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The Journal of Search and Rescue (JSAR) is an open access peer-reviewed electronic journal for the collation and distribution of original scholarly material on search and rescue (SAR).

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Editorial: Phases of Rescue Organisation

As a result of my research and day job, I speak to volunteers and professionals in the SAR and emergency sectors daily and hear frequent tales of practitioners commonly going the extra mile, performing heroic rescues, working with their communities to make them safer and working far beyond what they are paid (or volunteer) to do officially. Sadly, I also hear frequent reports of frustration, lack of focus, mismanagement and border-line illegal activity within teams across the world.

As such, I have been thinking recently about change throughout the lifetime of a team, and how many SAR teams, especially charity-sector teams, seem (to my eyes) follow a common pattern of phases through time. Having worked with and for a number of them over the last decade, and having written about many more in various outlets, I started to notice some patterns, and with them some common potential dangers facing teams.

The advantage of the editorial brief is that I can, to some extent, make an argument or observation without having to justify it to the level of a peer-reviewed piece, and so this editorial reflects some initial, un-validated thoughts that I hope may stimulate a debate or perhaps a fuller piece of work from someone in the future.

My thoughts are loosely based within classic organisational theory (Daft, 2010), although I don't claim to have any true expertise in that field, and suggests that there are a number of phases of development that are common to rescue organisations as they reach maturity. My proposed phases are described as follows:

Demand phase

This initial phase occurs when there is the demand or requirement for a rescue service, yet none exists. For example, prior to the 1960s there was no organised SAR set-up in Yosemite, but as the park became more and more popular with climbers, and as climbing itself became more advanced and adventurous, the need became apparent. In the UK in the 1970s, there was little organised International USAR team organisation and so volunteers started to create their own teams in response to the perceived gap.

This phase maybe typified by calls from regional media for "something to be done", or perhaps the gap of provision is matched by a gap in knowledge, with agencies, public and media all unaware of the issue. Recent developments with the London Search & Rescue team, or the initial establishment of MOAS in the Mediterranean (a few years ago) may fit this phase.

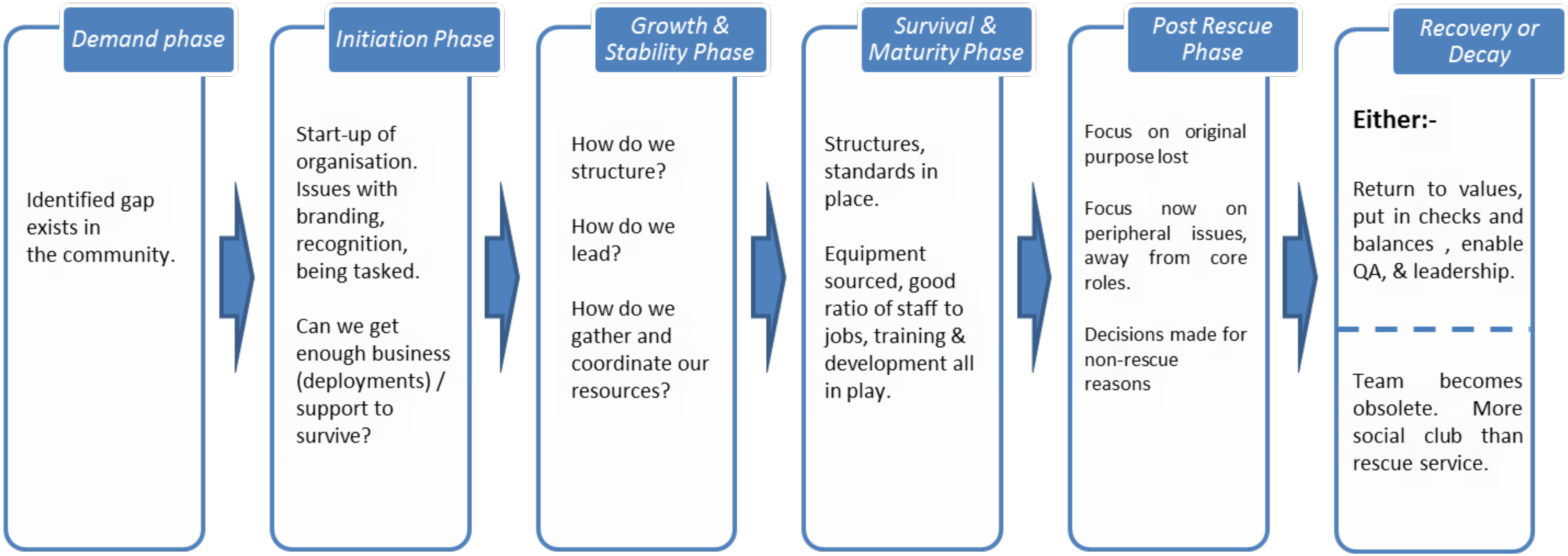

Figure 1: A theoretical lifecycle of SAR teams.

Initiation phase

There may be legal requirements, such as vetting, that is required, or a period of probation whilst the local law enforcement or emergency services agency verifies the good intentions or proficiency of the new team.

Alternatively the environment may be entirely void of governing or competing bodies. There may be no requirement for a new "search and rescue" charity to register or conform to existing standards.

Growth & stability

This phase is often turbulent, typified by internecine struggles of or the control of the scope and direction of the team. The essential questions are asked and answered regarding the fundamentals of the team. Issues of structure, command and control, governance, training, recording, growth and future sustainability are addressed.

This phase sees the team begin to carry out operations, and gain a reputation. The initial enthusiasm of the members in addressing the need of the community results in good morale within the team, and a good initial working relationship with state services. There is likely to be some suspicion amongst some professional organisations, but at this stage the limited scope, teamed with that enthusiasm, means that the team is likely to have initial successes operationally.

Survival & maturity

The team has forged sustainable links with state bodies, national standards organisations and has an established PR presence, securing more stable fundraising and the ability to engender goodwill with positive news stories about its activities. The team grows and starts to expand its activities beyond its initial core function. This is often entirely reasonable, and seeks to support the core function. For example, the creation of an off-road vehicle capability to enable foot searchers to embed deeper or to extract causalities more easily.

The team may well become more involved in strategic thinking, internally and externally. For example it may have a voice on a local emergency planning or resilience forum, and be a part of a local authority's plans for major incidents. They may have established a relationship with the media and may be called upon to comment on cases and issues in the public domain, outside their direct jurisdiction.

Post rescue phase

This phase is typified by decisions being made for reasons other than purely to save life or further the core aims of the organisation. For example, money spent on training a member of staff to be a helicopter pilot, if there is little or no chance of helicopters becoming a part of that organisation. There are widespread occurrences of *folie de grandeur*, with funds being spent on vanity projects, vehicles or equipment for certain personnel that serves no practical use. An example may be creating a fleet of boats, trained to work in a coastal environment for a landlocked, inland agency. The process of training may be fun, and tangential links to rescue could probably be made, but realistically, the link between the two is tenuous – the true purpose of this exercise is to appropriate the glamour and kudos of other organisations.

At its worst, this stage sees the dismissal of members who disagree, or point out mistakes. There is often a strong, small core of self-interest, with culture of yes men, and any divergent opinions being put down, regardless of their validity.

There may be fraudulent manipulation of statistics to present certain members in a positive or negative light (for example team leaders with 100% recorded attendance or training records on paper, despite no real attendances). Hypocrisy and chaos is widespread, with members capriciously rewarded or punished for identical actions. Ultimately trust, integrity and the purpose of the team is eroded. Factions can develop within teams, resulting in communication within the team, between elements of the team and externally decline to the point of paralysis.

A disproportionate number of disciplinary actions against members may result from a leadership or factions within the team desperately trying to (re)gain control. These can be for trumped up, imaginary or wholly inappropriate reasons, and are often characterised by leadership paranoia - the objective is to remove members they perceive as rivals or as detracting from their status as a result of greater expertise or experience.

The decline could be for environmental changes of course, rather than team disintegration. In some cases, the teams could be argued to have done too good a job, and effectively removed the danger they were responding to – through structural changes, education campaigns or the introduction of technology.

This phase represents a danger that most teams face at some point. The majority of teams spend only a short time in this phase, before recovery. The *post-rescue organisation* should be something we all seek to avoid, being in essence a team that can only harm the sector, its members and the vulnerable we aim to serve.

Recovery or decay

Decay

The issues seen in the post rescue phase descend into farce, with the decisions and actions of the team having increasingly less connection to the initial purpose of that team. There are teams I know of that haven't been deployed for years, and seemingly have no intention or occasion to be, yet continue to fundraise and post on social media.

Recovery

Clearly, teams in the 'Post-Rescue' or 'Decay' phase are rare, and the vast majority either never reach this stage, or ever develop any of the bad practices associated with them. Even if they do, they typically identify issues early and start their recovery phase. The movement for recovery can be an internal or external force, and starts with a recognition of some of the post-rescue issues. There is likely to be a period of turmoil as the team re-focusses, and clearly those associated with bad behaviours in the post-rescue phase will not want to relinquish power. They will also have an entirely reasonable suspicion that they will be removed from positions of power once the recovery starts, making them less amenable to change. With this is mind, it would seem the more productive route to recovery would be a conciliatory approach, rather than a palace coup, with the emphasis being on recovery, rather than punishment of past transgressions.

Reading Jennifer Lois's 2001 paper on social structure and socialisation in a successful SAR team, you can see the way the team in question self-selected out the personalities that could be damaging to the team – any member who attempted to claim credit for the team's work, through awards or media contact. Arrogance or egoism was actively discouraged with the group and humility and respect were encouraged. Displays of pride or hubris were considered detrimental to the team, as were what Cialdini (et al, 1976) calls BIRGing (basking in the reflected glory of the team) – this could manifest itself in the use social media to self-promote or exaggerate role, changes to uniform to lend false authority to the individual or group or excessive vehicle enhancement.

Any member who showed humility and admission of mistakes was given kudos within the team, and this contributed to a greater sense of team spirit and a healthier and more productive team environment.

In Conclusion

As someone who was once accused having an "Agenda of Subversion" (within a SAR context), it's fair to say I have had my fair share brushes with the politics of SAR. I have to admit that my penchant for subversion has probably been strong in this editorial, and as such, it is deliberately provocative. That said, it is *not without purpose*; my intention is to provoke organisations to consider where they sit on the axis of organisational lifecycle and what the implications of that are.

Do we need to remind ourselves of our core purpose, or nudge ourselves back to the original mission? Do we need to refresh or restructure our leadership teams, seek external governance or validation? Are we sure we are acting in a legal manner, and are we confident that "white lies", idiosyncrasies and bent rules that we justify under the banner of volunteers doing good, will be seen in the same light by the authorities? Finally, what is the cost of these potential transgressions with our relationships with other agencies – voluntary or professional?

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Raft on a Highline:
Loads and Trim

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Abstract

This study examines the loads associated with the positioning of a 4.5m raft on a high line in moving water. Testing was conducted within a flow-calibrated channel demonstrating representative stream velocities typical (0.6 – 5.4ms/ also MPH) of those encountered during water related rescues. The raft was positioned from a high line mid-stream, and a load cell was utilised to collect force/time data. The independent variables of trim (relative positioning of the load within the boat) and average stream velocity were investigated. The findings challenge assumptions regarding the impact of trim on the loads within a highline, the relationship between flow rate and loads on highline and make recommendation for training and practice. The study contributes to understanding the loads placed on high lines by representative rafts during operational rescues.

KEY WORDS: High line, trim, force, current vector, water rescue training.

Introduction

Extrication of a casualty located on an obstruction mid-stream (for example vehicle or boulder) requires fine positioning of the craft against the flow of water. *'Holding station'* may not be achievable by paddle or motor power alone. Under these circumstances the raft may be positioned by virtue of a system of tensioned ropes rigged across the moving water (a high tensioned line). The high tensioned line allows the craft to be positioned accurately and facilitate the rescue. The techniques to construct the system vary but are internationally referred to as boat on a high line techniques, *all* position of the craft in the flow from a tensioned line. Loads with in other high line applications such as mountain and technical rescue are well understood (c.f. Attaway, et.al, 2013). However, comprehension of the loads generated by boats in flowing water have not been examined. We pose the question, what force will a rescue raft typically encounter when placed upon a high line and deployed in moving water during a swift water rescue?

As an initial study we measure the force acting on a raft while tethered to a highline in representative, but controlled, real-world conditions. The influence of trim (the fore and aft balance of the raft and velocity of the water in which the raft is operating are considered. Comparisons are made with related literature to contextualise the derived data. This study represents an initial step to understanding the load on (and consequences of overloading) a high line system when utilised to position a rescuing boat within moving water. It is hoped that the results of this research will be the first step to produce working guidance associated with empirical data in this field.

Boat High Line Rescue

Ray (1997: p 125-128) describes a continuum of tethered boat rescues. Ray outlines a single point tether (managed with a single line. P 125), a two point tether (p. 125), and a four point tether (p. 125). All of these methods are suitable for river current velocities that allow the tethers to be *hand held* by the operators. In situation where the river velocity prevents hand held operation a high line system offers management of the boat on the flow with greater security.

In this context this system has been adapted from the high line principles used in technical rescue and has evolved from two variants. The first a drooping highline (Brown, 2000, p. 271-301; Ray, 1997. P96, figure 1) in which the tension of the line can be varied to facilitate control of the craft (see figure 1), and reeved high lines, either English (Brown, 2000, p. 285; Ray, 1997. P126-127, figure 2) or Norwegian (Brown, 2000, p.285; Ray, 1997. P126-127, figure 3) in which the tensioned line remains taught and the boat is controlled via controlling lines. Water rescue practitioners have borrowed and adapted the technique from technical rescue in which gravity provides the load and is understood. However, an additional factor, the load generated by the water velocity is not understood. The water may provide two additional considerations for the rescuer; a change in direction of and additional load. Assumptions made concerning the safety implications in the original contexts of mountain and technical rescue may not be true in this new application of swift water rescue and therefore require investigation.

Method

The fieldwork was conducted in a calibrated channel situated within a manufacture water course. Obstructions were removed from the channel so producing an unrestricted laminar flow within a parallel-sided channel of 4.5m width.

Calibration and Control of Water Velocity (v)

Average stream velocity was calibrated by utilising the Manning formula (Akan (2006; Gierke, 2002), at the test site. The Manning formula is an empirical tool for determining discharge with respect to the potential energy of the flow, the nature and composition of the channel bed. The test channel was selected as exhibiting a constant cross sectional area resulting in steady flow. Further, the test site was selected with a fixed, constant and known gradient with consistent use of concrete during the channel construction.

Measurements were taken from the test site to enable the relationship between pumped volume and average stream velocity to be established. A steel tape measure was used to collect the dimensions of the channel width (m) and the channel length (m). The slope of the channel was calculated by referencing the engineering drawings of the site. The levels were obtained from the top and bottom of the gradient and subtracted (height lost) and divided by the channel length.

Slope = (top datum – bottom datum) / channel length.

Flow into the channel was introduced and increased in staged increments (55, 65, 75, 85 and 100% flows) into the channel, so the average depth could be established at each setting. This procedure established a calibration curve for the channel, for pump capacity (%) and *average stream velocity* (m s^{-1}). This approach was preferable to taking live ultra-sonic/Doppler reading because adjusting the trim of the raft would expose the hull to water at different depths, the stream velocity changes with respect to depth.

Load cell calibration

The data produced by the load cell were continuous mV signal with a quoted full scale deflection of 2.000V at 10kN. The data were captured via an analogue to digital signal convertor with the associated software set to sample a value every 0.5 seconds. The manufacturers calibration cited 1.987V for 10kN (0.1987mV = 1kN). This conversion factor was applied to the mV values in MS Excel™ to obtain values in N force, from which Force/Time Elapsed charts were produced.

Personal Protective Equipment (PPE) and Safety and Management

Technicians were selected on the basis of their qualification which was mapped against the Concept of Operations module 3 training syllabus (DEFRA, 2012). The Technicians were equipped with appropriate personal protective equipment (PPE) including water rescue boots, dry suit, thermal under-suit, knife, helmet and a personal floatation device (PFD).

The Raft

Ray (1997) identified that ‘Almost any watercraft can be used for the lower’ p126. Reflecting common use in the UK a 4.5m raft was selected. The raft is an inflatable multi compartment, self-bailing, lightweight rescue platform and has capacity to carrying multiple casualties. Raft of similar size are in common use by water rescue teams in the UK. Such rafts can be paddled, pulled by hand or motor driven. Its shallow displacement and flat hull allows easy maneuvering.

Procedure

The raft and associated rigging was set up as per Figure 1 with the addition of a Force Logic universal column load™ cell connected in series between the focal point of the anchor on the raft and the attachment point to the high-line.

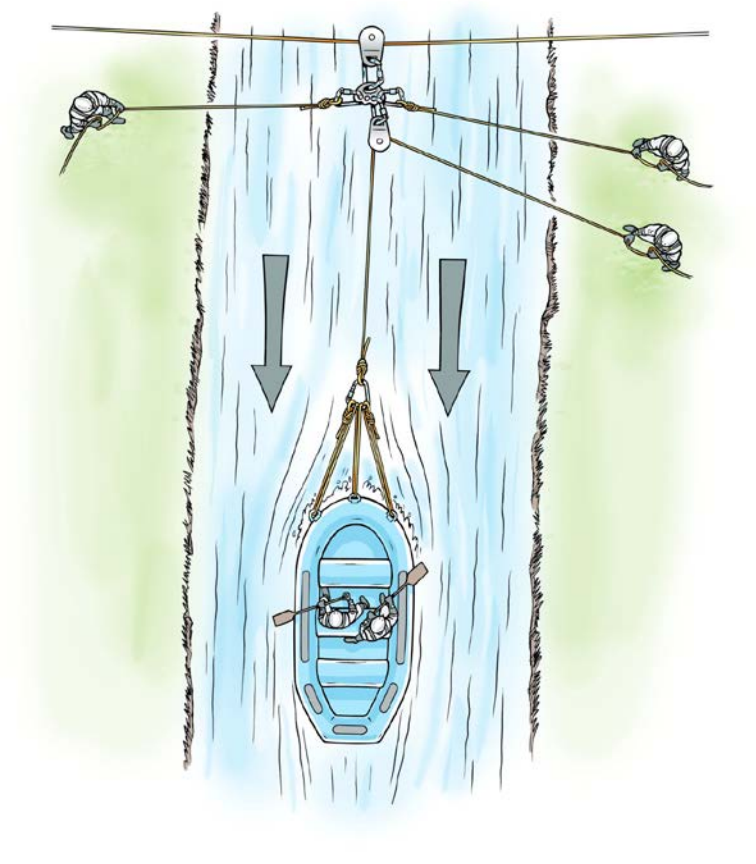

***Figure 1**. Boat on a Highline. Image by George Manley, courtesy of Rescue 3 (Europe). For clarity, the mechanical advantage rigging of the highline and reeving lines have been omitted.*

A 30m length of data cable was connected to an in-line signal amplifier positioned on the bank side which was used to collect streamed analogue data (Force/time) throughout the procedure via this equipment. The load cell, data cable length and amplifier had been calibrated by the manufacturer as a combined unit using a 5-point calibration procedure. A Data Translation™ analogue to digital signal convertor was used to transfer the mV signal to a laptop PC and was exported to Microsoft Excel.

The raft was positioned and the data recorded equipment set to record every 0.1 seconds. The Manufacturer's calibration curve was used to convert the mV signal to force (N) and the data were manipulated using MS Excel™. The nominal pumped volumes were converted into average stream velocity (ms^{-1}) via the Manning calculations and calibration curve

Test 1: Measurement of the forces induced on the highline.

The crew was positioned centrally in the boat (neutral trim) and maintained constantly. The water in the channel was switched on incrementally at 55, 65, 75, 85 and 100% flow and at each increment; the boat was deployed into the current vector via the high line. The raft was positioned mid-stream via alignment with a marker placed on the side of the channel and the loads recorded.

Test 2: Locating the load to the rear of the craft (stern trim)

The testing procedure for Test 1 was repeated for consistency with the crew (n=3) positioned towards the rear of the raft creating a stern trim. Force data were recorded and compared with the data from test 1.

Test 3: Locating the load to the front (bow trim)

The testing procedure for Test 1 was repeated for with the crew (n=3) positioned towards the bow of the raft and maintained constantly. Force data were recorded and compared with the data from Test 1.

Results

Test 1: Measurement of the forces induced on the highline.

Summary of mean and peak force induced on the highline by the raft, trimmed neutrally with respect to average stream velocity and subjected to an incremental increase in average stream velocity.

Trim - Neutral			
Average Stream Velocity (m/s)	Mean Force (N)	Peak Force (N)	Standard Deviation (N)
0.6	1224	1408	89
1.4	1132	1249	36
2.5	638	727	34
4.2	610	793	38

5.4	1128	2566	34

Table 1: Mean and peak force induced on the highline by neutrally trimmed raft.

The force profile reduces with respect to average stream velocity from 0.6 – 4.2 ms^{-1} and the highest force value recorded during the testing of this test (1224N) occurred at the lowest average stream velocity (0.6 ms^{-1}). Beyond an average stream velocity of 4.2 ms^{-1} the force value increased up to 5.4 ms^{-1}. At the highest stream velocity, the force recorded (1128 ms^{-1}) was comparable with the force recorded at the lowest stream velocity (1224 ms^{-1}).

Test 2: Locating the load to the rear of the raft (stern trim)

Summary of mean and peak force induced on the highline by the raft, trimmed to the stern with respect to average stream velocity.

	Trim - stern		
Average Stream Velocity (m/s)	Mean Force (N)	Peak Force (N)	Standard Deviation (N)
0.6	1120	1228	52
1.4	988	1162	38
2.5	1912	2081	56
4.2	2120	2256	47
5.4	1942	2072	33

Table 2. Mean and peak force induced by the 4.5m raft, trimmed to the rear.

The force is lowest (988N) at 1.4 ms^{-1} in this state of trim, and peaks at 2120N at 4.2 ms^{-1}

Test 3: *Locating the load to the front (bow trim)* with respect to force for a given stream velocity.

Summary of mean and peak force induced on the highline by the raft boat, trimmed forward (bow trim) with respect to average stream velocity.

Test 3	**Trim - Bow**		
Average Stream Velocity (m/s)	Mean Force (N)	Peak Force (N)	Standard Deviation (N)
0.6	1045	1158	34
1.4	1003	1077	36
2.5	1773	1886	49
4.2	2030	2141	44
5.4	2530	2674	60

Table 3. Mean and peak force induced by the raft, trimmed forward.

Above 1.4 ms^{-1} loads are higher than the corresponding values for neutral trim. Above an average stream velocity of 4 ms^{-1} the trace climbs with respect to load. Observations highlight that at velocities above 4ms^{-1} the hull is no longer demonstrating planning behaviour.

Discussion

Test 1: Measurement of the forces induced on the highline.

The highest loads experienced occurred at a low stream velocity (up to 1.5m/s). The raft was observed to be functioning as a displacement hull. Beyond stream velocities of 1.5m/s the loads reduce, the raft was observed to be functioning as a planning hull. The implication for practice is that in low flow conditions the loads are higher than may be anticipated. At these low flows the raft is functioning as a displacement hull exposing a greater surface are to the flow. At higher velocity the hull demonstrates a planning behaviour corresponding to lower loads because a smaller surface area is exposed to the flow. These finding appear counter intuitive, rescuers will need to be aware and recognise the planing action of the hull in rescue settings and anticipate higher loads on anchors when the hull is not planing. The assumption of low speeds equating to low loads on the highline is not true. However, the raft hull will have a planning speed. The data also demonstrates that loads will increase at even higher stream velocities. In short the raft has an optimum stream velocity in which it can operate, a sweet spot. This will clearly vary depending of raft design, size and water line length. The rescuers need to be aware of their rafts behaviour in different conditions.

Test 2: Locating the load to the rear of the craft (stern trim) with respect to force for a given stream velocity.

In this test the highest loads are observed at higher stream velocities (up to 1.5m/s) during which the raft was observed to be functioning as a displacement hull. Beyond stream velocities of 1.5m/s the loads increased and peaked at 4.2m/s. The raft was observed to be functioning as a displacement hull at all flow velocities. The implication for practice is that trimming the raft towards the stern changes the hull behaviour and prevents planning behaviour, thus maintain high loads on the highline. Rescuers will need to be aware and recognise that the action of the hull is not planning. In short, compensating for high stream velocities by trimming the raft towards the stern generates high loads on the highline system and is counter intuitive. Echoing our finding in test 1, this will clearly vary depending of raft design, size and water line length. Test 2 confirms the need for rescuers to being aware of their rafts' behaviour in different conditions.

Test 3: *Locating the load to the front (bow trim)* with respect to force for a given stream velocity.

At a low stream velocity (up to 1.5m/s) the load is lower than in the stern trimmed position. Above 1.5m/s the loads are higher than for the neutral trimmed state. The implication for practice is that in low flow conditions the loads are higher than may be anticipated because the raft is functioning as a displacement hull. At higher velocity the hull demonstrates a planning behaviour corresponding to the lower loads. The hull appears to retain its planning function, as shown in test 1. Observation highlights that the support provided by the reeving line, lifting the bow, is in effect compensating for the bow trim.

General Discussion

Key to understanding the loads on the highline is the planing behaviour of the raft. Brewer,(1993) and Fontaine and Cointe, (1997) identify that the displacing hull produces two waves, a bow wave and an aft wave The positions of these waves is determined by the wetted length of the hull. (see Fontaine and Cointe, for greater detail). A theoretical maximum velocity can be established for a given hull type and length while the boat demonstrates displacement behaviour (Miller et al, 2006). For the hull to exceed this velocity, it must transition to a planing hull behaviour, in which the hull has a reduced wetted area, and so resistance. This leads us to recognise a 'sweet spot' for a given hull on a high line.

Implications in Training and Practice,

Encouraging neutral trim in a range of flows and exploration of the optimal performance of a range of different craft would seem paramount in training. In practice observation of the planning and displacement behaviours of the raft would appear pivotal. In particular, the assumption that high velocities equate to high loads needs to be challenged.

During a rescue the change in trim that may occur as the Subjects of the recue board the raft needs to be considered. The resultant increase in load on the highline and change to the position of the raft in the flow needs to be anticipated by the rescuers. A change in rescuer position may compensate for this effect though this warrants further investigation.

Conclusion

The awareness of rescuers to the added dimension of stream velocity and direction is key to understanding the resultant load on the high line system. The influence of trim (how the load is distributed in the raft) has a profound effect on the resultant loads that may be counterintuitive. The results challenge the notion of low stream velocities equate to low loads in the highline. These findings expose the weakness in the transference of assumptions regarding loads from one domain to another (in this case technical rope rescue to swift water rescue). However, the importance of understanding the operational capacity of the raft is also highlighted. In particular, the transferability of knowledge regarding planning behaviour of hulls derived from power boat rescue and an ability to identify the ‘sweet spot’ of a rafts’ performance.

About the authors

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Factors Influencing the Performance of Visual Distress Signals

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Abstract

The present paper summarizes efforts undertaken to review the performance characteristics of visual distress signals using light emitting diodes that might replace pyrotechnic-based flare distress signals in the future. Field photometric measurements were made on board a rescue vessel and near the shore at a coastal station to ascertain typical visual environments under which visual distress signals might be viewed, and to understand the visual tasks associated with searching for and detecting these signals. With this information in mind, the literature was systematically reviewed to identify the factors that are likely to influence the performance of visual distress signals, and to provide preliminary guidance regarding the design of visual distress signals constructed with lighting emitting diodes.

KEY WORDS: *Visibility, Color vision, Effective intensity, Visual search*

Introduction

Similar to aid-to-navigation lights (IALA 2011), visual distress signals need to be viewed in the maritime environment under a wide variety of conditions by search and rescue personnel aboard watercraft and aircraft such as helicopters. By their nature, the locations of visual distress signals are not known before they are detected. Thus it is likely that the initial visual task, *detection*, will occur when the signal is located in the visual periphery. However, simple detection of a possible distress signal is not sufficient for proper and reliable identification, because the location(s) under search might also contain aid-to-navigation lights, lights from other vessels and lights from nearby shore areas that could serve as distractors. Thus, another important component of the visual is *recognition* of the detected light as a visual distress signal. Most likely, recognition is performed using central (foveal) vision following a searcher's initial detection of the signal light (Rea et al., 2009).

Detection and recognition of a visual distress signal are perhaps the key visual tasks associated with these devices. Once a searcher has detected and recognized the signal, it is possible to estimate a vector along which the distressed individual(s) or vessel might be located. If the vessel that has detected the distress signal will subsequently assist in the rescue of the individual/vessel deploying the signal, a secondary visual task of maintaining visual fixation might be performed, since currents and weather could result in the rescue being in a different location from that where the distress signal was initially detected.

The necessary distances at which visual distress signals must be detected and recognized can vary considerably in the search-and-rescue environment. For the present paper, a maximum distance of about 8 km is assumed.

Environmental Factors

The range of conditions under which visual distress signals must be detected and recognized can also vary considerably. Primary searchers will be Coast Guard personnel aboard vessels such as the 47-ft motor life boat (MLB). In order to obtain information about the search process and one example of the environmental and operational conditions under which search operations are conducted, a field visit to Coast Guard Station Point Judith in Narragansett, RI was made on 13 November 2012. Measurements and observations were made aboard an MLB and at the grounds of the Point Judith Lighthouse.

Field Visit Procedure

In both locations, illuminance and luminance measurements were made. Illuminance measurements provided an indication of the ambient lighting conditions (from the sky and/or adjacent light sources) in each location. A Gigahertz-Optik X9 illuminance meter was used. Luminance measurements were performed to provide information about the potential of on-board lights (such as cockpit displays) to detract from visual searching, and to provide information about the level of visual adaptation needed to identify visual elements in the field of view. A Minolta LS-110 meter, with a measurement aperture of 0.33^{o}, was used for measuring luminance.

Illuminance is a measure of the luminous flux density of light from a light source of a given intensity falling on a surface, such as on a horizontal work station or on a vertical plane located at an observer's eyes, and is measured in lux (lx, SI unit) or in footcandles (fc, British unit). As illustrated in Figure 1, illuminance from a light source is proportional to its luminous intensity and the distance between the source and the surface to be illuminated. All illuminances in the present document are reported in lx (10.76 lx = 1 fc; this is often simplified to 10 lx ≈ 1 fc). Luminance is a measure of the density of luminous intensity in the specific direction of measurement, and is measured in units of candelas per square meter (cd/m^2), sometimes called nits. Luminance is somewhat analogous to the perception of brightness of a surface. For example, a typical horizontal desktop illuminance in an office is 500 lx. The luminance (and approximate brightness) of white paper on a gray desktop will be higher than the desktop even though both have an incident illuminance of 500 lx, because the paper reflects more of the incident light than the desktop. Figure 1 shows an approximate calculation method for luminance of an illuminated surface based on its reflectance (white paint typically has a reflectance of 0.8) and the incident illuminance.

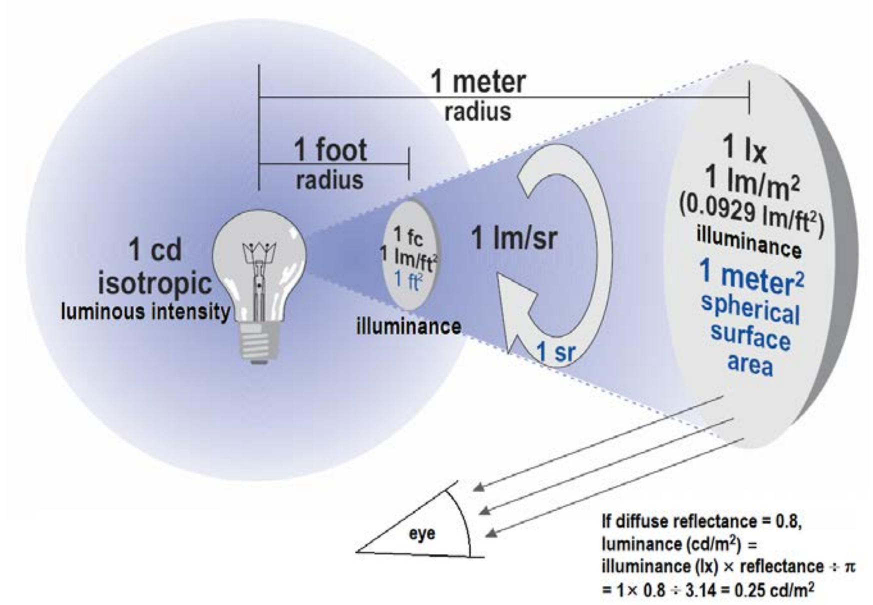

Figure 1: Relationships among luminous intensity, illuminance and luminance.

While conducting measurements on board the MLB, informal discussions with the Officer in Charge helped to describe operating, searching and scanning procedures during search and rescue operations.

On-Board Measurements

Measurements on-board the MLB were conducted while the boat was docked adjacent to a fishing boat dock, between 17:30 and 18:30, after the end of nautical twilight and during a new moon. Conditions were cloudy with periods of light rain, but little to no fog or haze was present. Lights from the fishing dock and boats were present during measurements, but were shielded or blocked by shadows to the extent possible. The brightness levels of cockpit instruments were adjusted by the Officer in Charge to the level that would normally be used during search and rescue operations. The officer explained that during search operations, the brightness level would be reduced to the lowest level possible while still maintaining legibility. Most other sources of illumination were switched off, as would be done during these operations. The motor lifeboat contains two bridges, an open, upper bridge used under most conditions, and an enclosed, lower bridge that would be used only when weather conditions made it impossible to work from the upper bridge. Measurements were made at both bridges.

Upper Bridge

Ambient light levels measured on the upper bridge (while shielding light from the adjacent fishing dock) ranged from 0.1 to 0.2 lx in the horizontal plane at work-plane height (approximately 1 m above the floor). With lights and displays switched off, the vertical illuminance was approximately 0.1 lx at eye height (approximately 1.5 m above floor level) when standing about 0.6 m behind and in front of the chart plotter (the plotter is shown near the center of Figure 2). This value includes the contribution of the ground-based lights ahead of the boat shown in the background of Figure 2. The 0.6 m distance was chosen because the upper bridge was relative open and this was the approximate viewing distance to the plotter when standing behind it.

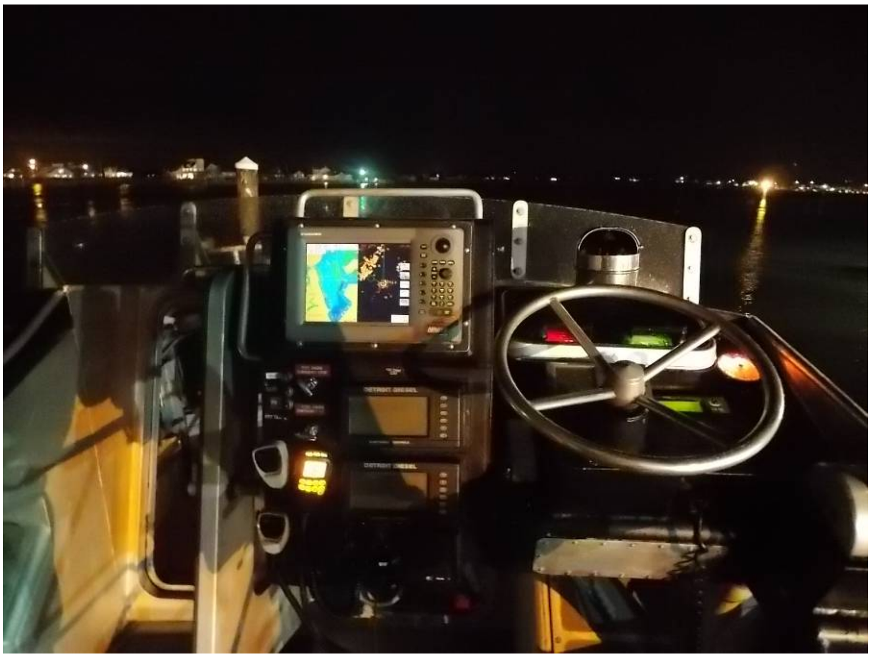

Figure 2: Forward view of upper bridge cockpit.

The maximum luminance of the plotter screen (displaying a white color) was 0.45 cd/m^2. The luminance of the plotter screen when displaying a black color was 0.02 cd/m^2. The luminance of the graphite-colored bevel around the plotter screen was between 0.03 and 0.05 cd/m^2. When the plotter screen was switched off, its luminance was 0.01 cd/m^2. The luminance of the small red display behind the steering wheel to the right of the plotter was 0.62 cd/m^2. The luminance of the small green display adjacent to the red one was 0.99 cd/m^2. Below the chart plotter was a small radio microphone with an illuminated yellow display. The luminance of this display was 7.45 cd/m^2.

Lower Bridge

Ambient light levels in the lower, enclosed bridge, measured while shielding light from the adjacent fishing dock ranged from 0.06 to 0.1 lx in the horizontal plane at work-plane height. With on-board lights and displays off, the vertical illuminance at eye height was 0.1 lx about 1 m directly behind the chart plotter (the plotter is near the center of Figure 3). The 1 m distance corresponds to the location of the seat position in the lower bridge.

The luminance of the white portion of the chart plotter screen was between 1.39 and 1.57 cd/m^2, and the darkest, black portion of the screen was 0.02 cd/m^2 when shielding light from the adjacent fishing dock. The luminance of the smaller, amber display screen to the lower right of the plotter was 2.12 cd/m^2. The luminance of the blue display screen to the right of the amber display was 0.57 cd/m^2, and the luminances of the green and red displays above the blue one were 7.65 cd/m^2 and 8.42 cd/m^2, respectively. The luminance of the blue-gray display to the lower left of the plotter was 0.74 cd/m^2, and the luminances of the gray display screens above the white display, to the left of the plotter, ranged from 0.15 to 0.20 cd/m^2.

Figure 3: Forward view of lower bridge cockpit.

Ground-Based Measurements

Between 18:30 and 20:00 on the same night, photometric measurements were made on the grounds of the lighthouse at Point Judith Station, which has a 180^o+ panoramic view of the Block Island Sound and Rhode Island Sound, including Narragansett, Block Island, Newport, Jamestown and the Newport Bridge (see Figure 4). Conditions were cloudy with periods of light rain, with little to no fog or haze evident. The lighthouse remained in operation; when the light was on, the ambient illuminance was between 0.1 and 0.15 lx in the horizontal plane at ground level. When the light was off the ambient horizontal illuminance was reduced to 0.01 lx. Although the ambient illumination changed considerably, there were no measurable differences in the luminances of dark areas of the sea, land or sky when the lighthouse was either on or off.

When measuring the dark area toward the southeast of the observation location, the sky had a luminance of 0.01 cd/m^2 and the water had a luminance between 0.01 and 0.03 cd/m^2. When placing the luminance meter measurement spot (0.33^o) over the steady-burning green and amber lights of a ship estimated to be about 10 km offshore from Point Judith, the maximum luminances ranged from 0.03 to 0.07 cd/m^2.

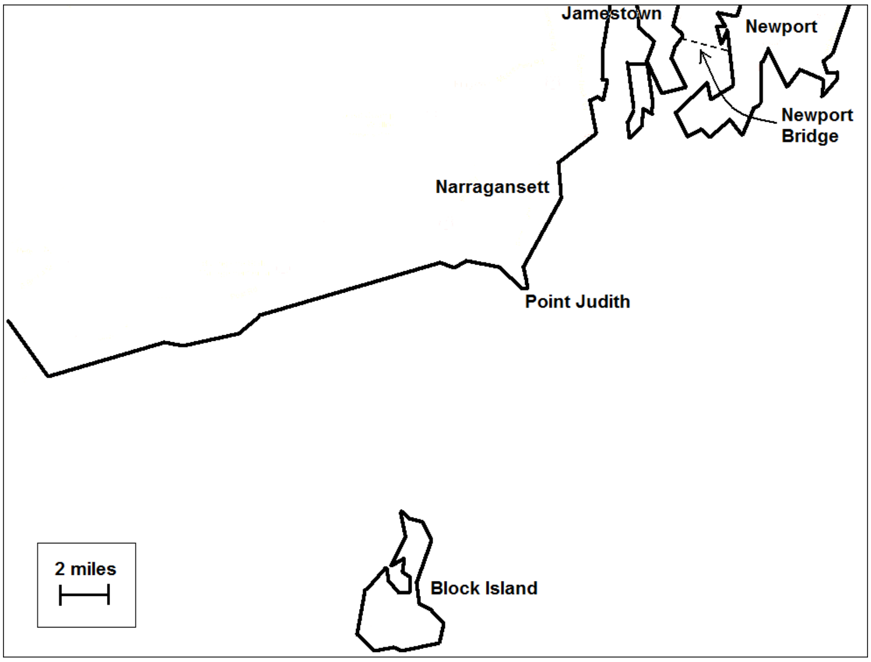

Figure 4: Map of ground-based measurement location and surrounding areas.

In and around Newport many of the lights had the characteristic yellowish color of high pressure sodium (HPS) lamps. Lights along the Newport Bridge were white, with red flashing obstruction lights (1 Hz) on the bridge pillar tops. There was also a flashing green light (0.5 Hz) visible near Newport. Above Newport, the luminance of the sky glow (similar in color to an HPS lamp) above the city was between 0.03 and 0.07 cd/m^2. The luminance of the sea in front of Newport ranged between 0.02 and 0.03 cd/m^2. Portions of the dark terrain in the vicinity of Newport had luminances of 0.01 to 0.02 cd/m^2. When measuring the luminance of (and adjacent to) the lights on the Newport Bridge, the maximum luminance was 0.10 cd/m^2. When measuring the luminance of (and adjacent to) the HPS lights in and around the Newport vicinity, the maximum luminance was 0.41 cd/m^2.

Around Narragansett (see Figure 5), many HPS sources were visible, as well as a visible sky glow with the same color as HPS. A steady-burning green light was also present near Narragansett. The luminance of the water in front of Narragansett was 0.04 cd/m^2. When measuring the luminance of (and adjacent to) the HPS lights in and around Narragansett, the maximum measured luminance was 9.8 cd/m^2.

Around Block Island, a few HPS sources were faintly visible, but no visible sky glow was present. There was also a steady-burning white light source, an amber flashing light (0.25 Hz) and a red flashing light (1 Hz) present around Block Island. A red flashing buoy with a frequency of 0.25 Hz was visible to the left of Block Island. When measuring the luminance of (and adjacent to) the steady-burning white light near Block Island, the maximum measured luminance was 0.15 cd/m^2.

Figure 5: View of lights around Narragansett (in the left portion of the photograph) as seen from the measurement location.

Field Visit Summary

The measurement data are summarized in Table 1. These data can be used to define some representative viewing conditions experienced by search and rescue personnel when conducting search operations.

Table 1: Summary of Field Visit Photometric Measurements

On-Board Measurements (Ambient Illuminance: 0.06 – 0.2 lx, horizontal at work plane)	
Location	**Luminance Range (cd/m^2)**
Chart plotter	0.02 (minimum, black) – 1.57 (maximum, white)
Chart plotter bevel	0.03 (minimum) – 0.05 (maximum)
Radio microphone display	7.45 (maximum)
Various displays	8.42 (maximum)
Ground-Based Measurements (Ambient Illuminance: 0.01-0.15 lx, horizontal at ground)	
Location	**Luminance Range (cd/m^2)**
Sky	0.01 (minimum) – 0.07 (above Newport with sky glow)

Sea	0.01 (minimum) – 0.04 (in front of Narragansett)
Terrain	0.01 – 0.02
Lights near Newport*	0.10 (bridge) – 0.41 (maximum, city/town lights)
Lights near Narragansett*	9.8 (maximum, city/town lights)
Lights near Block Island*	0.15 (maximum, steady-burning white light)
Lights on stationary ship*	0.03 – 0.07 (maximum, steady burning green/amber lights)

**Value within 0.33^{o} viewing angle.*

Range of Environmental Conditions

The photometric characteristics described above and summarized in Table 1 do not characterize the range of conditions under which distress signals can be viewed in the operational environment. During the on-board field measurements the MLB was docked adjacent to nearby fishing boats, and during both the on-board and ground-based measurements, the weather was largely clear and the sea was relatively calm. No moonlight was present, but in combination with swelling and crests of the sea, moonlight and other lighting might create highlights and reflections of visual "noise" superimposed upon the visual search area. In particular, the detrimental effects of outdoor shore-based lighting such as streetlights and parking lot lighting, advertising lights, and other outdoor systems for recreational use has been recognized as a severe and growing problem for visibility of navigational lights by the National Academy of Sciences (Benson et al., 1971) and by the International Association of Lighthouse Authorities (IALA, 2011).

For this reason, the literature review included in the present paper addresses visual conditions of greater complexity than those characterized during the site field visit.

The primary on-board source of light that is likely to create problems for personnel during search operations is the chart plotter. Bright objects in the field of view create scattered light within the eye's optical media that reduces the contrast of objects in the field of view. The amount of scattered light can be expressed as a location-dependent *veiling luminance* that is superimposed onto the scene being viewed (Fry, 1954). The veiling luminance (L_v, in cd/m²) from a glare source producing an illuminance E (in lx) at the eyes, and located θ degrees from the line of sight, is estimated by the equation:

$$L_v = 9.2E/[\theta + (\theta + 1.5)] \qquad (1)$$

Consider, for example, a chart plotter containing an all-white display with a luminance of 1.57 cd/m², matching the highest chart plotter luminance measured during the site visit, having dimensions of 0.2 × 0.25 m, and located 1 m from an observer's eyes 15^{o} from the primary line of sight. The approximate illuminance at the observer's eyes from the plotter would be 0.08 lx and the veiling luminance would be less than 0.003 cd/m². This is less than 30% of the lowest-measured sky, sea or horizon luminance measured under visually clear, moonless conditions (0.01 cd/m²) and is considered by the Illuminating Engineering Society (IES, 2000) a value unlikely to contribute to substantially reduced nighttime visibility.

Signal Light Performance Characteristics

In the present section of this paper, the characteristics of light signals are discussed with emphasis on how these characteristics should be defined to ensure adequate visibility under an appropriate range of visual conditions. Literature from the vision sciences, transportation engineering, illuminating engineering and psychology was consulted.

Luminous Intensity

Perhaps the most important parameter related to the visibility of a distress signal is its luminous intensity. As illustrated in Figure 1, it is the luminous intensity, in conjunction with the distance, which determines the illumination from a signal light at an observer's eyes.

Much of the literature on the threshold intensities for light detection against background luminances varying in value are for stimuli having relatively large angular dimensions (Blackwell, 1946; Boff et al., 1986). Visual distress signals, being generally portable devices suitable for hand-held use, are likely to have point-source sizes when viewed from a km or more away. For white point-sources viewed against a white (achromatic) background, Hill (1947) reported that up to a background luminance of 0.1 cd/m², the threshold illuminance from the point source was nearly constant, and an illuminance of about 0.1 microlux (μlx) was needed for threshold (50%) detection; triple this value provided highly reliable (90%) detection. Above a background luminance of 0.1 cd/m², the threshold illuminance increased along a logarithmic function to nearly 400 μlx at a background luminance of 10,000 cd/m², the maximum likely to be experienced outdoors during the daytime. At this luminance, highly reliable detection required double the threshold illuminance, about 800 μlx.

For nighttime viewing conditions, Rea et al. (2009) investigated the necessary intensity of an array of four flashing lights viewed against mostly dark backgrounds (with some rival lights to simulate rural villages) to be reliably and confidently detected and identified. A scotopic luminous intensity of 20 cd for a simulated viewing distance of 8 km was determined as a value at which detection and confidence were both high. This corresponds to a scotopic illuminance at the eye of approximately 0.3 μlx, which (leaving a discussion of the difference between scotopic and photopic units to later in this paper) is largely consistent with the threshold for highly reliable detection measured by Hill (1947).

Even when a light source is highly reliably detected, increases in luminous intensity will result in shorter reaction times to the onset or presence of a light. Under most conditions, reaction times to stimuli decrease with increasing luminous intensity according to a power function with an exponent value near -0.33 (Vaughan et al., 1966; Pollack, 1968; Lit et al., 1971; Vicars and Lit, 1975; He et al., 1997).

Influence of Background Complexity

As described above, increased background luminances require increased threshold luminous intensities for a light signal to be detected. Much of the work on thresholds has been conducted using visually simple backgrounds (Hill, 1947), or backgrounds of fixed complexity (Rea et al., 2009). In addition to the data presented above on field measurements, Worthey (1988) conducted several sets of photometric measurements in the New York City harbor area, a highly built up location, and found typical lights (mostly judged to be streetlights using HPS or mercury vapor sources) to produce 10 μlx from distances ranging between about 1 and 15 km away.

A number of researchers have investigated the role of the background complexity itself on detection and identification of signals. For example, Haines (1968) found that detection of a point source of light increased from 0.5 to 0.8 s when it was displayed against a simulated star-field background, and to 1.7 s when a high-luminance (about 188,000 cd/m^2) glare source subtending 0.3^o was located 27^o off axis. Langmuir and Westendorp (1931) reported that the presence of 30 irrelevant steady-burning lights increased detection times of a flashing light by 30% when they were similar in intensity to the signal light, and by 100% when their intensity was 100 times higher than the signal.

An outdoor experiment was conducted in the 1960s by the Applied Psychology Corporation (APC, 1962) to evaluate the impact of city-light backgrounds on the detection of signal lights, using a location overlooking Tucson, AZ. Flashing signal lights were located such that from a subject's viewing location, they could be superimposed over dimly and brightly lighted sections of the city. Significant impacts of background complexity were found. Against little background lighting, detection times averaged about 2 to 5 s; against backgrounds with intermediate complexity, average detection times were between 7 and 9 s. Against the brightest backgrounds, detection times averaged more than 12 s.

Several attempts to quantify the relationship between signal light detection and the number of irrelevant lights have been made. Crawford (1962, 1963) found that with no irrelevant lights, detection times to steady and flashing lights averaged about 0.8 s, but with 21 irrelevant lights present, the times increased to 1.3-2.6 s. Different increases were found for different combinations of the signal and irrelevant lights being flashing and steady-burning. When the signal was flashing and the irrelevant lights were steady-burning, the shortest detection times were found. Flashing signal lights among flashing irrelevant lights had the longest detection times.

The IALA (2008) recommends that when minor background lighting is present, the luminous intensity of aid-to-navigation lights should be increased by a factor of 10, and when substantial background lighting is present, the luminous intensity should be increased by a factor of 100.

Spectral Distribution (Color)

When a light signal has a much higher luminance than the background against which it is seen, and when it has sufficient intensity for its color to be identified (Hill, 1947), the color plays relatively little role on the speed and accuracy of detecting the signal (Ueno et al., 1985). When the background luminance approaches the intensity of the signal light, such as when it is viewed against a bright daytime sky, the color will strongly influence the reaction times elicited by the signals (Ueno et al., 1985; Bullough et al., 2000).

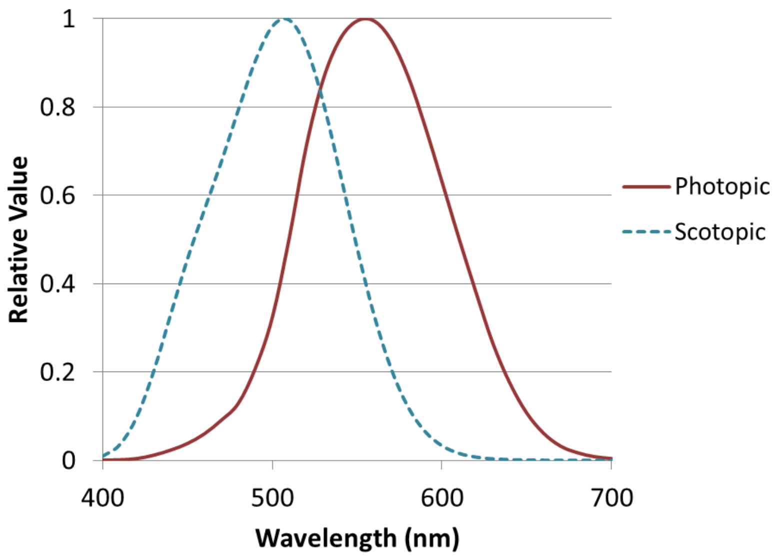

Figure 6: Photopic and scotopic luminous efficiency functions.

When the background illuminance is very low, and when the signal light intensity is low enough that its color cannot be readily ascertained, the spectral sensitivity of the visual system is best characterized by the *scotopic* luminous efficiency function, in contrast to the *photopic* luminous efficiency function used to define conventional photometric quantities (Figure 6). As the average background luminance decreases below about 1 cd/m², the spectral sensitivity of the human visual system shifts from a peak spectral sensitivity at 555 nm (yellow-green light), the combined sensitivity peak for the eye's cone photoreceptors, toward 507 nm (blue-green light), the peak sensitivity of rod photoreceptors (He et al., 1997; Rea et al., 2004). Under dark nighttime conditions background luminances can be as low as 0.01 cd/m² (see Table 1) and it is reasonable to assume that the spectral sensitivity for faint light signals would be characterized by the scotopic sensitivity curve in Figure 6. At intermediate luminances, the so-called *mesopic* spectral sensitivity is characterized by a weighted average of the photopic and scotopic functions (Rea et al., 2004).

Data from Rea et al. (2009) on the detection of dim flashing light signals varying in color (red, yellow, white, green and blue) illustrate this phenomenon (Figure 7). For the same low background luminance conditions, equal luminous intensities from each of these colors do not elicit equal response times. Higher luminous intensities are needed for red and yellow signal lights relative to green and blue ones, consistent with the relative sensitivity to light for these colors in Figure 6. However, once the luminous intensity were 50 cd or higher, the response times would be asymptotic and there would be little difference among the colors.

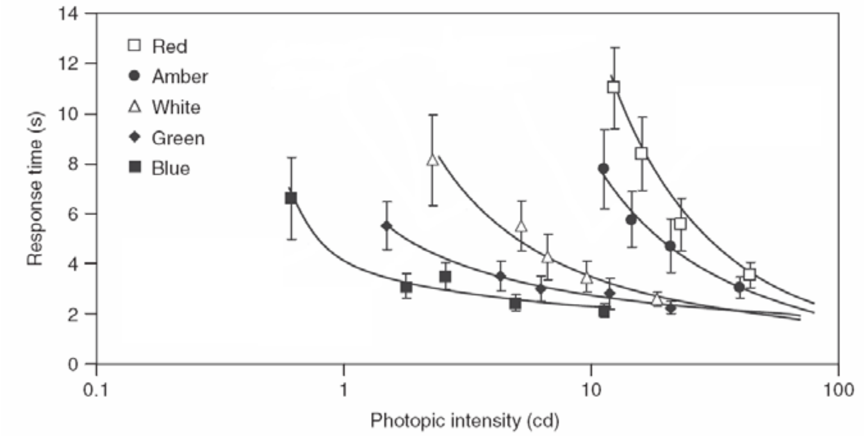

Figure 7: Response times to signal lights varying in color under dark background conditions (Rea et al., 2009).

Another interesting finding from Rea et al. (2009) is that the identification of the orientation of signal light arrays (and not merely their detection) appeared to be more related to the photopic intensity of the lights than their scotopic intensity, even when the background luminance was very low. This suggests that detection and identification might be served by two visual channels: one channel in the visual periphery with a spectral sensitivity similar to the scotopic luminous efficiency function, and one channel in the central (and rod-free) visual field where only cone receptors exist, with a sensitivity matching the photopic luminous efficiency function in Figure 6.

Visual sensitivity in the peripheral retina at all light levels under which cone photoreceptors respond (photopic and mesopic) also appears to have a substantial short-wavelength lobe (Weale, 1953; Wooten et al., 1975) suggesting that blue light signals might be effective for peripheral detection during daytime and nighttime.

Regarding the potential for light sources of different colors to be scattered by the atmosphere to different extents, Boelter and Ryder (1940) reported that in fog, the amount of backscattered light was nearly the same for a wide range of colored light beams from blue (short wavelengths) to red (long wavelengths). This finding is consistent with the conclusion from Middleton (1952) that no special theory of visual range for colored signal lights through even a clear atmosphere is needed, relative to white signal lights. Over long distances, however, the scattering properties of the clear atmosphere will tend to result in greater extinction of short wavelengths so that color appearance can shift slightly toward yellower or redder appearance (Middleton, 1952).

Temporal Characteristics

Flashing lights are often employed for warning and signaling applications over steady-burning lights because of observations that flashing increases the conspicuity or attention-getting properties of a light source. Published literature confirms such observations (Goldstein and Lamb, 1967). However, when viewed well above the visual threshold (suprathreshold conditions), detection of a signal light that is steady burning is improved over a flashing signal light (with a maximum intensity equal to that of the steady-burning signal), in a manner consistent with predictions of the calculated effective intensity (Gerathewohl, 1953). Near the visual threshold, faster-flashing signals are detected more readily than slower-flashing signals, for a flash frequency range between 0.33 and 3 Hz (Gerathewohl, 1957). De Lange (1958) reported peak temporal sensitivity for small stimuli at low light levels around 3 Hz. Low duty cycles (the percentage of time a flashing light is on) also appear to be more effective than higher ones (IALA 2008).

When flashing lights are employed to increase conspicuity, sources having more rapid onset times will provide modest benefits in terms of response times. Because of their shorter onset times, LED and neon signal light onsets are detected more quickly (Sivak et al., 1994; Bullough et al., 2001a) than incandescent signal light onsets, but are not necessarily detected any more reliably, at least within 1 s (Bullough, 2005). And although steady burning lights are often less conspicuous than flashing signal lights, steady-burning light sources can provide superior visual information regarding closure detection than flashing lights (Bullough et al., 2001b). For foveal and peripheral signals up to several degrees of arc in size, the integrated product of the luminance and the duration of a flash of light (i.e., the light-energy) can be traded off as illustrated in Figure 8 (Bullough, 2005). For example, a signal that is double the luminance but with a flash duration that is half of another will appear equivalent at threshold (Baumgardt, 1972).

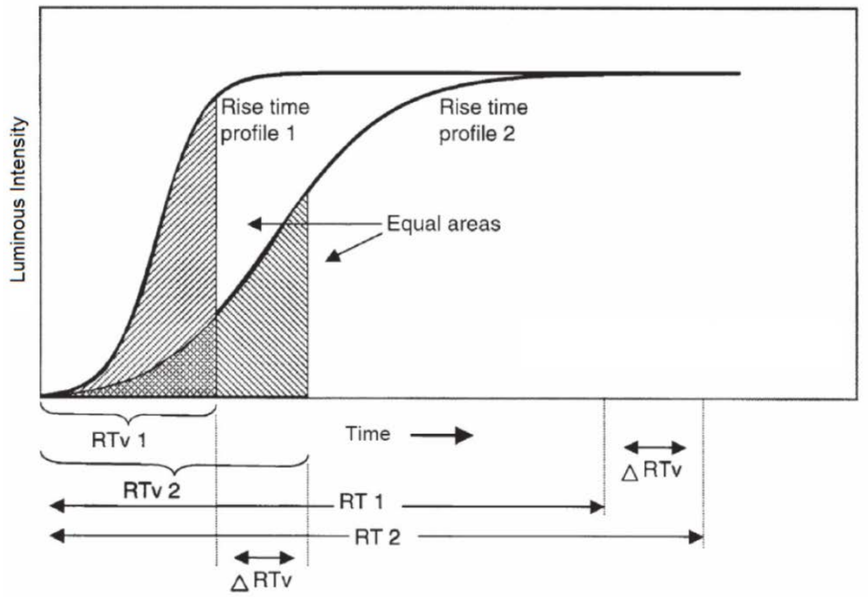

Figure 8: Two sources with different onset profiles will elicit response times based on the amount of time required to achieve a criterion level of light-energy (Bullough, 2005).

Effective Intensity

One method used extensively across transportation modes to quantify the visual effectiveness of flashing signal lights has been through the luminous intensity of a steady-burning signal light with equal effectiveness, a concept known as effective intensity. One of the most commonly used formulations for effective intensity is the Blondel-Rey formulation based on studies conducted by Blondel and Rey (1912). According to this formulation, the effective intensity (I_e, in cd) of a flashing signal light at near-threshold viewing conditions is defined as follows:

$$I_e = \int_{t1}^{t2} I \, dt/(a + t_2 - t_1) \qquad (2)$$

where I is the instantaneous luminous intensity (in cd) at any moment between times t_1 and t_2 (both represented in s); and a is a constant (in units of s) determined experimentally by Blondel and Rey (1912) to have a value near 0.2.

Various studies on the perception of flashing lights have confirmed that the Blondel-Rey (1912) formulation is reasonably predictive of the effectiveness of flashing light signals (such as visual range or relative brightness) under a wide range of conditions (Neeland et al., 1938; Projector, 1957; Williams and Allen, 1971; Howett, 1979; IALA, 2008; Vandewoorde, 2009; Bullough et al., 2013; Bullough and Skinner, 2013). This is significant because different light source technologies can produce a wide range of temporal waveforms of light output as a function of time (Lomer, 1970).

Values for the constant *a* in the Blondel-Rey equation have been found to be different depending upon factors such as the overall intensity of the light, for either near- or supra-threshold (Toulmin-

Smith and Green, 1933; Hampton, 1934; Neeland et al., 1938; Rinalducci and Higgins, 1971; Schmidt-Clausen, 1971; Chander et al., 1991), the color of light (Schmidt-Clausen, 1971; Ikeda and Nakayama, 2006) and spatial configurations of the light (Schmidt-Clausen, 1971; Saunders, 1971; Wagner and Laxar, 1996; Bullough et al., 2015). Bullough et al. (2013) found different values of *a* for different response types (apparent brightness, conspicuity or overall visibility). Reviewing a number of findings from the literature, Projector (1957) suggested the published data contained sufficient imprecision that the value of *a* should be kept at 0.2 in order to facilitate comparisons between different flashing lights.

Thus, despite alternative formulations for effective intensity (Ohno and Couzin, 2003), the formulation proposed by Blondel and Rey (1912) remains largely accepted for use in a wide variety of contexts (IALA 2008) although it may not be suitable for predicting the relative effectiveness of very complex temporal waveforms, such as a rapidly alternating high-low sequence superimposed onto a sinusoidal temporal waveform of lower frequency (Ohno and Couzin, 2003).

Spatial Characteristics

Size

The spatial characteristics of aid-to-navigation lights have been investigated by the Coast Guard (Wagner and Laxar, 1996). However, given the requirements of visual distress signals to be relatively portable for possible handheld use during emergencies, and the large distances (i.e., 8 km) at which they must be detected and identified, it is not likely that visual distress signals can have a spatial extent large enough to render them as anything but point sources in the search and rescue operational environment.

Distribution

Visual distress signals are often expected to be seen by search personnel on waterborne rescue craft such as the MLB described previously in the present paper, or by mariners on nearby commercial or private vessels assisting in search operations. Thus, the primary distribution of light from visual distress signals will be in the horizontal direction. Search operations can also be conducted by aircraft, however, so it is also important for visual distress signals to produce light output at angles above horizontal.

According to the Addendum to the National Search and Rescue Supplement of the International Aeronautical and Maritime Search and Rescue Manual (Coast Guard, 2009), the recommended altitude when searching for distress signals is 1500-2000 ft (450-600 m). At a distance of about 10 km, an altitude of 0.6 km corresponds to an angle about 4^o above horizontal. As the aircraft approaches the signal the angle will increase if the search aircraft does not adjust its altitude. From about 4 km away, the same altitude corresponds to about 9^o above horizontal. Thus, an intensity distribution in the cone from 0^o (horizontal) to 10^o above horizontal might be a reasonable specification for the intensity distribution of a visual distress signal. This is similar to the distributions of aviation signal lighting (Loch, 1961; Schwartz, 1971; Bullough, 2011).

The lateral distribution of a visual distress signal should be as broad as possible because it is not clear to the user where search personnel will be located. However, because a visual distress signal might be a source of glare for the individual using it, it is recommended that the distribution contain a “notch” of reduced intensity in the direction of the user, perhaps as wide as 90^o in angle.

Observer Characteristics

Age

Most studies of visual performance and detection and identification of light signals have not specifically studied subject pools varying substantially in age. Because of changes in the thickness and yellowing of the crystalline lens in the human eye with age (Weale, 1961), and reductions in both the light- and dark-adapted pupil size, retinal illumination changes almost linearly between the ages of 20 and 60-70 years (Wright and Rea, 1984). By the time the age of 50 years is reached, the retinal illuminance is only half that of a 20-year-old. At the age of 60 years it is about one-third. Although generally not noticeable by individuals because of the gradual nature of this change, it does affect the necessary illuminance at the eyes for signal light detection relative to a younger observer.

Color Deficient Vision

About 8% of the male population and a very small percentage of the female population have some form of color vision deficiency, usually of the protan or deutan types (Rea, 2000). Protans have a missing or shifted long-wavelength cone pigment, with the result of being generally less sensitive to long wavelengths in the red portion of the visible spectrum. Deutans have a missing or shifted medium-wavelength cone pigment but do not exhibit reduced sensitivity to any particular wavelength region. Both groups may exhibit confusion of colors along the axis from green to yellow to red in the chromaticity diagram. To help protans and deutans with color identification of signal light systems that include red, yellow and green, some specifications require green signal lights to have a dominant wavelength between 500 and 510 nm rather than 520 to 530 nm, which provides some separation from the red-yellow-green axis and assists with discrimination (CIE, 2001).

To assist protans with the detection of red signal lights, it is suggested that dominant wavelengths for red signals be no longer than 615 nm, rather than 630 nm or longer. Such a restriction has been found (Huang et al., 2003) to permit reliable detection by protan individuals, while still ensuring that a signal will be identified as red by both protan and color-normal observers.

Discussion

The information summarized in this paper provides some guidance as to the characteristics of visual distress signals that can be reliably detected by rescue personnel during search operations:

- *Intensity:* A minimum scotopic intensity of 20 cd appears to be necessary for detection of a flashing light signal array (Rea et al., 2009) from 8 km away. Since a visual distress signal is a single source of light rather than an array, a higher intensity may be necessary to ensure reliable detection, but 20 cd is a reasonable lower value for a range of test conditions. Higher intensities might be necessary for reliable detection in visually complex environments with many irrelevant lights present.
- *Spectrum/Color:* A short-wavelength color may be most effective for peripheral visual detection (Weale, 1953) and detection under scotopic and mesopic conditions.
- *Temporal:* Flashing lights, or a profile with modulating intensity, will generally have increased conspicuity over steady-burning lights, and most background city and short lights are steady-burning. Frequencies of 3 Hz appear to be more effective than low frequencies such as 0.33 Hz (Gerathewohl, 1953). This also seems to be consistent with flicker sensitivity data from De Lange (1958). Duty cycles below 50% also appear to be more effective than higher duty cycles (IALA, 2011).
- *Spatial:* Visual distress signals should be compact in size for convenience, and their maximum intensity distribution focused between 0^{o} (horizontal) and 10^{o} above horizontal to ensure detection by water vessels and aircraft between 4 and 10 km away, based on Coast Guard (2009) search and rescue practices.

One potentially promising approach for visual distress signals could be to use alternating color and intensity simultaneously to provide a distinct spectral and temporal pattern. IALA (2011) suggests such an approach as a possible means to increase conspicuity. An alternating combination of short-wavelength (blue or green) and long-wavelength (yellow, orange or red) stimuli would provide both photopic and scotopic sensitivity.

A factor not heretofore discussed in this paper is the necessary electrical power supply for a visual distress signal using LEDs. Obviously, the performance of a visual distress signal would be constrained by the necessary power available to produce the signal light pattern. For example, a typical D cell battery will produce at least 10 W·hours of energy (Energizer, 2012). Assuming an LED light source system efficacy of 50 lm/W (including optical losses), a single D battery might be able to produce 500 lm·hours, say 250 lm for a duration of 2 hours. If the signal light had equal intensity in all directions around the source, the luminous intensity would be 20 cd in all directions for those 2 hours. The zone between 0^{o} (horizontal) and 10^{o} above horizontal covers about 8.7% of the inside surface area of a sphere, so concentrating the 250 lm (for 4 hours) in the present example to this 10^{o} band would permit the intensity to be approximately 230 cd. This equates to an illuminance of at least 3 μlx at an observer's eyes from 8 km away, which should be sufficient for a broad range of nighttime viewing conditions, based on the data reviewed in this paper.

The data summarized in this paper can assist the designers of visual distress signals using LED sources to ensure that they can be reliably detected by search personnel when necessary. Of course these data are also applicable to other signal lights for aviation, navigation and other modes of transportation that need to be seen and identified over long (several km or greater) distances.

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Emergency Urban Search

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Abstract

The use of a video camera to support search immediately raises the question "for target location, what is the most effective way of presenting video camera output to a human observer ('spotter')". We examine three presentation modes: (a) unprocessed video output, (b) 'static visual presentation' (SVP) in which a series of static views of the search area can be examined in turn while keeping up with drone movement, and (c), a novel mode called 'Live SVP' in which the locations sequentially captured by a camera are presented discretely in real time, thereby preserving any movement such as a person waving to attract attention.

The dynamics of aerial video were modelled using game development software. The resulting videos were used to support realistic search exercises using human participants. The task attempted by each participant was the identification of lost school children in the simulated environment, using one of the video presentations described above.

It was found that the new LSVP viewing mode is superior in those tested for moving targets in a low distraction environment. Another principal finding was that the density of distractors (i.e., non-target objects) had a significant influence on the success of target identification.

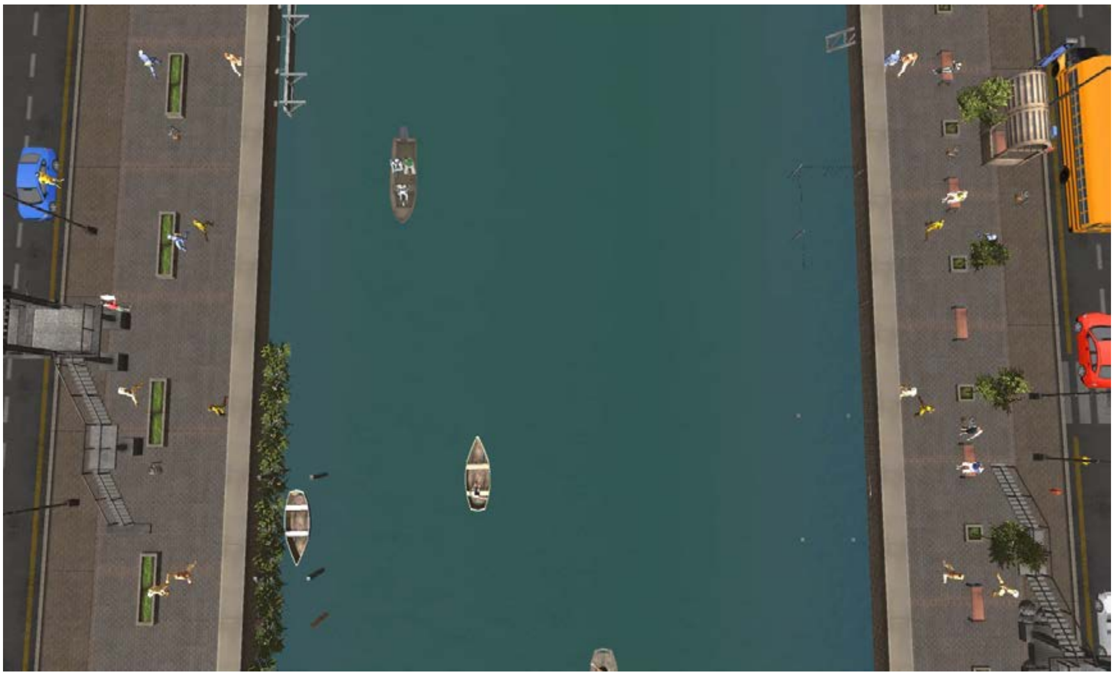
KEY WORDS: Search, Rescue, Drone, Video, Target, Presentation

Introduction

There are many scenarios within an urban environment where some type of 'target' must be located as quickly as possible. The target might be a dementia patient who has wandered unobserved, the victim of a boating accident, an escaping criminal, a person apparently intent on suicide or some artefacts associated with the person being sought. Typically a search vehicle (e.g., boat or automobile) and driver are called out, together with one or more human spotters who, with or without optical aids, conduct a visual search along a route determined by received intelligence and accumulated experience.

The likelihood of a successful search can potentially be enhanced in at least two ways. An obvious one is to employ drones carrying downward facing video cameras, since the flexibility of their positioning can provide a wide variety of views not always available to a conventional human spotter. A second way is to process and present the raw camera output in such a way as to enhance the likelihood that a spotter will identify a target. The latter approach is investigated in the study reported here.

Figure 1: A typical simulated output of a drone-borne video camera



Simulation

To perform the intended formal investigation it is necessary to control the experimental parameters. For financial and logistical reasons that is infeasible within a real-life search and rescue scenario, so simulation was employed, using game development software to model the overflown terrain as well as the dynamics of drone movement and the generation of video camera output. The resulting views of terrain provided by processed video camera output were of a quality more than sufficient to carry out realistic tests using human participants as spotters. An example of simulated processed video camera output is shown in Figure 1, which depicts a canal and part of its shoreline. Both the canal and its shoreline are populated with commonplace objects, some of which are the targets being sought.

Typical objects, both human and non-human, are illustrated in Figure 2.

Figure 2: Some objects populating the canal and its shoreline

Related work

The enhancement of urban search and rescue calls for attention to be paid to a very wide range of issues spanning many disciplines. Of topical interest is the use of a drone, the output of whose downward facing camera is transmitted to a base station where trained human spotters attempt to identify a missing person or related cues as to their location (Simerson 2004, Goodrich et al. 2008; Doherty & Rudol, 2007). The resulting flexibility of search, as well as the issues demanding investigation, increases when multiple drones (swarms) are deployed: constraints are imposed by the environment (e.g., obstacles, weather conditions) (Wahate & Trigoni, 2010) and by the topography, the latter also impacting upon communication between swarms and ground control (Wahate et al, 2009).

There are many essentially human issues to be addressed. One is that of training: the typical success rate of untrained personnel can be as low as 30% (Croft, 2007), and research has shown that a trained "spotter" can only provide an improvement of about 10% (Stager, 1975). Nevertheless, even expert spotters can suffer the detrimental effects of inattentive blindness (Drew et al, 2013). Issues related to human cognition and visual perception can draw upon decades of research: see, for example Wolfe & Pashler (1998), Wolfe (2004, 2007) and Ware (2012). In these and other reports, the significance of preattentive processing (Healey & Enns, 2012) and distractors is apparent (Wolfe et al, 2002; Wolfe & Gray, 2007). Recently, investigations of visual search have been set within the specific context of search and rescue (Adams et al, 2009; Mardell et al, 2013) and have focussed upon the influence of human cognition and visual perception. For wilderness search and rescue Mardell et al (2013) investigated how the perceptual ability of a human spotter can be supported by the appropriate processing and presentation of the images obtained by a drone's camera: they discovered that a sequence of static views led to target identification performance significantly better than unprocessed video output. The general focus of the present paper is the same, but specifically directed to urban search and rescue and the proposal and evaluation of a new method of image processing of potential value when targets are moving.

Processed video output

In the context of wilderness search and rescue, Mardell et al (2011, 2013) have evaluated a number of ways in which the output of a downward pointing video camera might usefully be processed before presentation to a spotter. Six possibilities were evaluated of which two are directly relevant to the present study:

Standard Moving Presentation (SMP): No processing takes place and camera output is displayed directly to the spotter.

Serial Visual Presentation (SVP): here, the spotter is presented with a sequence of static images of the terrain captured by the camera as the drone moves along a path. Each image is presented to the spotter for a specific amount of time until it is replaced with the next one, though at a rate that 'keeps up' with the drone. In the context of wilderness search and rescue it was found (Mardell et al, 2013) that, statistically, SVP leads to significantly better target identification than does SMP.

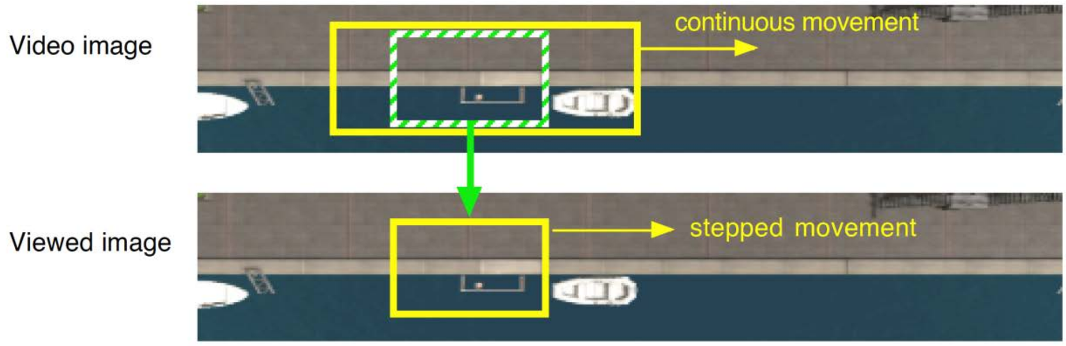
Despite the identified advantage of SVP over SMP, a remaining problem associated with the SVP viewing mode (but not with the SMP mode) is its inherently static nature. For example, if a missing person were to be waving in order to attract attention, this basically dynamic aspect of the captured image would be hidden from view in the SVP mode.

The need for a video processing mode, which retains the established advantage of SVP but allows a spotter to see temporal changes within a fixed area of terrain, prompted the investigation reported here. At the same time, it was decided to focus on urban search and rescue in view of its frequent daily occurrence and the typically higher density of distractors (i.e., non-targets).

A new viewing mode

Partly suggested by the work of Holcombe (2010) and Abrams (2003), a new video processing technique (Live Serial Visual Presentation - LSVP) was proposed that would support a viewing mode in which temporal changes are preserved. The principle is illustrated diagrammatically in Figure 3. The upper part shows (yellow box) the continuous moving image captured by the on-board video camera. Part (hashed) of that image corresponding to a fixed area of terrain is then presented (yellow box in the lower part of the figure) for viewing by a spotter, inherently retaining any temporal changes occurring in the original video image.

Figure 3: Schematic illustration of the basis of the tested Live Serial Visual Presentation ***(LSVP).***



Hypotheses

The principal aim of this experiment was to test three hypotheses. The first goal was to see if the results obtained by Mardell et al (2013) for wilderness search and rescue are equally relevant for search in the very different urban environment and with a high density of distractors:

H1: SVP will lead to a higher target identification success rate than SMP.

The second hypothesis concerns the effectiveness of the newly introduced Live SVP viewing mode. It was expected that LSVP would combine the advantage of a static view with the live movement associated with SMP:

H2: Overall, LSVP will lead to a higher target identification success rate than SMP and SVP.

A third hypothesis refers to the anticipated unique advantage of LSVP over SVP and SMP for targets that are moving:

H3: LSVP will perform better than SVP and SMP for moving targets

Experimental design

The scenario adopted for the experimental investigation comprised a canal and its immediate surrounding area. It was populated with people and artefacts (e.g., cars, boats and lighting fixtures) to constitute a representative environment in which an urban search and rescue might take place. Figure 1 illustrates an overall view of the search area, and Figure 2 illustrates various objects that populated it. In the reported experiments, six of those objects (all people) were designed to be targets, the remaining objects (including people) being considered to be distractors.

The task that was presented to participants taking part in the experiment was that of identifying six children who had been lost during a visit to the canal area. The lost students were characterized by their apparel, comprising a red top and blue trousers. Human distractions were introduced into the environment, wearing a red top with trousers that were not blue, and vice versa.

To allow study of the influence of different viewing modes, each of the six missing children constituted one of the following types of target:

Static target:

Sitting in the sidewalk area; standing in the sidewalk area; and within the river area on a static floating object

Moving target:

Running and hiding on the sidewalk (behind a bus stop); sitting in a moving object (e.g., boat); and standing and waving on the sidewalk.

Unity 3D" game engine software (http://www.unity3d.com/) was employed to create a model of the simulated environment (e.g., canal, sidewalk and populated objects) using items provided in the "Town Constructor Pack".

Pedestrians were modelled using the "Adventure Character Set" from the Unity 3D Asset Shop and their clothes created to show a range of colours. Their movement paths were defined along four virtual lanes, two forwards and two backwards. Figure 4 shows the six targets used in the experiment: they fall within the six categories defined above. Boats and cars were modelled and introduced into the scenario in a variety of ways. Twenty variations of boat type and number of passengers were introduced, and seven different models of car moved along the streets.

Figure 4: the six types of target: Top left (sitting); Top middle (standing); Top right (sitting in moving boat); Bottom left (running); Bottom middle (sitting); Bottom right (waving)

The simulated video output was chosen to be compatible with a drone flying at an altitude of 40 meters and moving at 6 meters per second.

Experimental procedure

A total of 56 participants took part in the first experiment. All were visiting a two-day university festival and volunteered their participation upon noticing an exhibit related to human vision. Their ages ranged from under ten to over seventy. In view of this age distribution the four viewing modes were, as far as possible, spread roughly equally over that age range.

Each participant was first introduced to the task by the experimenter reading from a script. They were then provided with a set of on-screen instructions with illustrations, stating:

"A drone with a video camera flies over a canal.
You will be observing the output from the drone's camera.
Your task is to find six lost school children along the canal.
All the children are wearing a red top and blue trousers.
Whenever you think you see one of the children point to that child on the screen.
The sequence will last about 3 minutes – please watch it to the end.
Say START when you are ready".

To familiarize each participant with the task and the environment, two example targets were introduced in the first part of the scene and pointed out by the experimenter: thereafter, after the drone had passed over a bridge that blocked the view, the participant was given no further assistance with target location.

Since the scenario was the same for each viewing mode, each participant was tested with only one viewing mode in order to avoid any learning effects. Each test lasted 3 minutes.

Every time the participant pointed to the screen the experimenter recorded the location and noted whether a target had been correctly or incorrectly located (i.e, whether the identification was a True Positive or a False Positive). At the conclusion of the task the participant was asked to complete a questionnaire concerning age range, gender and vision as well as subjective views concerning their experience. They were thanked for their participation.

Experience with the first experiment (see Experiment 1 below) and the pilots preceding it suggested that the relative advantages of the three viewing modes might be sensitive to distractor density, so a second experiment (see EXPERIMENT 2 below) was carried out to investigate this issue.

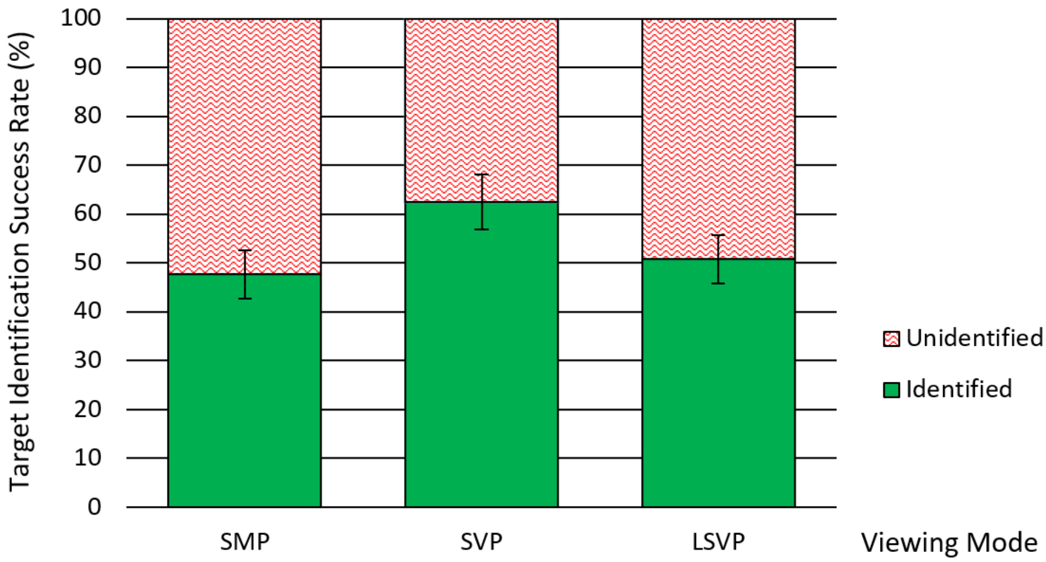
Experiment 1 (high distractor density)

Results

Target identification

The result of the first experimental investigation is shown in Figure 5. With SMP, participants achieved an average identification success of 47.6 % (SD = 18.3%, N=84), compared with 62.5% (SD = 22.4%, N=96) for the SVP mode. Statistical analysis using the t-test indicates that hypothesis H1 is confirmed at a 5% confidence level ($p=0.003 < 0.05$) in agreement with the findings of Mardell et al (2013) for wilderness search and rescue.

Figure 5: Result of Experiment 1 showing the target identification success rate (green) for each of the three viewing modes.



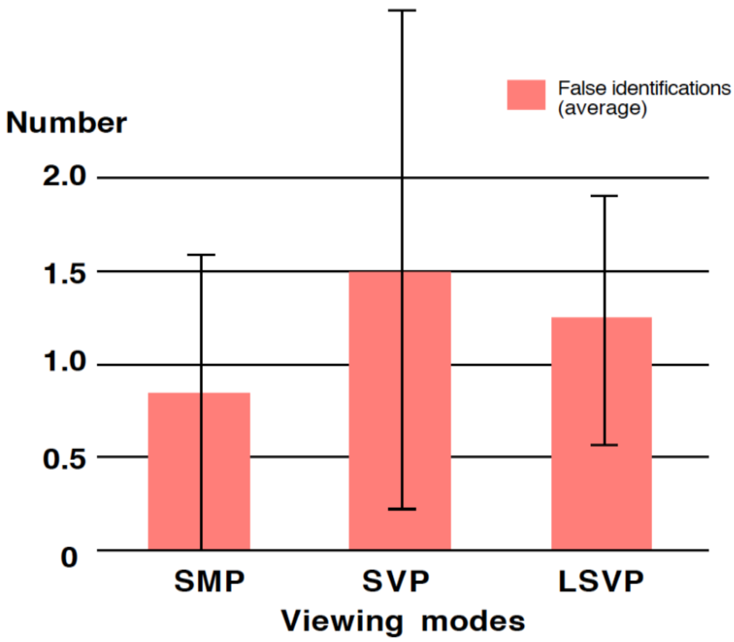
With regard to the LSVP viewing mode, the result shown in Figure 5 shows that participants correctly identified 50.7% (SD =26.2%, N=144) of targets. Statistical analysis using the T-test indicates that the first part of hypothesis H2 – that LSVP is more successful than SMP – is not significant at the 5% confidence level. Additionally, the analysis established that the second part – that LSVP is more successful than SVP – is also invalid at the 5% confidence level.

To summarise, H1 (that SVP will lead to a higher target identification success rate than SMP) is confirmed and H2 (that, overall, LSVP will lead to a higher target identification success rate than SMP and SVP) is rejected.

False positives

Also of interest is the occurrence of False Positives, where participants identified a target where one did not exist, potentially triggering wasted search effort. Figure 6 shows the false positive averages for the three modes investigated. Note that the SVP mode, which leads to more effective identification than SMP, is nevertheless associated with a significantly higher False Positive performance (significant at the 5% confidence interval ($p=0.006<0.05$).

Figure 6: The average number of false target identifications for the three viewing modes.



Moving targets

The new LSVP mode needs further consideration, especially in view of its expected ability to preserve movement when compared with SVP. We recall that, of the six targets, three were moving. Thus, with the LSVP viewing mode those targets are still moving, whereas in SVP mode none are moving. So it is appropriate to separate the results for the three moving targets from those for the static targets when viewed in SMP, SVP and LSVP modes, as presented in Figure 7.

Over all moving targets (targets 3, 4 and 6), participants correctly identified 48.8% (SD=22.91%, N=42)) with the SMP mode, 53.3% (SD=21.32% N=48) with SVP and 51.1% (SD=22.32%, N=66) with LSVP. Statistical analysis using the T-test indicates that that the hypothesis that LSVP is more successful than SMP for moving targets is not significant at a 5% confidence interval (p=0.74>0.05), and that the hypothesis that LSVP is more successful than SVP is, again, not significant at the 5% confidence level ((p=0.99>0.05). Thus, there is no evidence that LSVP outperforms SMP or SVP for moving targets and hypothesis H3 (that LSVP will perform better than SVP and SMP for moving targets) is rejected for the conditions tested.

Figure 7: Target identification success rate (green) for each of the six targets, three static and three moving.

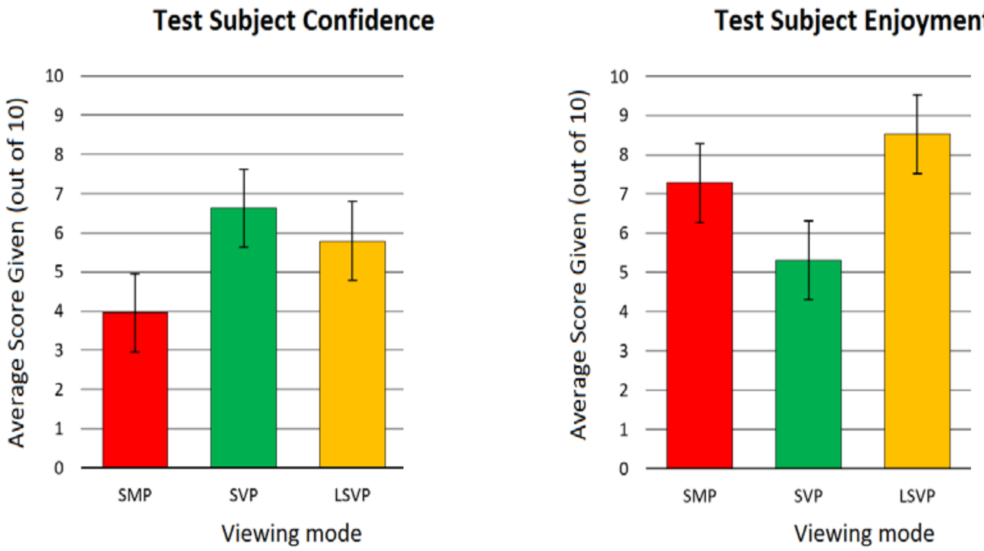
Static targets

A related suggestion is that SVP will outperform LSVP for static targets. It can be postulated that moving distractions distract more than static distractions. Thus, the only change between the two tested cases is that in SVP the distractors will be static, whereas in LSVP they will be moving. All six targets were still presented, but identification success only recorded for the static targets. With SVP, participants correctly identified 49.3% (SD=24.09%, N=48) of static targets, compared with LSVP where correct identification occurred for 49.7% of static targets (SD=25.89%, N=66). Statistical analysis showed that the hypothesis that LSVP performs better than SVP is not significant at the 5% level ($p=0.54>0.05$). In other words, SVP does not outperform LSVP for static targets. This conclusion – that the moving distractions did not distract more with LSVP than with SVP is compatible with the findings of Holcombe (2010) and Abrams (2003) that, unless the movement of a subject is 'odd' or unusual in some way, it will not attract a participant's attraction more than if it were static.

Subjective questionnaire

Responses to questionnaires revealed interesting facts about the opinions of participants concerning the three viewing modes. Responses to the questions "How easy was it to perform the task?" and "How confident are you that you found all the targets?" (Figure 8) provide a measure of the confidence and enjoyment with which the participant performed the test. Note that SMP shows a lower level of confidence than the other modes.

Figure 8 (Left): measures of participant confidence, (right): Measures of participant enjoyment



Experiment 2 (low distractor density)

As mentioned earlier, experience strongly suggested that a factor significantly affecting the relative advantages of the viewing modes SMP, SVP and LSVP was the density of distractors. A second experiment was therefore carried out using a distractor density significantly lower than used in Experiment 1. Figure 9 shows a view of the environment employed in Experiment 2.

Figure 9: A view of the low-distractor environment

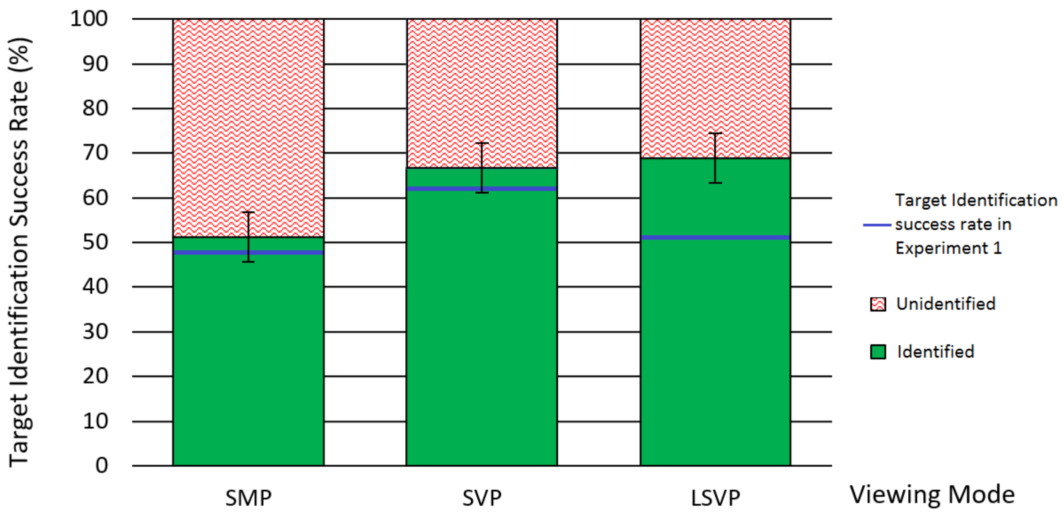
Other than the lower density of distractors, the design of Experiment 2 is identical to that of Experiment 1 but with two differences. First, with the help of 10 participants the difficulty of the targets was modified to bring the overall identification success rate closer to 50% in order to be comparable with Experiment 1. Second, most of the 48 participants were IT specialists and engineers in contrast to members of the public who took part in Experiment 1.

The following hypothesis was proposed:

H4: With the lower distraction density, LSVP will, overall, lead to higher target identification rate than SMP or SVP.

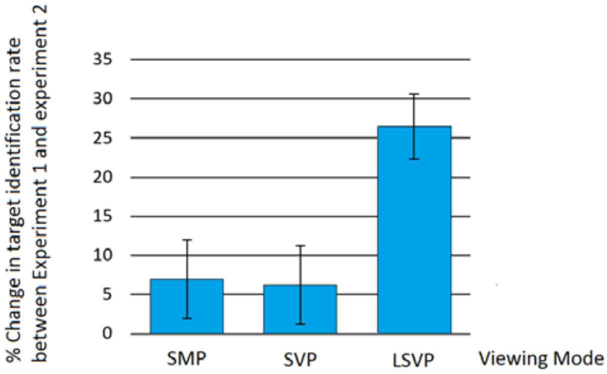
Figure 10 shows the results for the three viewing modes, using the same mixture of static and moving targets, as well as the same targets, as in Experiment 1. With SMP, participants correctly identified 51.3% (SD=18.1%, N=96) of the targets; with SVP the identification level was 67.5% (SD=17.9% N=96); and with LSVP 68.1% (SD=17.2%, N=96) of targets were correctly identified. Statistical analysis using the T-test indicates that the hypothesis that LSVP is superior to SMP is significant at the 5% level (p=0.0002<0.05). It also establishes that LSVP is not significantly superior to SVP at the 5% confidence level (p=0.51>0.05). Thus, LSVP does not lead to a significantly higher success rate than SVP, though it represents a significant improvement over SMP when compared with the higher distraction level of Experiment 1 as shown by the blue bars in Figure 10.

Figure 10: Overall target identification rate for the three viewing modes, observed in Experiment 2 using a lower distraction density.



The question naturally arises as to the extent to which distraction level influences target identification for the three viewing modes. The result of this investigation is shown in Figure 11. With SMP the percentage changes to the identification rates were 6.97%, for SVP it was 6.5% and for LSVP it was 26,4%. Statistical analysis indicates that LSVP provides a significantly greater improvement in target recognition in comparison with both SMP and SVP when compared with the higher distraction level. Hypothesis **H4** is therefore **confirmed**.

Figure 11: Percentage change in target identification rate between Experiment 1 (high distractor density) and Experiment 2 (low distractor density).



The result shown in Figure 11 is significant in that it points to the sensitivity of target identification to distractor density, and suggests that, with even lower distraction levels, the LSVP mode may be even more superior to SMP and SVP. If this were true then, for example, LSVP has the potential to perform well in scenarios – such as Wilderness Search and Rescue – where the distractors may be at a much lower level and where it is essential to identify a target that is moving in some way (e.g., waving). The rate of false positives for each viewing mode was recorded. Generally the rates were marginally higher than for the high distractor situation, with the rates for SMP being noticeably lower than for SVP and LRSVP.

Moving targets

In view of the interest in LSVP the identification rate for moving targets alone was observed for the three viewing modes (Figure 12). Statistical analysis established that LSVP performs better than SVP and SMP for (moving) targets 4 and 6, but worse than SVP for moving target 3. Examination of the nature of target 3 subsequently identified a flaw associated with the period for which it was visible, so the statistical analysis was repeated with target 3 removed. The result showed that, with this removal, LSVP (average 87%) was significantly better than SVP (58.7%) and SMP (54%).

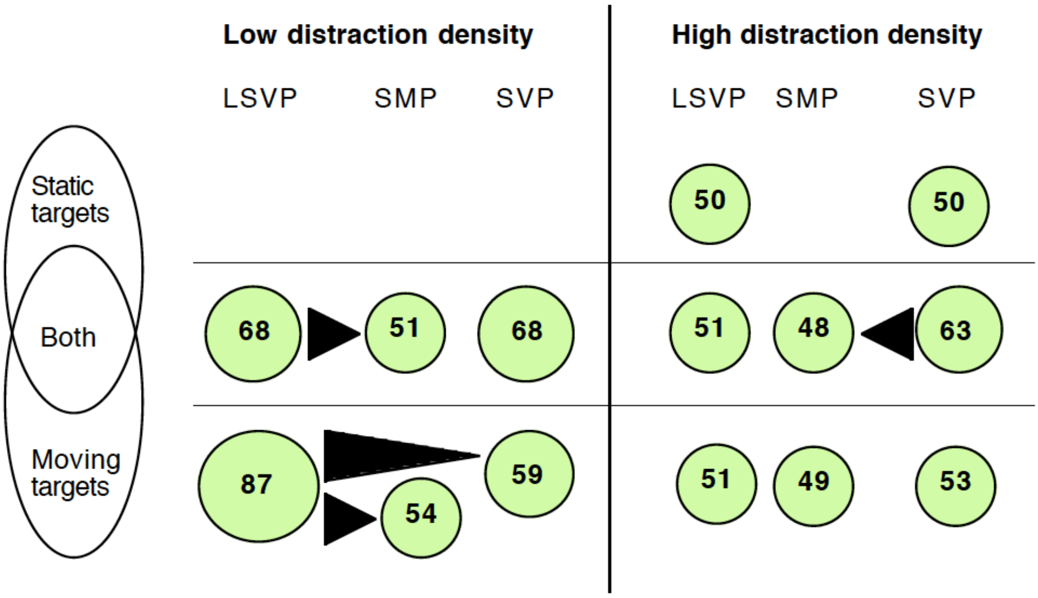
Figure 12 Target identification success rate for moving target in the low distraction density environment of Experiment 2.

Discussion

Figure 13 summarizes the findings obtained from statistical analysis of the experimental results regarding target identification success. Significant confidence levels (5%) are indicated by the black arrows. For high levels of distraction density (on the right) three groups of results are shown according to whether the targets were solely static or moving, or were a mixture of those two types.. Because the results were obtained for representative samples of each of the three viewing modes (LSVP, SVP and SMP) no boundaries between the three groups are shown. Similarly, distraction levels have not been quantified. Examination of the results for high distraction levels suggests that SVP might usefully be chosen as a default whatever types of target are involved.

On the left of Figure 13 we see a different picture. With only static targets there is no reason to favour any one of the three viewing modes, whereas with moving modes alone there is strong evidence that LSVP is superior to both SVP and SMP. For the equal mixture of moving and static targets LSVP and SVP are equally effective under the conditions tested.

Figure 13 Summary of the statistical analysis of the results obtained in Experiment 1 (high distraction density) and Experiment 2 (low distraction density). Black arrows indicate statistical significance at the 5% level. Circle diameter is proportional to average target identification, the latter also being indicated numerically. The result for moving targets at low distraction density ignores one exceptionally challenging target.



In the course of the investigation reported above, various limitations to the generalisation of the results were identified. They include the design of targets – especially the duration of their visibility – and the specific features of pedestrian appearance and animation.

Future research

The existing literature on Search and Rescue identifies a wide range of fundamental questions requiring research. The fruitful lines for future research noted below focus on the topic of this paper.

Recording of a spotter's eye gaze movement would yield data whose study could beneficially influence the future development of viewing modes. Useful information about the reason for false positives might also emerge. Similarly, the form of interaction used to identify targets (e.g., touch, gaze, mouse) would benefit from experimental study. Also, the potential influence of gaze on the temporary slowing down or magnification of tentatively identified targets, as investigated by Mardell et al (2011) could benefit from study.

Freedom of choice of the camera's spectral range must also be investigated (e.g., infrared)

Automatic target recognition (both true and false) and its appropriate presentation to the spotter is an additional route for future research.

Conclusion

Two principal conclusions can be drawn from the experimental results.

First, and with two significant exceptions, target identification varies little between viewing modes. One exception is the identified superiority of SVP over SMP at high distraction density and which tends to confirm earlier work by Mardell et al (2013). The other is the newly discovered superiority of LSVP at low distraction densities. There would appear, therefore, to be potential for the use of LSVP when targets may be moving, particularly at low distraction levels, and its further investigation is encouraged by the observed sensitivity of target identification to distraction density (Figure 11)

Second, the use of game development software appears to support the simulation of a search scenario sufficiently realistically to support useful experimental investigation.

Abbreviations

SAR	Search And Rescue
SVP	Static Visual Presentation
LSVP	Live Static Video Presentation
SMP	Standard Moving Presentation
SD	Standard Deviation
N	Number of trials for statistical analysis

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