownings present in the experiment.

There was also no difference in the accuracy of detection between lifesavers, lifeguards, and trainers. This could be a result of the trainers skilfully passing on the knowledge of drowning detection to the lifeguards, which brings them to a level that matches their own ability. This possibility would imply that the limited training in visual search that occurs brings search detection up to a high standard, with all three experienced groups detecting more than 90% of targets. There are still some limitations however as some drowning incidents were missed. It may be that, with the addition of a dynamic and realistic visual search task, training for drowning detection could be further improved. This provides an interesting avenue for possible future research.

Alternatively, it may be possible that once an individual has experience in the behavioural characteristics of drowning targets, this is enough to bring visual detection accuracy up to a high level. This knowledge may aide the trained participants in similar ways to situation awareness. This theoretical framework suggests that as an individual's experience with a situation increases, they are able to create a mental catalogue of events that could occur in similar situations. For example, a lifeguard or lifesaver would know that splashing is not an exclusive behaviour to drowning and needs to be accompanied by other behaviours.

GENERAL DISCUSSION

The primary aim of the current study was to explore the effect of experience in a visual processing task to detect a drowning swimmer. The first experiment measured behavioural responses and eye-movements, while a second experiment incorporated additional expertise groups in a localised touch screen task. The results confirmed lifeguard superiority of drowning detection seen in similar research (Lanagan-Lietzel & Moore, 2010; Laxton & Crundall, 2018; Page et al., 2011). Eye-movement measures did not show any overall differences between the lifeguards and non-lifeguards, though it appeared 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.

One interaction result from the eye-tracking measures suggested the presence of *looked but failed to see* errors (Crundall et al., 2012; Hill, 1980). This was particularly evident for non-lifeguards detection of passive drownings in the highest set size, where they fixated 100% of targets but only responded to an average of 84% of targets. This error was also a potential issue in Page et al., (2011) who reported that 12 lifeguards looked in the area of a simulated drowning, but only 7 of those 12 correctly reported the drowning. The increase of fixations to targets in the largest set size may also result from the search zone becoming more cluttered. With more items in the array, the searcher would be expected to look around the scene more, however the quality of the information processed with each fixation may be reduced, limiting the searcher's ability to recognize and respond to targets in a crowded scene (Whitney & Levi, 2011).

In both Experiment 1 and 2, passive drownings were consistently detected faster than active drownings. This finding may initially appear at odds with literature showing that several aspects of motion appear to attract attention (Franconeri & Simons, 2003) such as motion onset (Abrams & Christ, 2003) and abrupt changes in motion direction (Howard & Holcombe, 2010). Furthermore, the search for a moving target amongst stationary distractors is more effective than search for a stationary target amongst moving distractors (Verghese & Pelli, 1992). The movements associated with active drownings might therefore be expected to have greater salience than passive drownings. There are two potential sources of explanation for faster responses to passive over active drownings. First, the active drownings were not displayed in a pool of stationary distractors. Rather, distractors were swimmers moving across the pool in both directions and with reasonably predictable body movements. Search for a stationary target amongst moving distractors is facilitated by order or structure in the motion displayed by the distractor set (Royden, Wolfe & Klempen, 2001). Therefore, it appears that the relative orderliness of the back-and-forth motion of the distractor swimmers may have afforded sufficient advantage to the search for passive drownings than would otherwise have been the case.

Second, the *instinctive drowning behaviour,* often displayed in active drownings, has some feature overlap with normal swimming behaviours. For example, active drownings and normal swimming both involve arms being lifted out of the water, submergence and re-emergence of the head, and associated splashing. The similarity between the active drowning behaviour and normal swimming behaviours may make the active drowning harder to identify. A passive drowning, conversely, is often characterised by be someone floating face down in the water, and the absence of movement in such incidents is likely to be maximally different to the distractor swimmers in this study. However, it should be noted that these studies used regimented swimmers as distractors. Under less formal swimming conditions, it is likely that face-down floating may be displayed by some non-drowning swimmers who are merely playing. This may reduce the detection advantages we have found for passive over active drownings when generalised to the real world.

Similar results have been found in traditional laboratory studies exploring similarities between targets and distractors. It is well established that target-distractor similarity is used to guide search (Guest & Lamberts, 2011; Wolfe, 1994) and that search is easier when the target and distractors differ. Thus, in this task, searching for passive drowning should be easier because of its low similarity to distractors. Importantly, although it is known that a target defined by a unique feature will “pop out” in abstract displays, in changing, dynamic scenes such as those used here, such pop out effects might not occur for targets. It is likely that the passive drowner does not pop out as such, but that their low target-distractor similarity aids attentional capture once fixated as these similarity-based effects have been shown in studies using real world objects (Alexander & Zelinsky, 2012, Neider, Boot, & Kramer, 2010). The accuracy data from both studies raise the possibility of ceiling effects masking further group differences. Given that the drowning targets were available for nearly 12 seconds on average and the low number of background swimmers, it is unsurprising that absolute detection rates are high. Given this possibility, it is perhaps more surprising to find that group differences in accuracy are still visible in the second study, with lifesavers spotting more targets than non-lifeguards. Despite this factor, a difference between groups was upheld across both studies for the response times to drowning targets.

In the current study, the staged nature of the stimuli may raise questions about whether the true range of subtle drowning behaviours is truly represented. Furthermore, the distractors’ regimented swimming did not display the full range of naturally occurring in-pool behaviours. Unfortunately, the pragmatic and ethical issues of obtaining naturally occurring drowning incidents in video-based footage provide a barrier which needs to be overcome for these findings to be linked to ever-more realistic scenarios in an applied lifeguarding domain.

It should be noted as a limitation that further information on the experience of lifeguards and lifeguard trainers was not collected in Experiment 2. Nor were these participants asked if they had seen a real drowning incident. This information may be beneficial to collect in future research to perform more fine-grained analyses of different levels of experience, such as novice lifeguards verses experienced lifeguards.

In conclusion, this study has demonstrated that the visual processing skills of people with experience of lifeguarding and lifesaving skills can be assessed in a simple computer test. The core findings of these experiments are clear, with lifeguards detecting drowning swimmers faster and more frequently than non-lifeguards. There was some evidence that small gains in time to first fixate the drowning swimmers and the processing time may add up to make the significantly faster response times of lifeguards in detection of drowning swimmers. However, it should be noted that there are interesting effects within this research that are harder to explain. Given the novel area, we have opted to extract the clear findings and to avoid post-hoc over-rationalisation of complex sub-effects (i.e. any interactions that did not involve the factor of experience). The use of applied naturalistic and dynamic stimuli has offered a realistic visual search environment, which offers insights to factors that influence visual processing in real-world settings, such as target/distractor similarity in naturalistic and dynamic search items. Future research should investigate whether such stimuli can also be used to train future lifeguards or improve current lifeguards' skills.

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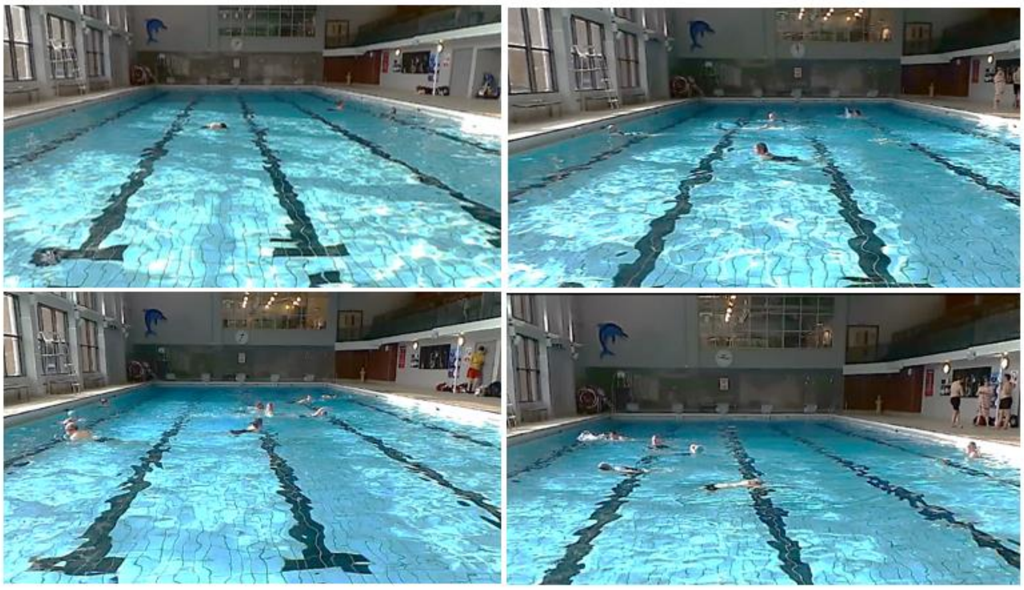

Figure 1. Four screen shots of the swimming pool stimuli from Laxton and Crundall (2018).

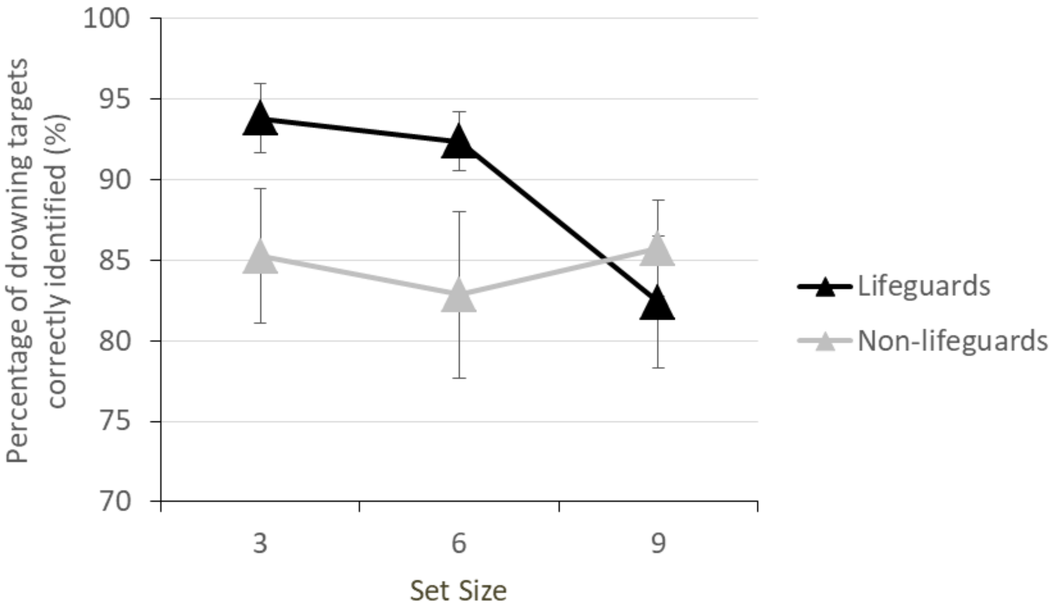

Figure 2. The mean percentages of trials containing a drowning target that were accurately responded to (with standard error bars). The significant interaction was driven by the contrast between set sizes 6 and 9, across the two groups (*p* < .007).

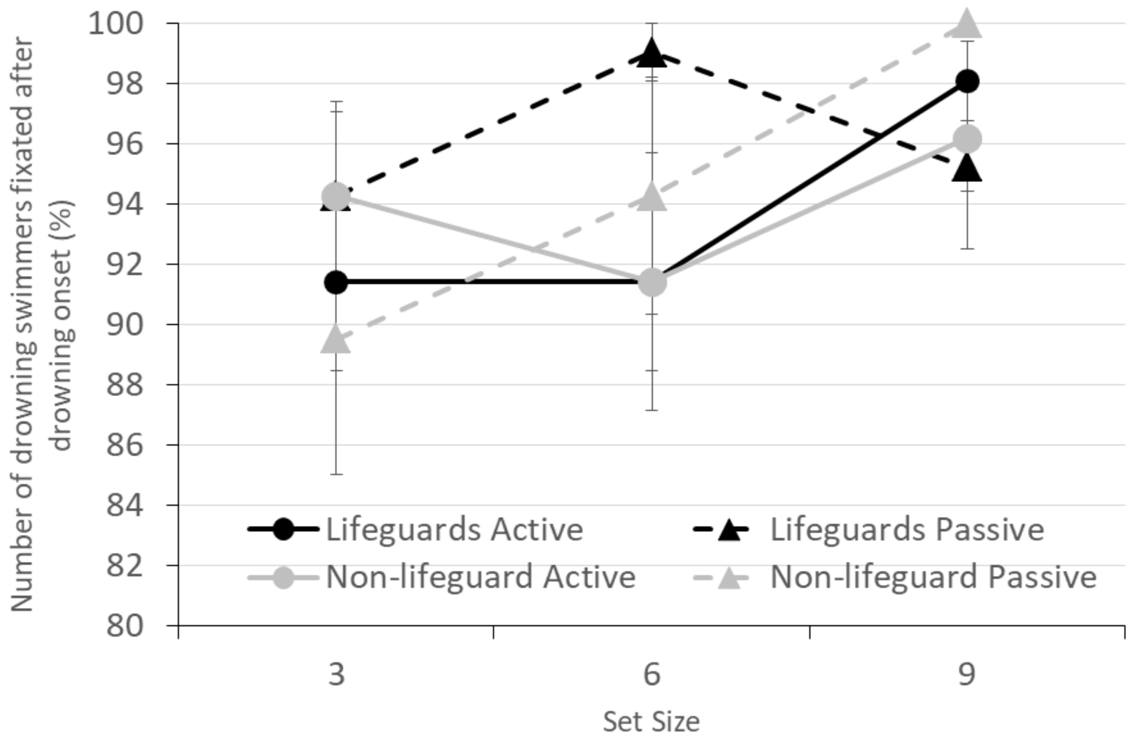

Figure 3. The mean percentages of the number of targets that were fixated after drowning onset (with standard error bars)

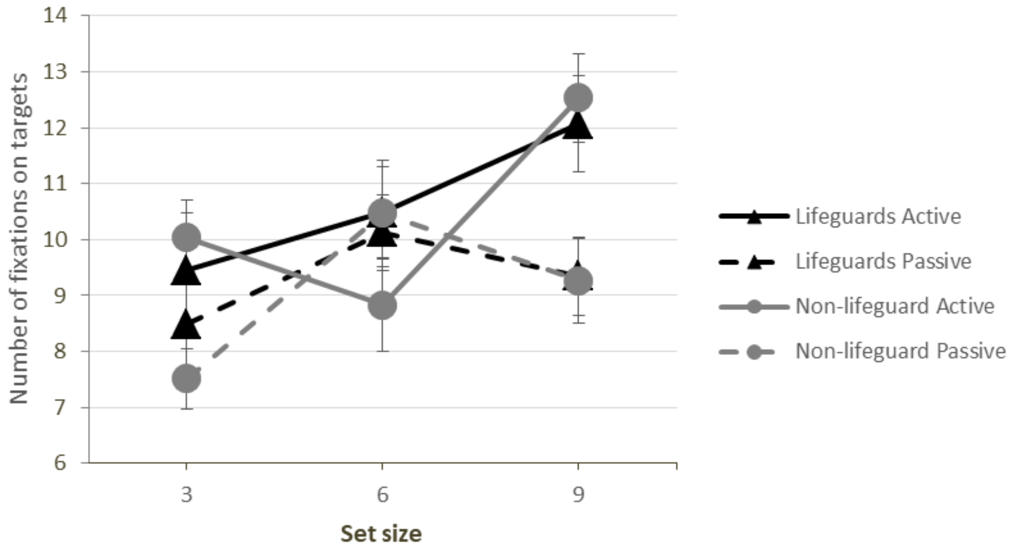

Figure 4. Average number of fixations made to the active and passive drowning targets (with standard error bars).

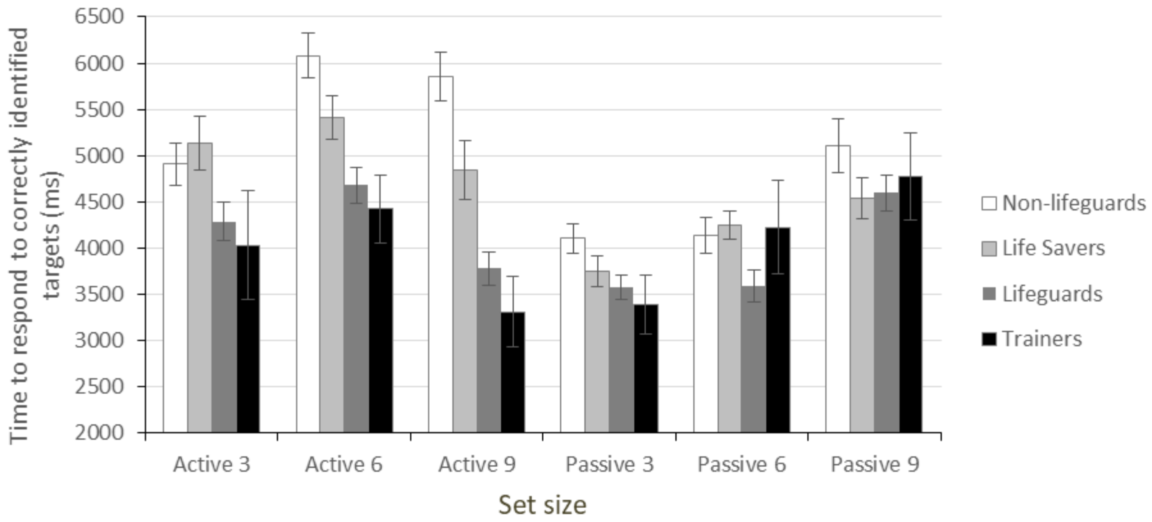

Figure 5. The mean responses times of correctly responded to trials (with standard error bars) in Experiment 2.