The effect of lifeguard experience upon the detection of drowning victims in a realistic dynamic visual search task

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Abstract

Lifeguard surveillance is a complex task that is crucial for swimmer safety, though few studies of applied visual search have investigated this domain. This current study compared lifeguard and non-lifeguard search skills using dynamic, naturalistic stimuli (video clips of confederate swimmers) that varied in set size and type of drowning. Lifeguards were more accurate and responded faster to drowning targets. Differences between drowning targets were also found: passive drownings were responded to less often, but more quickly than active drownings, highlighting that passive drownings may be less salient but are highly informative once detected. Set size effects revealed a dip in reaction speeds at an intermediate set-size level, suggesting a possible change in visual search strategies as the array increases in size. Nonetheless, the ability of the test to discriminate between lifeguards and non-lifeguards offers future possibilities for training and assessing lifeguard surveillance skills.

Introduction

Drowning incidents are potentially severe but thankfully rare for most lifeguards. Due to the infrequency of drowning incidents, the visual search for such occurrences is challenging (Lanagan-Leitzel, Skow & Moore, 2015). The difficulties involved in detecting infrequent drowning targets are reflected in other areas of real-world visual search with uncommon target items, such as airport security screenings (Wolfe, Horowitz & Kenner, 2005; Biggs & Mitroff, 2015). For example, Wolfe et al., (2005) found low-prevalence targets (occurring on 1% of trials) were missed more frequently than high-prevalence targets (occurring on 50% of trials), with error rates of 30% and 7%, respectively.

In regards to lifeguarding, visual search has been defined as observing part of an aquatic environment (beaches, pools, open water), and processing and assessing the events happening within that location (Fenner et al., 1999). While this definition suggests that the surveillance of the water is a fundamental and critical role of the lifeguard, there is relatively little focus on training in these areas (Lanagan-Leitzel & Moore, 2010). This is reflected in the UK National Pool Lifeguard Qualification (NPLQ) training manual (Blackwell, 2016), where only 6 out of 214 pages are dedicated to the education of scanning and observation behaviours (Blackwell et al., 2012). With this limited focus on visual training, lifeguards may be underprepared for detecting struggling swimmers in a timely manner.

Within the limited training that lifeguards do receive, one key method that is taught is the 10:20 scanning technique. This technique recommends that a lifeguard has 10 seconds to scan their aquatic zone in search of target behaviours, then 20 seconds to respond to an individual whom they have identified as a potential drowning target, so that no swimmer is drowning for longer than 30 seconds (Blackwell et al., 2012). In support of the 10:20 scanning method, lifeguards are trained to detect specific behavioural characteristics of distressed swimmers. These include two distinct types of drowning: active and passive.

Active drowning is characterised by a swimmer in distress struggling to keep their head up and out of the water. They may attempt to continue swimming to the pool side or a shallow location, and some stronger swimmers may be able to call out for help at this point. In more severe instances, typically with weak or non-swimmers, instincts take control of an individual's behaviour, resulting in flailing arms, a vertical body position, with head tossed back. These behaviours are collectively termed the *instinctive drowning behaviour* (Pia, 1974); a silent struggle transpires as victims fight to keep the head out of the water, possibly submerging and re-emerging on several occasions, with breathing taking precedence over everything else.

These swimmers are in immediate danger of slipping under the surface of the water without hope of immediate re-emergence (Vittone & Pia, 2006). A victim will struggle for as long as their energy permits, however research suggests that a drowning victim may begin to slip under the surface of the water within 20-60 seconds, with children becoming submerged within 20-30 seconds (Pia, 1974).

Conversely, passive drownings refer to those swimmers who have lost consciousness in the water. There is no struggling and the transition from normal swimming can happen quickly. The victim will either slip slowly under the water, or remain face down and motionless on the surface. There are a variety of causes of passive drowning, including prolonged underwater swimming, head injuries or heart attacks (Fenner et al., 1999).

Once submerged the vital organs that require oxygen quickly begin to shut down. The longer an individual is under the water the greater the risk of severe, permanent brain damage. Therefore, it is crucial for lifeguards to be vigilant, searching for behaviours linked to drowning in order to prevent serious situations.

Unfortunately, the limited number of studies that have focused on lifeguards' visual interrogation of the scene suggest that the limited training they receive does not necessarily raise their visual skills to a sufficiently high level. For instance, Brener and Oostman (2002) reported a study where a submerged manikin was introduced to a swimming pool without the knowledge of the lifeguards on duty. This was repeated over 500 times, with lifeguard responses videotaped for later analysis. The researchers found that over 90% of lifeguards failed to notice the submerged manikin within the industry standard of 10 seconds. Less than half of the lifeguards (43%) identified the manikin in less than 30 seconds. On average it took successful lifeguards 1 minute and 14 seconds to detect the submerged manikin, with 14% of lifeguards completely failing to detect the manikin with a 3-minute time limit. While motivation and distraction may have played a role in these poor results, it raises the question of whether the training that these lifeguards had received was adequate enough to provide the fundamental skills of visual search to detect victims in the complex environment.

Why is the visual search task of a lifeguard so difficult?

Many factors have a negative impact on successful target detection in basic studies of visual search, including crowding (van den Berg, Cornelissen, & Roerdink, 2009), target-distractor similarity (Wienrich, Hesse, & Muller-Plath, 2009), and attentional set (Theeuwes, Kramer, & Belopolsky, 2004). These factors are also likely to play a negative role in the visual search of lifeguards.

For instance, crowding is typically defined as an effect that limits perception of objects' features when surrounded by neighbouring distractors. The ability to recognize and respond to crowded targets is dramatically reduced during visual search (Whitney & Levi, 2011). The negative impacts of crowding overlap considerably with the related concept of *visual clutter* (van den Berg et al., 2009). As the number of items in a search area increases, the space between items becomes smaller and this limits the searcher's attention to smaller areas (Pelli & Tilliman, 2008). This phenomenon of crowding has obvious relevance to lifeguarding, for example, with increased numbers of swimmers, physical space within the zone of supervision will become visually cluttered, causing delayed reaction times in visual searches (Lanagan-Leitzel et al., 2015). This problem of visual clutter is also noted in other research studies, both in the laboratory and in applied settings. For example, Neider and Zelinsky (2011) found that individuals were better at detecting targets in rural scenes with limited clutter, compared to urban city scenes with high rates of visual clutter. Ho et al., (2001) found similar effects in young and old people in their visual searches of roads, with more clutter in the search area having a detrimental effect on searches of road signs.

Target-distractor similarity has also been noted in prior research to have a negative influence on visual search outcomes. Wienrich et al., (2009) found target detection for circles among oval distractors improved as the distractors became more ovoid. Alexander & Zelinsky (2012) applied target-distractor similarity to a more real world search, with visual arrays of teddy bears. They found that reaction times increased for target bears that shared 3 out of 4 features with distractor bears, and that more false alarms were made when targets and distractor bears shared similar features. In terms of lifeguarding there is a large overlap of drowning behaviours with normal swimming behaviours. For instance, an active drowning victim, displaying splashing behaviour and bobbing up and down in the water, can easily be mistaken for a swimmer engaging in horseplay (Fenner et al., 1999). Similarly passive drowning can be mistaken for intended submergence or floating face down in the water (colloquially known as the ‘dead man’s float’ among some lifeguards).

The inclusion of extra target behaviours alongside those of drowning and distress also add to the complexity of lifeguard visual search: not only must they keep alert for drowning targets but they must also be attentive to risk-taking behaviours, rule-breaking, and the quality of the water. Research into attentional set suggests that the greater the number of target features that may define a target (drowning behaviours, risk-taking etc.), the less efficient visual search is (Theeuwes, Kramer, & Belopolsky, 2004). Recent research argues that this is because different features in the search set need to be searched for sequentially (Moore & Weissman, 2014). A related problem is termination of search due to the detection of a task-relevant (but non-drowning) target: if a lifeguard identifies swimmers engaging in risk-taking behaviours, they would need to interrupt their scan of the pool to intervene and stop any potentially dangerous actions (Lanagan-Leitzel et al., 2015), thus possibly missing a drowning target. As rule-breaking and risk-taking are more prevalent targets than drowning incidents, there is also the problem that expectations may lower the threshold for detecting these common events at the expense of detecting swimmers in trouble.

While these factors may add to the complexity of the lifeguards' visual search there are factors that may aid search. One of these is the ability to use memory to guide attention through the search array (Peterson et al., 2001; cf. Horowitz & Wolfe, 1998). Searchers are suggested to use memory to tag search items, which in turn guides their attention away from re-examining objects.

However, unlike the static images used in surveillance based visual search tasks (such as airport security and radiology), lifeguards are faced with the challenge of dynamic scenes. Lifeguards are required to observe swimmers moving around a pool. The scene they observe constantly changes. This creates difficulties in using memory as a swimmer that has already been checked may later begin to drown or move into an area that has already been scrutinised. What may be more relevant to the searches of lifeguards is the theory behind *Multiple Object Tracking* (Pylyshyn, 1989). This theory suggests that searchers are able to track a small number of multiple moving objects around a screen by pre-attentively tagging them. In recent research it has been shown that expert sportsmen, such as basketball players who need to be able to follow the ball and other players in a game, have substantial superior visual skill in complex neutral dynamic tasks after training in three dimensional multiple object tracking. It was also found that these expert sportsmen have a greater capacity for learning these skills compared to amateur and non-athletes (Faubert, 2013). Regular surveillance of swimmers may help to improve lifeguards' search skills in tracking multiple objects at a time, resulting in an increased ability to detect drowning swimmers in the search zone.

Lifeguard experience effects in visual search

Many other complex, real-world contexts contain similar problems to those faced by lifeguards, where visual search often seems inadequate for the task at hand (e.g. driving, radiology and aircraft pilots). However, in such contexts, researchers have demonstrated that visual search improves with domain experience (e.g. Crundall & Underwood, 1998; Nakashima et al., 2013; Robinski & Stein, 2013). Does this experiential effect translate to lifeguarding?

Unfortunately, the evidence is mixed. Some studies have demonstrated clear experiential effects. For instance, Lanagan-Leitzel (2012) recorded lifeguards', instructors', and non-lifeguards' verbal responses to critical events while watching twenty 2-minute-long video clips of outdoor swimming activity. The three groups differed in opinion on the events that should be monitored, with instructors identifying more critical events than lifeguards, though even within the groups there was a lack of consistency in the prioritisation of search areas.

In a review of lifeguarding standards, DeMers and Giles (2011) summarise that lifeguard reaction times and their sensitivity to the detection of the target stimuli improve after a period of practice. However, it was further concluded that practice only improved the speed with which they detected drowning targets, rather than the number of targets detected. If compared to non-lifeguards however, their ability to spot drowning targets may in fact be superior. A result shown in an observational study of drowning-incident videos available in the public domain shows that lifeguards may in fact have a superior search. Avramidis, Butterly and Llewellyn (2009) found in an investigation of rescuer characteristics that the average untrained bystander failed to recognise the majority of drownings, despite the presence of substantial outward drowning behaviour. Whereas with the lifeguards on duty it was found that they remained highly vigilant, accurately detecting any drowning behaviours, showing the superiority in detection and recognition of a distressed swimmer, despite the lack of response from other bystanders.

To better understand the effects of training, Lanagan-Leitzel and Moore (2010) compared three groups: experienced lifeguards, a group of non-trained naive participants and a group of individuals who had been given short training on drowning behaviours and scanning. All participants were required to watch sixty 30-second video clips, while eye movements were recorded. In terms of fixations it was concluded that lifeguards show a superior search of the whole visual scene, with shorter and more frequent fixations than trained and naïve participants. Results further showed that the experienced lifeguards monitored more critical events than both the trained and naive participants, but this was not to a level of significance. The qualified lifeguards' performance was not much better than the participants who received short training. Out of 150 critical events presented to participants, lifeguards only monitored 54%, which proved to be little better than the trained participant's average of 49.2% and did not reach conventional levels of statistical significance. This suggests that lifeguards are not scanning and detecting incidents as well as they potentially could be. A possible argument arises from these findings which suggest the positive impact of training. With short instruction, such as the few minutes training Lanagan-Leitzel and Moore's participants received, individuals with no prior experience were able to detect critical events to a similar standard of experienced lifeguards.

In terms of measuring lifeguards' visual search speeds in recognition of a drowning victim there have been a limited number of studies. There has however been one notable study that has investigated visual search patterns and detection rates of lifeguards. Using computer-animated beach scenes, with 63 swimmers placed equally across the screen, Page et al., (2011) found the detection rates between novice and experienced lifeguards differed significantly when they were given additional contextual information (e.g. the location of a riptide), with experienced lifeguards detecting 31.6% compared to novice lifeguards' detection rate of 16.7%. When no contextual information was provided (i.e. that there is a rip current in the area), overall detection rates dropped. However, experienced lifeguards were still superior in detection rates and were five times more likely to detect a drowning victim than the novices, 0% and 19.2% respectively. Despite this finding of lifeguard superiority, low detection rates were reported for both novice and experienced lifeguards, on average 29% in biased conditions and 16% in non-biased conditions. For example, in the final 3.5 seconds of the 5 second disappearance, 12 out of the 69 lifeguards tested fixated in the relevant section of the screen, but only 7 of these 12 detected the drowning victim.

The study of Page et al., (2011) could not identify how experienced lifeguards achieved higher detection rates, as eye movements showed that visual search patterns in both groups followed the same systematic gaze behaviour, using similar scanning patterns. Suggestions were made by Page et al. to offer explanations for the detection differences, including the advanced contextual knowledge of experienced lifeguards and differences in processing visual information. It is possible that some lifeguards suffered from an increase in ‘Look but Fail to See’ errors, where fixation on the drowning target does not equate with detection (Hills, 1980).

A further issue with this study is the low detection rates of both the experienced and novice lifeguards. This low detection rate of both novice and experienced lifeguards could be related to the speed in which a victim submerged under the water, which was within 5 seconds with no visible signs of struggling, distress, or weakness. This is potentially unrealistic, and does not correspond to the much longer struggles of swimmers noted by Pia (1974), or allow sufficient time to be detected using the 10:20 second scanning method that is taught.

On the basis of the reviewed literature, there is limited evidence for the superiority of trained lifeguards’ visual skills, with previous research using naturalistic stimuli (e.g. CCTV footage of general swimming activity; Lanagan-Leitzel, 2012) or tightly controlled laboratory studies (e.g. low-fidelity computer generated imagery, Page et al., 2011). Unfortunately the former studies suffer from a lack of control, making it difficult to conclude anything, while the latter studies use extremely artificial stimuli, which makes it difficult to generalise findings back to the pool or beach environment. Accordingly, this study will attempt to identify superiority in trained lifeguards through the use of videoed pool swimming scenarios that vary in set size (3, 6, or 9 swimmers) and which vary in the type of drowning target (comparing both passive drowning to active drowning to control trials). The purpose of the research is to demonstrate that lifeguards have better visual search skills than controls, and under which condition they show this superiority (crowded situations, active drownings, or passive drownings). With the advanced knowledge and experience of lifeguards, it was predicted that the lifeguards will have faster and more accurate responses in detection of a drowning victim. As active drownings have a set of behavioural characteristics, which include increased splashing (Pia, 1974), it is believed that they will have a pop-out effect, therefore it was predicted that active drownings will elicit the faster response times overall. Due to the pop-out effect of active drownings (that should attract the attention of both lifeguard and control participants), it is expected that the less salient passive drowning targets will better demonstrate lifeguards’ superiority. With increased numbers of swimmers, a delay in reaction times is expected; it is predicted that response times will gradually increase as the set size increases. This is expected to have a greater effect in control participants, due to lack of experience of performing scans of increased numbers of moving swimmers in a pool. Furthermore an increase in response times with set size will be seen to a greater extent in passive drowning trials.

Method

Participants

Sixty participants were recruited to take part in the visual search study (with a mean age of 25.3 years; 26 female). Thirty of these participants had completed compulsory qualifications in lifeguarding prior to testing and had a varying amount of experience in pool-side lifeguard duties (with 4.2 years of lifeguarding experience on average). The remaining thirty participants had no lifeguarding experience. Lifeguard participants were recruited through local swimming pools. Non-lifeguard participants were an opportunistic sample from the U.K, made up of undergraduate students from a variety of disciplines, and members of the general public.

Design

A 2 x 2 x 3 mixed design was employed, comparing experience (lifeguards to control 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 trials with 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. If a participant responded before a target began to drown (which would terminate the clip) this was considered a false alarm and was coded as inaccurate. Alternatively, if no response was made this was also coded as incorrect. It was not possible to respond too late to the drowning, as the clip ended abruptly following the drowning event. The decision to terminate the clip following an initial response was made on the basis that a lifeguard would intervene at this point and therefore be unlikely to respond to a separate incident elsewhere in the pool.

Each drowning event was an average of 11 seconds in length from first indications to the completion of drowning. Only responses during the drowning window were considered accurate on the drowning trials. On the non-drowning trials, participants had to refrain from making a response. Response times were only recorded for correct responses to drowning trials and were taken from the onset of a drowning incident.

Apparatus and Stimuli

Initial video footage was recorded on a Samsung Galaxy EK-GC110 23mm handheld digital camera on a standard tripod. The camera was angled to record the length of the pool, capturing the shallow end of a 25 by 15 metre pool, but also environmental features, such as the poolside equipment, windows with views into a gym corridor and a pool-side clock on the distant wall (see Figure 1). The swimmers in the video footage were volunteers recruited from local lifesaving clubs, and had prior training in drowning simulation. All volunteers gave informed written consent before taking part in any filming.

Swimmers were placed in a 10m by 15m section of the pool, all within visibility of the camera, and asked to swim across the 15m width of the pool. A variety of swimming strokes were used by the swimmers. In the active drowning video clips a swimmer was primed, on cue, to become distressed in the water, showing signs of panicking and visibly struggling or displaying an instinctive drowning behaviour (Vittone & Pia, 2006). In passive drowning clips, on cue again, a swimmer would become motionless and face down in the water, in accordance with research presented in the literature (Fenner et al., 1999). The cameraperson was able to use verbal cues and a whistle during filming to direct the action. During filming every volunteer swimmer was able to perform both drowning types across different set sizes to ensure variety of targets.

Forty-five clips were selected from the footage, evenly distributed across the active, passive and non-drowning levels. Within each level of the drowning-type factor, an even number of 3, 6 and 9 swimmer trials were selected (5 of each per drowning type). The clips lasted an average of 30 seconds. The drowning incidents lasted an average of 11 seconds 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. Both types of drownings happened quasi-randomly within the second half of an average length video clip and all trials were presented in a single block.

Video clips were presented to participants without an audio track to avoid audible instructions (given to the swimmers during filming) appearing in the experiment. While the lack of an audio track may remove some cues to a drowning event (e.g. other swimmers calling attention to the drowning victim), many drowning incidents occur in relative silence (Pia, 1974). The removal of audio tracks in other studies of dynamic environments is accepted (e.g. hazard perception during driving), and allows researchers to focus on purely visual skills. As with driving, lifeguarding primarily relies on vision rather than audition.

The trials were presented on an Intel core i7 at 2GHz, Lenova laptop, with a screen resolution of 2880x1620, running Eprime2.

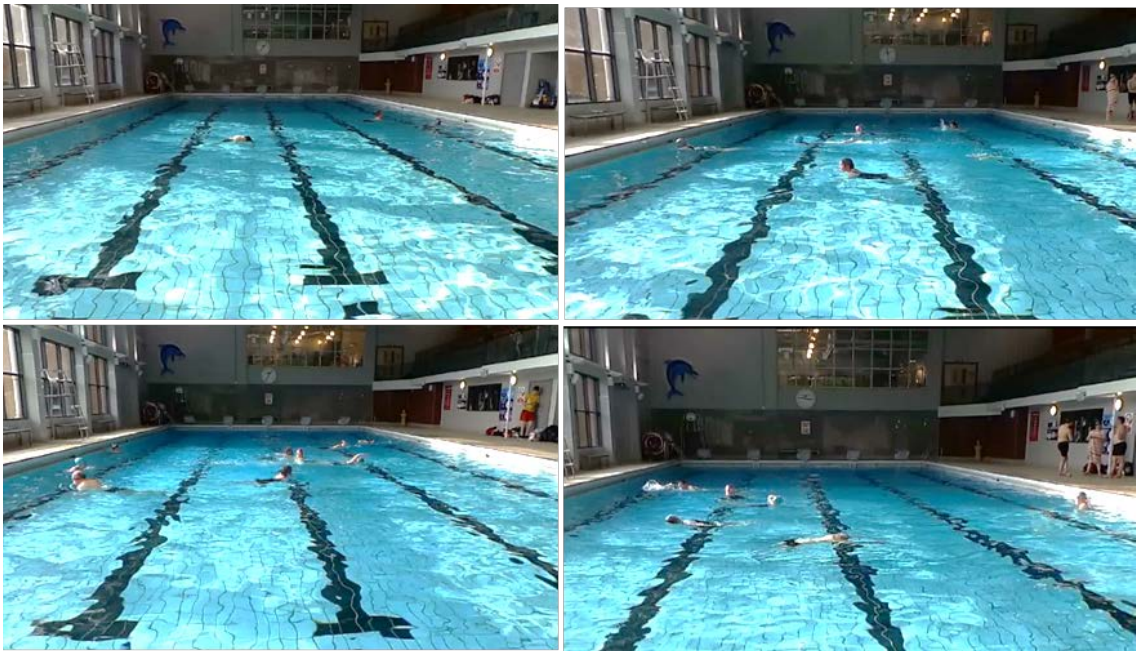

Figure 1. Four screen shots taken from the video stimuli. From top left in clockwise order: set size 3, passive drowning; set size 6, active drowning; set size 9, no incident of drowning (catch trial); Set size 6, passive drowning.

Procedure

In order to recruit lifeguards, the experimenter arranged testing sessions at various pools and leisure centres around Nottingham and Leicester, with a quiet office or side-room acting as the laboratory. Control 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 that they would be searching for any potentially drowning victims from a lifeguard's perspective, and that the study may contain a drowning. They were told to press the space bar on the laptop upon identifying a drowning target that would require lifeguard assistance or intervention, and were also told that this would terminate the clip (preventing detection of a subsequent drowning target should their first response have been premature). Participants were then given a practice trial followed by a final opportunity to ask any remaining questions before the trials began. Once the test had ended participants were fully debriefed and thanked for their time and participation. This research was conducted with approval obtained from the University ethics committee and run in accordance with British Psychological Society guidelines.

Clips refinement

Prior to analysis of accuracy data, trials were screened for excessive premature responses as some clips appeared to attract a relative large number of premature responses which may have been due to a misleading cue from one of the distracting swimmers. An analysis was undertaken to identify the impact of these premature responses on the results, comparing their distribution across the three factors using a 2 x 2 x 3 mixed ANOVA.

First, a group effect was noted ($F(1,58) = 7.7$, $MSe = 365$, $p < 0.01$) with lifeguards making premature responses on only 7.7% of trials while control participants made premature responses on 17.3% of trials. Main effects for drowning and set size were also noted ($F_{drowning}(1,58) = 14.9$, $MSe = 165$, $p < 0.001$; $F_{setsize}(2,116) = 3.9$, $MSe = 190$, $p < 0.05$): passive target trials received more premature responses than active trials (15.1% versus 9.9%), and the trials in set size 6 were also found to pose a problem (with the mean percentage of premature responses recorded as 11.5%, 15.3% and 10.7% across the increasing set sizes). The interaction between drowning type and set size only approached significance (F(2,116) = 3.9, MSe = 148, p = 0.081) with the tendency for passive trials to evoke more premature responses than active trials, diminishing at set size 9.

The difference between the percentage of premature responses on active and passive trials is intriguing as there should be no difference between the trial types at the point a premature response is made. This supports the possibility that some clips may contain misleading cues that evoke a high number of premature responses, and that these misleading cues may not be evenly distributed throughout the clip set. To confirm this, a simple k-means partitional cluster analysis on the number of premature responses per clip across all participants identified 2 clusters, with 6 target clips receiving premature responses from 32% of all participants (clips 9, 14, 18, 21, 24 and 27 in Figure 2), while the remaining 24 clips evoked premature responses from only 7.6% of participants on average. Of the 6 clips with excessive premature responses, 4 of these were passive target trials, including the worst offending clip with 51.7% of all participants responding before target onset. This appears to be the source of the main effect of drowning type upon premature responses.

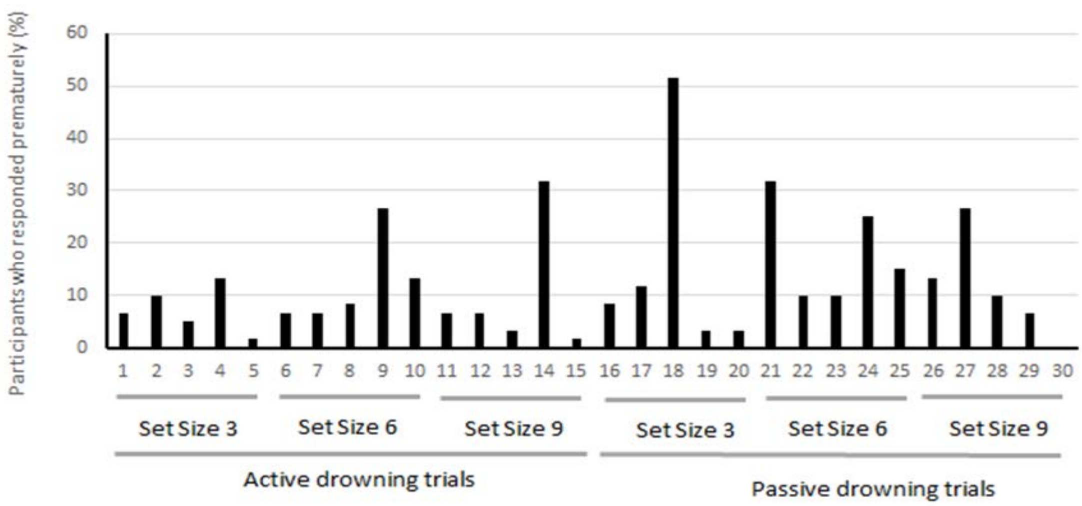

Figure 2. The percentage of participants who responded prematurely across 30 target-present clips categorised according to drowning type and set size.

On closer inspection of the worst offending clip, one of the swimmers makes an exceptionally long underwater stroke, and this delay in re-surfacing corresponds with the average time for premature responses in this clip (12.2 s). It appears that slight variations in swimmer actions across the 30 target-present clips led 6 of them to unwarrantedly evoke these premature participant responses. These six clips were removed from all further analyses.

Results

Before analysing accuracy of the drowning trials, the response rate to the non-drowning trials was assessed. On average, control participants successfully avoided responding on 62.7% of catch trials, while lifeguards were more successful with 80.2% ($t(58) = 2.96$, $p < 0.005$). Two control participants responded to all catch trials. The following analyses have been undertaken with and without these two participants, though their removal does not change the pattern of results obtained with the full data set.

In order to assess participant accuracy, responses across 24 trials (six trials removed that elicited premature responses) were converted into percentages for each participant and subjected to a group x drowning type x set size (2 x 2 x 3) mixed ANOVA.

A main effect was noted for group ($F(1,56) = 19.0$, MSe = 263.6, $p < 0.001$, partial eta squared: 0.25) with lifeguards correctly identifying more drowning targets than controls (94.8% vs. 81.6%). The factor of drowning type also revealed a significant main effect ($F(1,56) = 4.4$, MSe = 191.6, $p < 0.05$, partial eta squared: 0.07), with active drowning targets identified more often than passive drowning targets (89.7% vs. 86.6%). Finally there was also a main effect of set size ($F(2,112) = 7.4$, MSe = 237.6, $p = 0.001$, partial eta squared: 0.12). All effects involving set-size were investigated with planned contrasts comparing set size 3 with set size 6, and set-size 6 to set-size 9. For this particular analysis, the planned repeated contrasts revealed that set size 3 differed from set size 6 ($F(1,56) = 8.6$, $MSe = 678.9$, $p < 0.05$, partial eta squared: 0.13), and that set size 6 differed from set size 9 ($F(1,56) = 10.3$, $MSe = 457.2$, $p < 0.05$, partial eta squared: 0.16). This was not the linear decrease in accuracy that might be expected with an increase in set size however, as the means followed a u-shaped pattern (with mean % accuracies of 90.8%, 83.7% and 90.1% for set sizes 3, 6 and 9, respectively).

This main effect of set size is explained further by a significant interaction between set size and drowning type ($F(2,112) = 5.5$, $MSe = 245.9$, $p < 0.05$, partial eta squared: 0.09), with planned repeated contrasts confirming the interaction to lie in the comparison of both set size 3 to 6 ($F(1,56) = 10.4$, $MSe = 489.3$, $p < 0.05$, partial eta squared: 0.16) and set size 6 to 9 ($F(1,56) = 4.9$, $MSe = 511.5$, $p < 0.05$, partial eta squared: 0.08). This appears to be driven by a dip in accuracy for passive drownings at set size 6 (see Figure 3). Post hoc Bonferroni adjusted t-tests support this interpretation with passive drownings at set size 6 being different from active drownings at set size 6 ($t(57) = 3.1$, $p < 0.007$). Passive drowning accuracy at set size 6 was also found to be different from both passive drownings at set size 3 ($t(57) = 3.6$, $p < 0.007$), and passive drownings at set size 9 ($t(57) = 3.3$, $p < 0.007$).

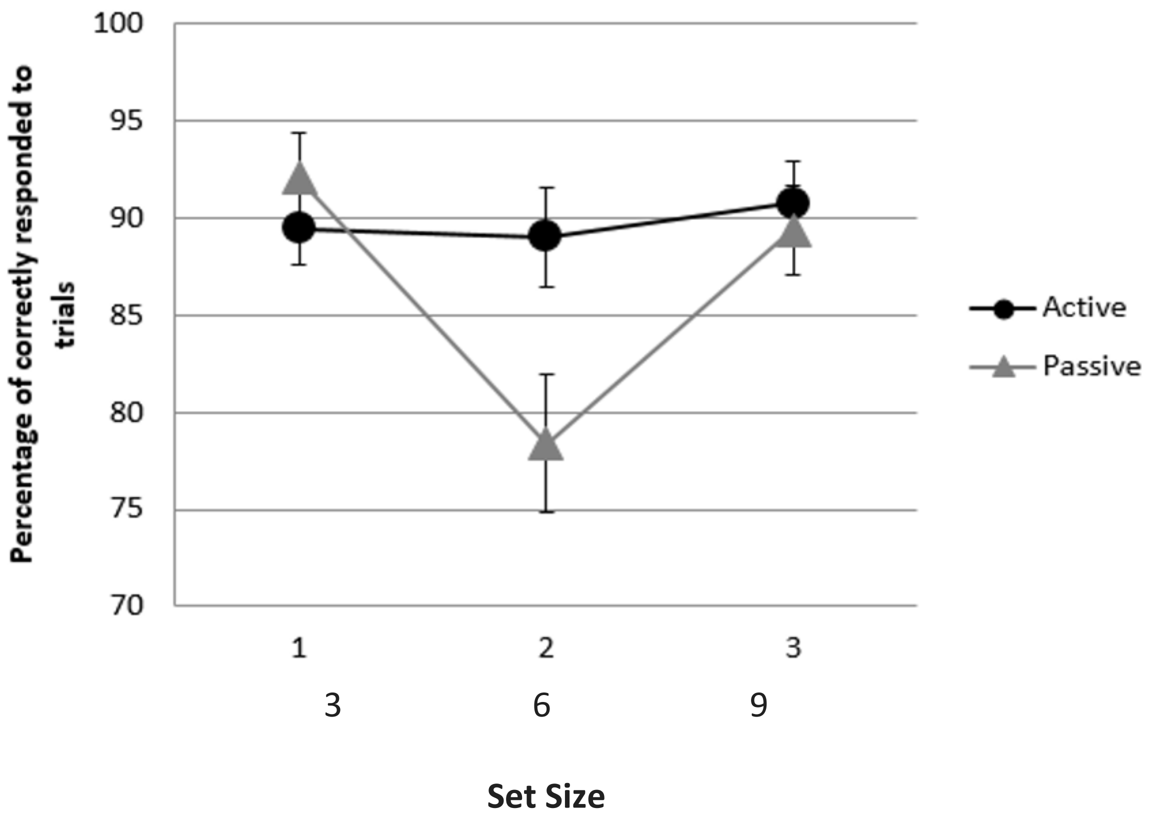

Figure 3. Percentage of trials correctly responded to (with standard error bars).

Response times to correctly identified targets were first cleaned for outlier responses that fell outside of 3 standard deviations from the mean (1.6% of all responses). Response times were then subjected to a similar 2 x 2 x 3 mixed ANOVA. Main effects were found for participant group and set size. The effect of participant group ($F(1,56) = 15.1$, $MSe = 1398404$, $p < 0.001$, partial eta squared: 0.21) revealed that lifeguards responded nearly a second faster to drowning targets than control participants (3597 ms vs. 4453ms). When the main effect of set size ($F(2,112) = 22.3$, $MSe = 1302287$, $p < 0.001$, partial eta squared: 0.29) was subjected to planned repeated contrasts, it was noted that the smallest set size produced faster response times than the intermediate set size ($F(1,56) = 34.5$, $MSe = 2822874$, $p < 0.001$, partial eta squared: 0.38), but there was no difference between the intermediate set size and the largest set size (F(1,56)

= 0.4, MSe = 3265646, $p = 0.513$, partial eta squared: 0.01) (with means of 3450 ms, 4368 ms, and 4257 ms, respectively).

The main effect of drowning type did not reach conventional levels of significance ($F(1,56) = 3.3$, MSe = 1961680, $p < 0.07$, partial eta squared: 0.05), with the ostensible advantage for passive targets being less than 300 ms (3888 ms vs. 4162 ms).

A significant 2-way interaction was noted between drowning type and set size ($F(2,112) = 8.9$, MSe = 1519343, $p < 0.001$, partial eta squared: 0.14), but this was subsumed by the significant 3-way interaction between group x drowning type x set size which approached significance ($F(2,112) = 2.9$, MSe = 1519343, $p = 0.056$, partial eta squared: 0.05). As can be seen in Figure 4 this appears to be driven by the response times of control participants being most adversely affected by an increase in set size but only when faced with active drowning targets.

To support this interpretation, separate drowning type x set size ANOVAs were conducted for each participant group. A number of important differences between the two groups became apparent which help unpack the three-way interaction. First, the main effect of drowning type (with active drowning targets responded to more slowly) only approaches significance for the control group. Second, while both groups show a significant interaction between drowning type and set size, the effect size for the contrast between set size 3 and 6 is much greater for control participants than lifeguards (partial eta squared: 0.43 vs. 0.13). This reflects the considerable increase in response times that control participants demonstrate with active drowning targets when set size increases to 6.

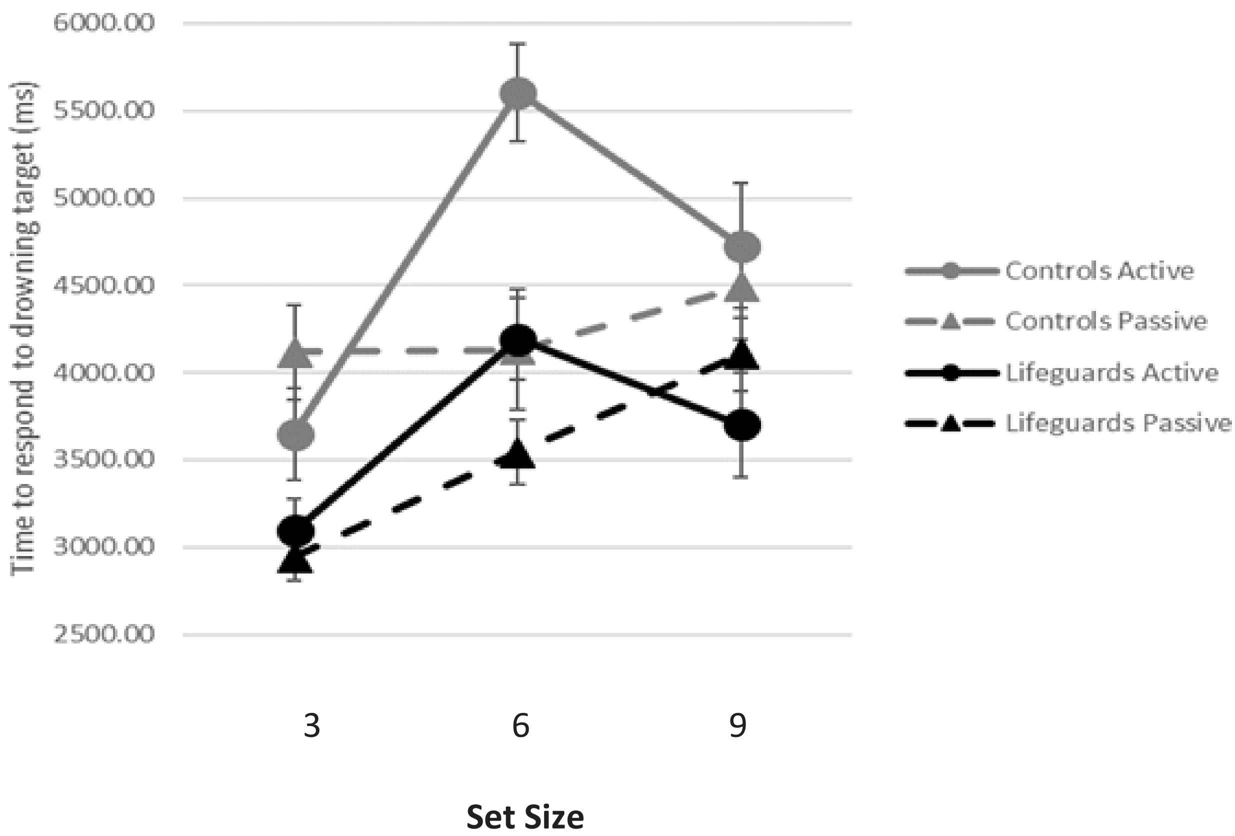

Figure 4. Time to respond to correctly identified drowning targets (ms) (with standard error bars).

Finally, both groups also demonstrate a narrowing of the RT gap between the two drowning types when set size increases to 9 potential targets. This effect is only significant in the lifeguard group ($F(1,29) = 10.1$, MSe = 877209, $p < 0.05$, partial eta squared: 0.26) than in the control group ($F(1,27) = 3.8$, MSe = 2554817, $p = 0.06$, partial eta squared: 0.13), and in fact produces a cross-over interaction component for the lifeguard group.

Discussion

The results of the current study have found the predicted advantage for lifeguards in spotting and responding to drowning targets in a swimming pool situation. They identified both active and passive drowning targets more frequently and more quickly than control participants, which suggest that experience and/or training have positively influenced the visual search and target processing skills of this specialist group. Lifeguards also appear to have a higher threshold for responding to a drowning target. This may reflect their greater sensitivity to visual cues that discriminate between drowning and normal swimming. Additionally, lifeguards may be more aware of the dangers of committing to a potentially drowning target. Once a response is initiated in a pool situation (e.g. entering the water to rescue the drowning swimmer) the lifeguard is limited in their ability to spot secondary drowning targets. Thus lifeguards may need greater evidence before responding, though this did not negatively impact on their time to respond when they chose to do so.

A second interesting finding lies in the different responses evoked by the active and passive drowning targets. Despite a tendency for a small cluster of predominantly passive-target trials to prompt premature responses, active targets were still more likely to be responded to than passive targets. However, at several levels of the set size factor, these active targets were also responded to more slowly than passive targets, which differed from the predicted results that active targets would elicit faster and more accurate responses. One interpretation of these results is that the *instinctive drowning behaviour* displayed by the active targets is highly salient, as it includes potentially faster and more arrhythmic movement than nearby distractors (e.g. flailing arms and limited forward movement in the water compared to the methodical strokes of nearby swimmers). This fits with search asymmetries that have been noted by Wolfe (2001), where searches for stimulus A among an array of B stimuli produces different results compared to searches for B among A. However, upon detecting the salient active targets, the participant then takes longer to process them and decide whether they are truly drowning, as the level of feature overlap with distractors is potentially high (e.g. both active drowners and swimmers will raise their arms, their heads may become submerged and then re-emerge, etc.).

While the absence of movement in the passive targets may not be highly salient in parafoveal vision, it may be highly informative once fixated (and therefore require less time to process). This would explain why passive targets are potentially missed more frequently, though when they are spotted they are responded to relatively quickly.

This explanation is of course dependent upon the nature of the distractors. In the current scenarios, the distractors were regimented swimmers crossing from one side of the pool to the other. In leisure pools however, especially during times of the day designated for 'family fun', one is more likely to find stationary people who are chatting, floating, or even deliberately submerging and holding their breath in competition with friends. In these situations, one could imagine that the overlap between the passive drowning targets and the distractors would increase, with a concomitant increase in the processing time for passive targets. In order to confirm the differential effects of active and passive targets on saliency and processing, further research is required. If one were to record eye movements with these stimuli one may find that the time to first fixate active targets from onset is quicker than with passive targets (indicative of higher peripheral salience), though the first fixation duration and/or total dwell time may be longer on active targets compared to passive ones (reflecting the greater difficulty of processing active targets). Furthermore, by varying the activities of distracting swimmers one could manipulate feature overlap with the targets, potentially reversing the fixation duration effect as the level of feature overlap decreases with active targets and increases with passive targets.

A third finding of interest is the influence of set-size on accuracy and response times. In regard to accuracy, the medium set size of 6 swimmers revealed the worst accuracy (even after accounting for the tendency for some passive trials to accrue more premature responses), while participants tended to perform equally well on sets sizes 3 and 9. With response times, active targets were responded to more slowly by all participants when 6 swimmers were present, though response times became faster when set size rose to 9. This does not fit with the typical prediction from a visual search experiment, which would suggest a general increase in response times as set size increases with the gradient of the search slope dependent on a number of factors including target salience and feature overlap with distractors. The visual search tasks that are often used in the literature are however typically context-free searches for arbitrary features, such as black vertical and horizontal lines on a white background (Wolfe & Friedman-Hill, 1992). Even when experimenters use naturalistic stimuli, these are typically impoverished in order to maintain a high degree of experimental control (Godwin et al., 2015).

This is further complicated by the dynamic stimuli used in this current study. In previous real world professional search tasks, such as airport security or radiology (Biggs et al., 2013; Berbaum et al., 2010), the search items are often static. In the clips used for this current experiment swimmers are moving objects in the search array. Furthermore, in these real-world professional searches the target item is often present throughout the duration of the trial. In this study the drowning event occurs at a quasi-random point during the trial, with stooge behaviour diverging from otherwise normal swimming at this point. Therefore searchers are required to look for changes in behaviour compared to what that swimmer was previously doing (tracking swimmers over time), as well as tracking changes in behaviour from the other distractor swimmers. These real-world complexities challenge the simple accounts of visual search when taken outside of the laboratory.

One possible effect of the video-based imagery of naturalistic events is that they may evoke different strategies in participants. Moreover, these stimuli may promote different strategies depending on the set size. In the current study, 6 swimmers posed a particular problem for participants, both in the frequency of detecting the passive targets, and in their speed to respond to active targets. Improvements are noted however once the set size increased to 9. This may reflect a change in visual search strategy. For instance, a more holistic strategy may be possible with only three swimmers, with peripheral vision used to effectively monitor all targets, while fixations are only directed to those targets that exhibit cues indicative of drowning. With 6 swimmers, the participants may be tempted to still use this strategy though they may find it begins to impair their ability to perform. However, when 9 swimmers are present, the option of using a predominantly peripheral monitoring strategy may be clearly rejected in favour of some other strategy that rejuvenates search performance. This most unexpected of results warrants further research to replicate this effect, and identify what search strategies are employed (perhaps by measuring eye movements).

This rejuvenated search performance may be a resulting factor of searchers engaging a chunking method. With fewer swimmers in the pool there will be more space between the search items. However, as more items are added to the display the area becomes more cluttered which may allow the searcher to group some items into chunks, resulting in more efficient searches. Similar findings have been demonstrated by Neider and Zelinsky (2008), who found that the time to detect a tank in an array of trees decreased as set size increased. In larger set sizes the extra clutter in the search scene aided the detection of the target, as similar items spaced closely together can be grouped and observed as one item. While swimmers differ from trees in appearance and in their movements, it may be possible to group people swimming in close proximity traveling in the same direction, which would aid in the detection of the one swimmer not making any forward progress (i.e. potentially drowning). This possibility presents a number of avenues for future research. Once again, the addition of eye movement measures to this study might be informative in identifying a change in search strategy with an increase in set size (perhaps revealing a shift from fixating between swimmers at low set sizes to fixating upon swimmers at higher set sizes). Furthermore, the provision of feedback would possibly influence the decision to change search strategies. In the current study participants were not given feedback on their performance, which may have created ambiguity for participants who were possibly exploring different visual search strategies during the progression of the study.

This ambiguity should be particularly noticeable in the control participants with no prior experience in this context, and may explain their particular problem with set size 6. Providing feedback may induce more efficient selection between visual search strategies (should these exist).

One potential limitation of the current approach is the creation of the clips using trained lifeguards. Lifeguards are trained to simulate drownings for training purposes, and therefore may be more accustomed to recognising a certain behaviour that they themselves have acted out in training sessions, picking up on unintentional cues (e.g. taking a big breath before simulating a passive drowning). It may be that with more realistic stimuli (e.g. holiday park pools with large numbers of young children playing) the performance of lifeguards may be altered. This could potentially highlight an issue within current training for lifeguards if they are becoming accustomed to people drowning in a certain way. Future research should also consider the use of localised responses via touch screen or mouse input to reduce the possibility of false positive responses during the drowning window.

A further limitation is that the current approach focuses upon drowning events on the surface, with clips ending at the point of complete submergence if the participant has not already responded. While the risk of injury and death is minimised if the target is spotted at this point, lifeguards should still be able to respond to fully submerged targets, even those who are prone at the bottom of a pool. Brener and Oostman (2002) demonstrated the difficulty of spotting submerged targets when they timed lifeguard responses to unexpected manikins that were allowed to sink in pools. Fourteen percent of lifeguards failed to spot the submerged manikin with three minutes, with 90% of them failing to spot the manikin within the industry standard 10 seconds. While a surface-based training tool may increase the detection of drowning targets prior to complete submergence, if this is not 100% reliable, then it may result in those few submerged targets who slip through the net of vigilance being even less easy to spot due to emphasis in training being on rescuing victims at the surface of the water, and always being given a warning before practicing deep water rescues.

Nonetheless, the current study has demonstrated a valid testing paradigm that can be extended to include the above suggestions. The method holds promise as a form of assessment, and could lead to the development of more useful training techniques, while simultaneously providing greater insight into visual search skills in complex, real world scenes.

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