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Changes in Lifeguards' Hazard Detection and Eye Movements with Experience: Is One Season Enough?

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Abstract

Surveillance is key to the lifesaving capability of lifeguards. Experienced personnel consistently display enhanced hazard detection capabilities compared to less experienced counterparts. However, the mechanisms which underpin this effect and the time it takes to develop these skills are not understood. We hypothesized that, after one season of experience, the number of hazards detected by, and eye movements of, less experienced lifeguards (LEL) would more closely approximate experienced lifeguards (EL). The LEL watched 'beach scene' videos at the beginning and end of their first season. The number of hazards detected and eye-movement data were collected and compared to the EL group. The LEL perceived fewer hazards than EL and did not increase over the season. There was no difference in eye-movements between groups. Findings suggest one season is not enough for lifeguards to develop enhanced hazard detection skills and skill level differences are not underpinned by differences in gaze behavior.

Keywords: Surveillance, hazard detection, lifeguards, eye movements.

Practitioner Summary

Surveillance is the primary task for lifeguards, yet training mainly focuses on first aid and rescue. We show working for one season does not allow newly qualified lifeguards to enhance their hazard detection skills to the levels of experienced lifeguards and number of fixations and fixation duration do not underpin this expertise.

Background

Surveillance is a critical component in many occupations such as lifeguarding (Lanagan-Leitzel, 2012; Lanagan-Leitzel & Moore, 2010; Page et al., 2011a), bridge watch keeping (King, 2000), and search and rescue (Cooper, 2005). In these demanding occupations personnel are required to search dynamic scenes for targets which indicate a hazard is occurring or may be about to occur. A hazard is defined as anything which may cause harm (HSE, 2017). Although there are similarities in the cognitive abilities and skills underpinning these occupations (e.g., perceiving relevant cues, processing relevant cues, decision making) there are differences in the dynamic scenes each set of personnel work with in terms of display complexity, prevalence of targets, and viewing angles. Long Term Working Memory theory (LTWM; Ericsson & Kintsch, 1995) conceptualizes expertise development and suggests task specific perceptual-cognitive processes are needed for performance development. An extensive body of research has examined the role experience plays in developing these processes (e.g. Reingold & Sheridan, 2011). Generally, these studies have found that increasing experience within a given task improves performance and these improvements can be underpinned by changes in perceptual-cognitive processes such as visual search (Ward et al., 2002).

In hazard perception tasks, experts have generally been shown to detect more hazards than novices (Koller, Drury, & Schwaninger, 2009; Page et al., 2011a; Wood et al., 2013; Wood et al., 2014) but there are contrasting findings when investigating less extreme skill level differences. Page et al. (2011a) found experienced beach lifeguards were 4.9 times more likely than less experienced lifeguards to detect a simulated person drowning. In contrast, Lanagan-Leitzel and Moore (2010) found that although lifeguards detected a greater percentage of the critical events than naïve participants, the hazard detection rate was not different compared to briefly trained participants. A later study found experienced instructors identified significantly more critical events than certified lifeguards, and non-lifeguards did not differ significantly from the certified lifeguards in terms of number of events detected (Lanagan-Leitzel, 2012). Outcome-based research has produced inconsistent findings in hazard detection tasks and there has been a paucity of process-based research to offer explanations for these findings. Therefore, there is a need to investigate the mechanisms which mediate performance differences and when these develop.

There are several explanations of how perceptual expertise develops. It has been proposed that experts have decreased cognitive demands and can therefore free up resources for higher order processes (Fitts & Possner, 1967; Schneider & Shiffrin, 1977). Experts may also develop more refined visual search patterns based on their advanced knowledge of what is relevant. These explanations are supported by the predictions of Long-Term Working Memory theory (LTWM; Ericsson & Kintsch, 1995), which suggest experts have extended capacity for information processing due to the acquisition of retrieval structures that allow them to rapidly encode information in long-term memory and efficiently access it for later task operations. Such rapid encoding and retrieval should result in shorter fixation durations and enhanced hazard detection. Therefore, LTWM is a useful perspective to investigate the mechanisms underpinning skill level differences.

Empirical studies have investigated whether visual search is a discriminator of expertise in hazard detection but have produced conflicting results. Indeed, experts have been shown to produce: fewer fixations (Manning et al., 2006), fewer fixations on preferred locations (Krupinski et al., 2006), shorter fixation durations (Krupinski et al., 2006), and more fixations on target locations (Wilson et al., 2010; 2011) relative to novices. Others have found a range of significant and non-significant differences in search strategy which are dependent on stimulus characteristics (Schriver et al, 2008; van den Bogert et al., 2014;), with further studies showing no significant differences in search strategy (Page et al., 2011a; Schulz et al., 2011; Vogt & Magnussen 2007). Much of this research is cross sectional and it would therefore be beneficial to conduct longitudinal studies to examine how experience impacts the development of perceptual and cognitive processes underpinning expertise in hazard detection.

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Such issues are also evident in the literature specifically in lifeguarding. Laxton and Crundall (2018) suggested lifeguards were more accurate and responded faster than non-lifeguards to drowning targets. While the study suggested differences might be underpinned by visual search behavior, no measures of eye movements or other mechanistic measures were reported. Two previous studies that did measure eye movements (Page et al., 2011a; Lanagan-Leitzel & Moore, 2010) showed experienced lifeguards' eye movements were not significantly different from newly-trained lifeguards. As well as the need for longitudinal work, the conflicting findings reported in these cross-sectional studies also may be caused by unrepresentative stimulus design; for instance, the use of unrealistic visual angles (small computer screens) using real footage (Lanagan-Leitzel, 2012; Lanagan-Leitzel & Moore, 2010; Laxton & Crundall, 2018), and the use of realistic visual angles but using animated stimuli (Page et al., 2011a). Laxton and Crundall (2018) also critiqued the lack of realistic stimuli used in this area of research, and investigated detection of drowning incidents using non-animated footage of simulated active and passive drowning incidents in a swimming-pool. Representative task designs are essential to understanding perceptual expertise (Pinder et al., 2011; 2015). However, despite the increased realism of the footage used compared to previous work, participants viewed this footage on a laptop screen using push-button responses, meaning the visual search patterns and decision-making processes used were unlikely to represent those used in real-life scenarios (Dicks et al., 2010; Travassos et al., 2013).

As well as these methodological limitations, empirical work investigating hazard detection has lacked clear theoretical groundings which may offer clearer explanations of why skill-level difference may or may not have been observed. The LTWM theory suggests the amount of domain-specific experience would mediate differences found in mechanisms underpinning performance (Ericsson et al., 1993). As lifeguard-related knowledge develops, lifeguards would become more aware of different types of hazards and would therefore not only search for more hazards as they become more experienced but also recognize more hazards in a scene. Furthermore, cognitive processes relating to decision-making following the identification of a potential hazard would be predicted to become more refined with experience as lifeguards develop the knowledge structures which identify what hazards require a physical (active) response against those that require observation only (inactive response). Szpilman et al. (2017) identified 64 variables that can influence the process of a single rescue and therefore refining decision making is key in terms of responding quickly. While it is clearly important that newly qualified lifeguards can quickly obtain safe levels of hazard detection skills, the task-specific engagement required to produce mechanistic changes is not considered in current lifeguard training programs, which typically last for less than one week.

This study used real-life beach footage displayed using a realistic visual angle to examine the hazard detection ability (indicative of the performance), visual search (indicative of the perception of relevant cues) and responses to hazards (indicative of the processing of cues and resultant decision-making) of less experienced lifeguards at the beginning and end of their first season compared to experienced lifeguards. Based on predictions of LTWM theory (Ericsson & Kintsch, 1995), previous empirical work showing experts are better at detecting hazards than novices (Koller et al., 2009; Page et al., 2011a; Wood et al., 2013; 2014) and experience with a given task improves performance substantially (Godwin et al., 2015), it was hypothesized that experienced lifeguards would detect more hazards than less experienced lifeguards due to more refined perceptual-cognitive skills; and less experienced lifeguards would detect more hazards at the end of a season compared to the beginning due to the increase in task-specific experience. This would be underpinned by more refined visual fixations. Furthermore, experienced lifeguards would exhibit more passive decisions than less experienced lifeguards due to accrued domain specific experience developing more efficient retrieval structures.

Method

Participants

Beach lifeguards (n = 43) were recruited from four beaches in the UK. Data from four lifeguards were discarded due to data capture errors caused by the lifeguards not keeping their heads still enough during the calibration phase or by the eye camera moving during testing. All lifeguards provided informed consent prior to participating in the study. Of the 39 lifeguards, 33 were male (average age 24.5 years, SD 8.7) and 6 were female (average age 18.0 years, SD 2.3), 20 were considered as *less experienced lifeguards* (LEL; in their first season and had worked a maximum of 11 shifts on the beach) and 19 were considered *experienced lifeguards* (EL; five or more seasons on the beach). The 85% male to 15% female ratio is similar to the 75% male and 25% ratio that exists in the Royal National Lifeboat Institution (RNLI), a primary trainer of beach lifeguards in the UK. This design meant the experiment had 80% power to detect a smallest average difference between pairs of 2.91 detections with a significance level of 0.05. All lifeguards reported normal or corrected-to-normal vision, none wore spectacles during testing and they wore lifeguarding uniform during testing. Prior to conducting the study, institutional ethical approval was obtained from the University Science Faculty Ethics Board.

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Materials

Test Film Development

For the video stimuli, footage of complex beach scenes which represent real-life, demanding decision-making scenarios was captured. Prior to the video capture a focus group of experienced lifeguards and an industry expert determined the behaviors needed to be included in the video. Following on from this, lifeguards (out of uniform) were asked to partake in the hazardous behaviors, amongst natural busy beach scenes. For example, a bather taking a flotation device in the water in windy conditions; a simulation of a person drowning; and a lifeguard at the shoreline turning their back on the water. There were other hazards which took place during the video due to the naturalistic behavior of the participants. However, the videos were controlled and matched for content as far as possible with the volunteers displaying similar behaviors between videos, but in different locations and time points as instructed by the lead author. The prescribed hazards took place at the following times: a bather taking a flotation device in the water in windy conditions (Video One: 11 min 33s; Video Two: 10 min 38sec); a simulation of a person drowning (Video One: 1 min 38s; Video Two: 4 min 43s); and a lifeguard at the shoreline turning their back on the water (Video One: 12 min 17s; Video Two: 6 min 53s). To ensure both videos had a similar number of hazards an independent t-test was conducted. There were no significant differences between the number of hazards detected by the EL in video one (Mean ± SD; 21.53 ± 11.36) and two (19.53 ± 13.00; $t(36) = .499$, $p = .621$). This confirms both videos did not differ significantly in relation to the number of hazards. Guidance from the RNLI suggests the filmed beach had low risks for wave breaking, surf zone energy, and total cut off. No rips were present and approximately 70 people were in attendance.

Once the videos were captured the focus group met again to decide the most realistic clips to be used for the study. From the two hours of footage, two 20-minute continuous videos of complex beach scenes representing real-life, demanding decision-making scenarios were captured (Figure 1). The videos were counterbalanced throughout the experiment with half of the LEL lifeguard watching video one at the beginning and video two at end of the season and vice versa. Half of the EL watched video one first and half watched video two first.

To ensure the final films were consistent with the view of a lifeguard, the footage was captured from the frontal plane. This position allowed the researchers to capture the entire beach scene and provided a display representative of a lifeguard's view when working at a beach, thereby increasing physical fidelity (Lintern et al., 1989). The 'own point-of-view' recording provided minimum distortion of the complexity and dynamics of naturalistic environments (Omodei et al., 1998) and allowed context-specific information to be captured.

Figure 1
A still showing the beach scene in video one (A) and video two (B)

A B

Collection of Visual Search Data

To enhance ecological task validity, the footage was projected on to a large screen (1.1 m by 1.4 m) and lifeguards were seated 2.2 m away. To capture visual search data the Applied Science Laboratories (ASL) Mobile Eye head mounted eye-tracker system was used. The ASL eye-tracker operates by illuminating the eye with the beam from a near infrared source, whilst the optical system focuses an image of the eye onto a solid-state video sensor (eye camera). A second solid camera is focused on the scene being viewed by the lifeguard. The illuminator, optics and both cameras are mounted on a pair of glasses.

Procedure

The LEL group data were collected at the beginning (LEL B) and end (LEL E) of their first beach lifeguarding season. The EL group data were collected during the season, to determine the actual number of hazards for comparison, with at least a 30-minute break between videos. Each testing session followed the same procedures.

Upon arrival at the venue, the nature of the study and the method of data collection were explained to each lifeguard. Room temperature was 20 °C and lighting levels were low (< 10 lux) during testing to facilitate eye tracker function. To reduce researcher bias and increase consistency of the environment, the study was explained using a pre-designed prompt sheet and a short training video to ensure each lifeguard received the same information and instructions. Lifeguards were then seated and the ASL mobile eye-tracker was fitted using the head mounted system. The head was secured using a small strap to avoid unnecessary head movement during calibration. Once it was clear all instructions had been understood, a five-point calibration was performed. This involved each lifeguard fixating on each of the five points on the calibration slide in a systematic order while the eye tracking system was adjusted for accuracy. The calibration was performed according to the ASL hardware protocol,

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with the five points covering the corners and center of the full screen, and was visually monitored for loss of calibration throughout the 20-minute videos. Calibration took approximately five minutes. Once this was completed, the video (including instructions) was started. Specifically, lifeguards were told

*'You are about to see 20 minutes of footage of a beach scene. Please watch it as if you were at the beach lifeguarding. Please behave as naturally as possible – this is **NOT** a test. All data will be kept confidential and will not be shared with your employers until it has been made completely anonymous. There may or may not be a number of hazards that appear when you are watching the footage. If you see any hazards please let me know by doing **4** things: 1) press the button as quickly as possible, 2) verbally state what the hazard is, 3) Show on the scene where each hazard is using your laser pen, 4) Identify if and how you would respond to the hazard. Please view this footage as if you were on duty from the Lifeguard hut. Please note that you and the lifeguard that you may see in the footage (on the water's edge) are **equally responsible** for watching the sea. We will show you how this will work and give you two attempts to practice it'*

Once the two, one-minute practice attempts had been completed and any questions answered, the lifeguards watched the beach footage and responded as requested.

Measures

Number of Hazards

The total number of hazards identified by each lifeguard in each 20-minute video was measured by the number of 'button' clicks with follow up laser pen (to show where the hazard was) and verbal responses. If a button was clicked by mistake (or double clicked) and there was no laser or verbal response these data were omitted.

Verbal Responses

Identification. The description of the hazard given by each lifeguard (e.g. 'lifeguard has turned his back on the water'). The requirement to deliver verbal responses negated any tendency to overuse the button press to increase hazards identified.

Intervention. The description given by the lifeguard regarding how they would deal with the hazard (e.g., 'I would radio him and ask him to turn around'). The interventions were analyzed to understand the percentage of 'Inactive' responses (where lifeguards engaged in further surveillance only, with or without binoculars) and 'Active' responses (all other responses from speaking to people, use of PA, to launch of rescue craft etc.).

Visual search. Data from the ASL Mobile Eye was processed to combine the scene and pupil footage and produce a video of the scene with a crosshair representing the location of foveal vision. This footage was then exported to Windows Media Player where frame-by-frame analysis was used to record the location and duration of all fixations (for the purpose of this study a fixation was defined as the eye remained within a specific area of interest for >120ms). Once these analyses had been completed the number of fixations and mean fixation duration for the full 20 minutes were calculated.

Statistical Analyses

Having established normal distribution (p>0.05), paired samples t-tests were used to compare the LEL number of detections, number of fixations, and mean fixation duration at the beginning and end of their first season. Independent samples t-tests were used to compare the number of detections, number of fixations, mean fixation duration, and number of active responses between LEL and EL.

Results

Number of Hazards Detected

There was no significant difference in the number of hazards detected by LEL at the beginning (12.95 ± 6.19) and end (13.30 ± 6.22) of the season (t (19) = -.298, p = .796; Figure 2). The EL (20.52 ± 12.22) detected significantly more hazards than LEL B (12.95 ± 6.20; t (56) = 2.595, p = .012) and the LEL E (13.30 ± 6.22; t (56) = 2.443, p = .016). Figure 2 shows EL detected more hazards than LEL at both time points.

Eye Movements

There was no significant difference in the total number of fixations per video by LEL at the beginning (1333.25 ± 322.78) and end (1410.15 ± 346.08) of the season (t(19) = -.962, p = .348). There were also no significant differences in the mean number of fixations by the EL (1387.03 ± 335.63) and either the LEL B (1333.25 ± 322.78; t(37) = -.510, p = .613) or the LEL E (1410.15 ± 346.08; t(37) = -.212, p = .834).

There was no significant difference between the mean fixation duration by LEL at the beginning (0.826s ± .255s) and end (0.827s ± .239s) of the season (t(19) = -.025, p = .981). There were also no significant differences in the mean fixation duration by the EL (0.855s ± .235s) and either the LEL B (0.826s ± .255s; t(37) = -.369, p = .714) or the LEL E (0.827s ± .239s; t(37) = -.364, p = .718).

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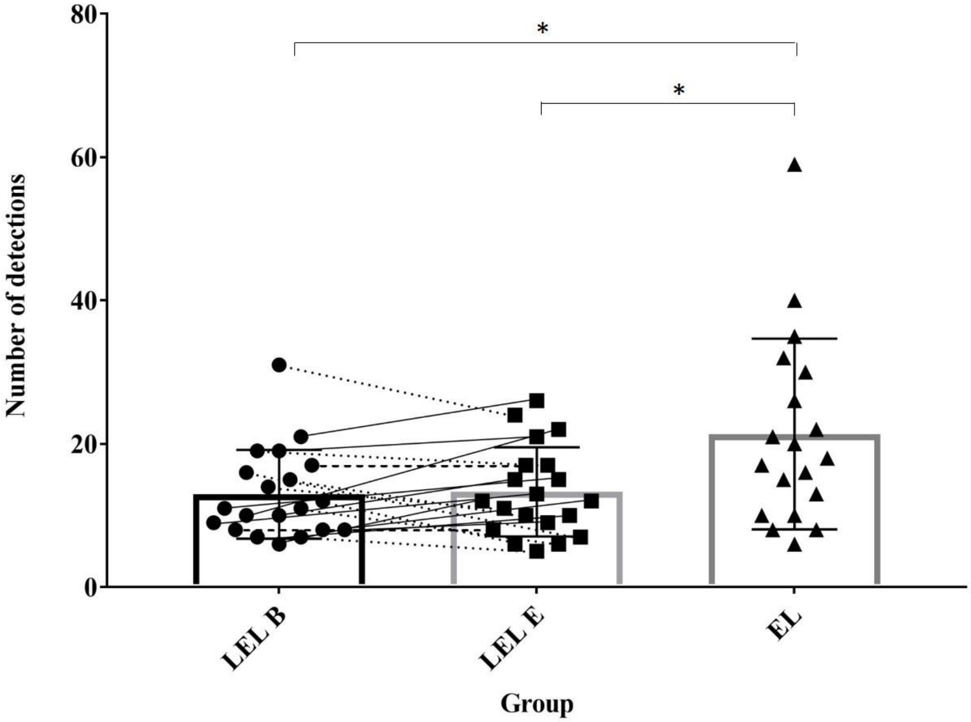
Figure 2

Number of detections by less experienced lifeguards at the beginning (LEL B) and end (LEL E) of their first season



Note. Data for experienced lifeguards (EL) are a mean of videos 1 and 2. Bars plots represent group means. Error bars represent standard deviation.
*Denotes significant difference ($p < 0.05$).

Table 1
Verbal responses and resultant interventions from the LEL and EL

Hazard	Group (n)	Proposed action taken (n)
Jet Ski 1 drives towards shoreline *Video 1 – 1 min 25s* *Video 2 – 1 min 10s*	LEL (7)	Public announcement if going too fast (1) Maintain observations and advise to stay away from bathing area (3) Paddle out and advise Jet Skis to stay away (1) Look out for jet ski and send away (2)
	EL (15)	Maintain observations and ensure jet skis stay away (6) Radio to advise stay 400m away (1) Paddle out and advise jet Skis to stay away (1) Jet skis too close, call in to have a chat (1) Binocular check (1) Maintain observations on swimmers (1) Go out on rescue board and identify craft (1) Risk of coming into swim zone, whistle in and have quick chat (1) Maintain observations (1) Let swimmers going in know of jet skis (1)
Path to rescue board impeded *Video 1: 0 min 8s* *Video 2: 3 min 2s*	LEL (6)	Clear path to board (1) Ask people near rescue board to move (1) Remove clothes from board (2) Tell lifeguard on shoreline to remove clothes from board (1) Remove clothes and ask people to stop playing near the board (1)
	EL (2)	Remove clothes from board (2)
Swimmer with hand in the air/ Drowning *Video 1: 1 min 38s* *Video 2: 2 min 43s*	LEL (7)	Take board out to check (2) Alert lifeguard to rescue swimmer (1) Maintain observations as reappeared (1) Rescue with board (3)
	EL (17)	Rescue immediately (3) Take board out to check (1) Jet Ski out to assist / use rescue board and let someone know (1) Binocular check or use board if needed (2) Send lifeguard out to assist immediately (3) Radio lifeguard to go out on rescue board (3) Go in on rescue board and check immediately (4)
People playing too close to rescue board *Video 1: 8 min 56s* *Video 2: 2 min 39s*	LEL (7)	Stop playing near board – move them (6) Send lifeguard to tell people to move (1)
	EL (4)	Ask people to move (3) Send lifeguard to tell people to move (1)
Lifeguard with back to the water *Video 1: 12 min 17s* *Video 2: 6 min 53s*	LEL (25)	Radio and tell lifeguard to turn and face the water (7) Tell lifeguard to turn and face the water (17) Ask for rotation so lifeguard on shoreline switches to the tower (1)
	EL (24)	Tell lifeguard to turn and face the water (11) Radio lifeguard to turn and face the water (8) Tell lifeguard to turn and face the water and send cover while he talks (1) Tell lifeguard off and tell him to turn and face the water (1) Radio lifeguard to turn and face the water and use binoculars (2) Radio lifeguard to turn and face the water and report to supervisor (1)

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Man on floatation device in windy conditions *Video 1: 11 min 33s* *Video 2: 10 min 38s*	LEL (25)	Keep observations, if he goes out too deep go in and assist (3) Warn of conditions and dangers (8) Binocular check (1) Use board to assist (1) Radio shoreline lifeguard (2) Talk to the man on the floatation device - stay in shallows (2) Send lifeguard on shoreline to advise of conditions (2) Maintain observations (3) Talk to the man on the floatation device or get lifeguard on shoreline to (1) Public announcement to warn of weather conditions (1) Keep observations and have a chat (1)
	EL (32)	Advise to stay in shallows (3) Advise on conditions (4) Lifeguard to advise not to use floatation device (2) Maintain observations (3) Look at flags, if offshore winds, no flotation devices allowed (1) Maintain observations and liaise with unit (1) Send lifeguard out to investigate (1) Paddle out and advise to stay in depth (1) Public announcement to stay in depth (1) Warn of dangers and advise not to go in (2) Advise on wind (2) Maintain observations and public announcement to stay in depth and flags (2) Maintain observations as no concern (1) Call him in (1) Advise not to take floatation device out, if does, stay in depth, and put up windsock (1) Advise and warn not to go in too far (2) Advise to stay in waist deep water and within flags (1) Have a chat about conditions then maintain observations (1) Okay at the moment, maybe public announcement to warn of conditions (1) Maintain observations and check depth (1)
Child on body board *Video 1: 14 min 52s* *Video 2: 12 min 01s*	LEL (3)	Advise parent to keep an eye (1) Parent should be with him (1) Maintain observations (1)
	EL (14)	Maintain observations (4) Surf not big so no concern (1) Send lifeguard on shoreline to find parents (1) Chat with child and advise stay in flags (1) Tell lifeguard to maintain observations (2) Check not going in too deep (1) Check if child is on his own, if so, advise to stay safe (1) Maintain observations and locate parents (1) If surf any bigger advise child not to go in (1) Chat with child and ask where his parents are (1)
Jet Ski 2 drives towards shoreline *Video 1: 16 min 15s*	LEL (29)	Maintain observations, public announcement to ensure Jet Ski stays far enough out, paddle out or use Jet Ski if needed (13) Use public announcement and tell Jet Ski to move away (3) Use rescue board to move away (2)

Video 2: 13 min 22s		Send away (1)
		Send lifeguard to use rescue board to move away (1)
		Wave away from flags (1)
		Maintain observations (1)
		Use rescue board to go out and move Jet Skis away (1)
		Go out on rescue board and move away, public announcement to warn swimmers (1)
		Jet Ski going slowly so only need to maintain observations (1)
		Use Jet Ski to move away (1)
		Public announcement or send lifeguard to use rescue board to move away (2)
		Radio to senior staff to move Jet Ski away (1)
	EL (33)	Public announcement 400m offshore and send lifeguard on rescue board to move away (6)
		Get attention and advise not to come any closer (1)
		Radio base, IRB to advise to move away (1)
		Ensure not coming too close (1)
		Maintain observations (2)
		Get RNLI to talk to them and move them out (1)
		Ensure not coming too close (2)
		Public announcement, whistle, or Jet Ski to go out (1)
		If Jet Ski comes closer, paddle out and chat – stay 400m offshore (1)
		Public announcement 400m offshore and send lifeguard on rescue board to move away (1)
		Tell Jet Ski to slow down (1)
		Lifeguard on shoreline on rescue board to move away (1)
		Ask to move further out (1)
		Public announcement too close (1)
		Wave away from swimming area (1)
		Make sure 400m out (1)
		Public announcement 200m offshore (1)
		Get attention and advise not to come any closer (1)
		Send lifeguard on shore to send Jet Skis away and remove swimmers in worst case scenario (1)
		Public announcement, whistle, or Jet Ski to move out (1)
		Make sure far enough out – at least 200m (1)
		Make sure not too close – whistle away if needed (1)
		Maintain observations (1)
		Relay that Jet Ski is in the water to lifeguard on shoreline (1)
		Public announcement if too close (1)
		Public announcement – should be 400m offshore (1)
Swimmer with limp/ disability *Video 1: 16 min 57s* *Video 2: 0 min 18s*	LEL (4)	Maintain observations (2)
		Talk to swimmer to see where he is going (1)
		Tell lifeguard on shoreline to maintain observations (1)
	EL (9)	Send lifeguard to have a chat (1)
		Have a chat and maintain observations (1)
		Maintain observations (2)
		Check how he swims out/leaves water (1)
		Tell lifeguard on shoreline to maintain observations (1)
		Ask what his ability is and what his intentions are (1)
		Talk to swimmer to see where he is going (1)

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		Tell lifeguard on shoreline to maintain observations (1)
Jet Ski 3 drives towards shoreline * *Video 1: 18 min 16s*	LEL (0)	
	EL (3)	Maintain observations (2) Send lifeguard to paddle in to talk about laws and move away (1)
Child on water's edge unattended *Video1: 19 min 6s* *Video 2: 18 min 10s*	LEL (4)	Maintain observations (2) Send lifeguard on shoreline to ask children who they are with (1) Maintain observations but children near lifeguard on shoreline (1)
	EL (12)	Maintain observations (6) May need assistance (1) Tell lifeguard on shoreline to maintain observations (1) Get unit to check and keep observations (1) Maintain observations, see if go any deeper, ask where parents are (1) Ask child where parents are (2)
Swimmer right of flags/out of view* *Video 1: 15 min 30s*	LEL (1)	Send lifeguard to check where swimmer went (1)
	EL (2)	Maintain observations (1) Send lifeguard to check where swimmer went (1)
Dog on beach** *Video 2: 1 min 43s*	LEL (3)	Ask the dog owner to remove dog (1) Give advice to owner (1) Ask the dog owner to remove dog (1)
	EL (0)	

Note. * denotes only happened in video 1, ** denotes only happened in video 2.

Verbal Responses and Interventions

The verbal responses to the hazards and resultant interventions are shown in Table 1. Each hazard appeared a total of 78 times (once in each video and both videos were viewed by each of the 39 participants). The LEL could have a maximum of 40 detections for each hazard meaning the hazard was detected by each LEL (N = 20) in both videos. The EL could have a maximum of 38 detections for each hazard meaning the hazard was detected by each EL (N = 19) in both videos.

There was no significant difference in the percentage of active responses by LEL B (67.01% ± 20.11%) and LEL E (71.90% ± 20.96%; $t(18) = -1.238$, $p = .232$). There was no significant difference in the active responses between LEL B (67.01% ± 20.11%) and EL (55.40% ± 23.41%; $t(57) = 1.858$, $p = .068$). However, LEL E (71.90% ± 20.96%) displayed significantly more active responses than EL (55.40% ± 23.41%; $t(57) = 2.613$, $p = .011$).

Discussion

This study, using real-life beach footage displayed at a realistic visual angle, aimed to examine the hazard detection ability, visual search, and responses to hazards of less experienced lifeguards at the beginning and end of their first season compared to experienced lifeguards. Contrary to our predictions based on LTWM theory, one season in the occupation did not enhance the hazard detection ability of LEL. Compared to EL, LEL detected significantly fewer hazards at the beginning and end of their first season. The LEL also had no significant increase in hazard detection through the season. In addition, there were no significant differences in the total number of fixations per video or mean fixation duration between the EL and LEL. LEL used more active responses when intervening with hazards than EL at the end of the season, but not at the beginning.

Our results, using a representative task design, show LEL identified fewer hazards than EL (Lanagan-Leitzel, 2012; Page et al., 2011a). Lanagan-Leitzel (2012) also found experienced lifeguard instructors identified significantly more critical events than certified lifeguards. The finding that LEL identified fewer hazards than EL could be explained by LTWM. Specifically, our data suggests experienced lifeguards may have more efficient access to information encoded in long term memory and are therefore able to identify more hazards when viewing a scene. For example, an EL and LEL may be fixating in the same region but the EL is able to identify that the particular cue fixated on could be hazardous. The experienced lifeguards may have heightened sensitivity bias and therefore enhanced ability to discriminate between hazardous and non-hazardous situations. Alternatively, experienced lifeguards could have lower thresholds of perceived hazardousness and therefore identify a cue as hazardous before it escalates into a bigger issue. Perhaps LEL wait longer in order for the situation to reach their higher thresholds of perceived hazardousness. Future research could confirm the existence of either suggestion using signal detection-based methods as well as qualitive designs to explore perceptions of hazards.

The increased hazard detection by the experienced lifeguards suggests that a more comprehensive (rather than selective) approach to hazard detection may be suitable for new lifeguards. Lifeguard training programs could include existing methods of hazard perception training such as commentary training (Isler et al., 2009) and / or task-specific hazard detection tasks (McKenna et al., 2006). Such training may enhance the existing hazard perception skills of lifeguards.

There was large variability in the number of hazards detected within the groups (Figure 2), suggesting that even within a group of experienced lifeguards, their perception of what constitutes hazardous activity varies. In support, Lanagan-Leitzel (2012) also found that levels of agreement as to what constituted a hazard was no higher in a group of lifeguards than students on a lifeguarding course. Such findings suggest the requirement for a consensus on what constitutes hazardous behavior and future research should explore this phenomenon using expert panels. Interestingly, despite the significant difference between the groups, some of the LEL performed better than the mean of the EL at the beginning and end the season. This suggests some of the LEL group may have had previous relevant experience that positively influenced their ability to detect hazards. Alternatively, it could suggest some LEL have higher sensitivity bias and lower thresholds of perceived hazardousness. Such variability is unsurprising when lifeguards have to process such complex scenarios involving so many potential variables (Szpilman et al., 2017). Also, given that some EL produced lower detection rates than LEL, this might suggest experience will not always allow the development of enhanced encoding and retrieval or enhanced sensitivity bias. Future studies may want to address the differences within the experienced and less experienced populations to explore why and how their perceptions differ and the trainability of hazard detection in this population.

We also examined the total number of fixations per video and mean fixation duration and found no significant difference between the EL and the LEL B and LEL E. The fact that there was no difference in fixation duration suggests that encoding times may be similar for EL and LEL, a factor which, according to LTWM, is predicted to be quicker in experienced individuals, than in those new to a task (Ericsson & Kintsch, 1995). However, perhaps the EL were encoding more detailed information per fixation and this was what enabled them to detect more hazards. Alternatively, it may be that the EL fixated on more relevant areas and this is what caused the difference in hazard detection performance. Future research should aim to examine the relationship between fixation location and hazard detection ability.

The lack of difference between the EL and LEL in relation to the eye movements, and significant difference in the number of hazards detected, suggests increasing or reducing search rate alone will not contribute to higher levels of hazard detection. These findings strongly suggest that training the development of domain-specific knowledge structures (cognitive processes), rather than eye movements *per se* (perception), would be beneficial in enhancing the hazard perception of less experienced lifeguards.

While LTWM theory predicts an increased level of top-down control in experienced individuals, we observed a high level of variability for the visual search variables for the EL and LEL suggesting that the knowledge driving the search patterns differs between individuals. This is reflected in the visual search data whereby even within a group of experienced lifeguards, where you might expect a more homogenous population, substantial variability occurs in relation to search strategy (Lanagan-Leitzel & Moore, 2010). Perhaps the different practices of the experienced lifeguards, caused by spending extended amount of time working on the beach, results in changes in internal representations and thus guide search strategies in different ways. Further studies examining context-specific knowledge and fixation location could help to understand this further. Given that prescribed scanning techniques are not taught during training for these lifeguards, the high level of variability is to be expected. This high level of variability in these data and other studies (Page et al., 2011a) may also contribute to the lack of significant differences detected between the EL and LEL in relation to the eye-tracking variables.

In relation to the prescribed hazards, Table 1 shows that the LEL detected the *swimmer with the hand in the air / drowning* hazard in 7 out of a potential 40 observations (17.5%), while EL detected it 17 times out of 38 potential observation (45%). This suggest that cues related to a person waving / drowning in the water may be a key discriminator with regards to lifeguards' expertise and resultant contextual knowledge. Further training around the context of drowning related behaviors could be included in training to help new lifeguards recognize this as a hazard. Furthermore, the *man on flotation device in windy conditions* hazard was detected by 25 out of a potential 40 observations (63%) by LEL and 32 out of a potential 38 (84%) observations by EL. Again, further training around the context of use of flotation devices may better prepare new lifeguards. The other prescribed hazard, *the lifeguard with his back to the water* was detected in 22 out of a potential 40 observations (55%) by LEL and 24 out of a potential 38 observations (63%) observations by EL suggesting that although both groups may need further knowledge in this area, their knowledge as to whether this constitutes a hazard is similar. Further exploration of agreement among experienced lifeguards with regards to specific hazards could help inform future training programs.

Differences in cognitive processes can be observed in the decisions made in response to hazards by the different experience levels. The LEL decided on significantly more active responses when responding to the hazards they had identified. While visual search behaviors were not different between groups, the experienced group had developed different processes for dealing with enhanced number of hazards detected. Decision-making data, combined with the number of hazards detected, may indicate EL are able to detect more hazards because they are more inactive when dealing with any other given hazard. That is, just monitoring a hazard rather than physically responding to it may make experienced lifeguards more effective. This difference between experienced and less experienced lifeguards could be further exacerbated when working on the beach, as during this study LEL were not physically able to enact the interventions they suggested, and were therefore able to attend to the video at all times.

The findings of this study develop the understanding of hazard detection across domains. Our results support the predictions of LTWM theory in relation to outcome (i.e., enhanced hazard detection). However, the predicted changes in visual search mechanisms between experienced and less experienced lifeguards, or for LEL over the course of a season, were not observed. Previous work has lacked clear

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theoretically-driven hypotheses and here we have shown that the use of LTWM theory to investigate hazard detection may be a useful vehicle to drive the field forward. Further, our results add to the empirical literature by shedding light on different decision-making tendencies of lifeguards at different stages of experience and supporting the contention that performance differences may be due to cognitive processes rather than perception.

As well as empirical developments, this study produces significant implications for practice in the training and development of lifeguards and other professionals who use hazard detection. We have shown that one season of experience was not sufficient for new lifeguards to develop hazard detection skills to the level of more experienced counterparts. Those using a beach while a less experienced lifeguard is on duty alone may be more at risk. Training cognitive processes regarding what experienced lifeguards consider to be hazardous within beach displays may help less experienced lifeguards enhance their knowledge-base. Less experienced lifeguards should be trained to adopt less active intervention strategies, which could facilitate them in detecting more hazards, and future research should investigate this further. It may be beneficial for LEL to work with EL in their first season to maximize hazard detection and overcome the weaker hazard detection abilities of the new lifeguards. The use of automatic drowning detection surveillance systems (Eng et al., 2003) may also assist lifeguards, although the empirical evidence supporting the use of these systems is currently limited.

While our use of real-life beach footage displayed on a large screen was a step forward from previous work in the field in terms of using a more representative task design, eye movements produced when watching videos can be different to those used *in situ* (Dicks et al., 2010). Given the complex scenes that lifeguards view, it is unlikely that exact in situ replications can be produced for multiple participants and therefore using real video footage, presented using realistic visual angles, is recommended for future research. As we found one season was not enough to develop hazard perception skills of experienced lifeguards, future research could use longitudinal designs to establish the time at which lifeguards develop these enhanced hazard detection skills. Furthermore, given the growing body of contradictory evidence showing visual search does and does not underpin skilled hazard perception for lifeguards, future research should aim to explore other potential mechanisms that may explain the performance effect including, but not limited to; vigilance, personality and working memory capacity.

Other limitations of this study include the context specific information that relates to the real-life footage. Specifically, given the conditions on the day of filming, there were between 10 and 20 people in the sea at one time and between 60 and 70 people on the beach. It is not clear whether the findings from this study would apply to a busier beach scenario. Page et al., (2011b) examined set size (by manipulating the number of bathers in the water) using animated footage and found no differences in search patterns when observing 43, 53 and 63 heads in water but we are not sure how this would be impacted by larger set sizes. Laxton and Crundall (2017) found a change in drowning detection accuracy with changes in set size between three, six and nine swimmers in a pool. Future research could investigate this further by using busier scenes with larger set sizes. Also, given the naturalistic footage, it was not possible to control the timing of the naturally occurring hazards. There were no hazards that occurred at exactly the same time but some did occur near each other (Table 1 gives the exact times for the main hazards). Future researchers could more tightly control the timing of the hazards but this might detract from the representativeness of the scenes.

To build on previous work that had simply required the detection of a hazard, this study used a decision task whereby lifeguards were asked to both detect a hazard and give an associated intervention. This combined with previous findings suggests that, regardless of the response requirement EL detect more hazards than LEL, and a range of different stimuli and response requirements can elicit expertise effects in lifeguards. Future research should aim to add clarity on what constitutes a hazard and the correct response to allow more direct comparisons of hazard detection accuracy (detecting the 'correct' hazards and appropriate interventions) rather than hazard detection frequency (detecting anything in the environment regardless of whether experienced lifeguards agree that it is a hazard). Furthermore, calling a lifeguard using a public announcement and performing a rescue were both considered "active" responses yet require vastly different amounts of effort. Future studies should aim to classify interventions in a more detailed manner as well as confirm the appropriateness of each intervention.

In summary, in this study we have used a novel representative task to investigate the development of hazard detection skills and perceptual-cognitive processes in lifeguards across their first season of experience. Results suggest one season of experience is not sufficient for new lifeguards to develop hazard detection skills that are equivalent to more experienced counterparts, and that less experienced lifeguards will engage in more active decisions following detection. Differences between experienced and less experienced lifeguards were not explained by different visual search strategies, suggesting that enhanced hazard detection skills may instead be underpinned by superior storage and retrieval characteristics. Findings have implications for the development of lifeguard training.

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